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ASIA ANALYSIS

INDUSTRIAL, TRADE AND INVESTMENT COOPERATION:
A new era for the EU and Japan

IN THIS ISSUE

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INTRODUCTION

It is with tremendous excitement that I can now give you a very warm welcome to the first ever edition of Asia Analysis.

In this exciting and thought-provoking issue, one of the many highlights comes from Masanori Osumi, Japan-side General Manager and Philippe de Taxis du Poët, EU-side General Manager of the EU-Japan Centre for Industrial Cooperation. In their article, they explain why a new era begins now when it comes to promoting industrial, trade and investment cooperation between the EU and Japan.

We also learn about the mission of the Ministry of Health, Labour and Welfare in Japan when it comes to protecting people now and in the future, as well as delivering a sustainable healthcare system.

A particularly interesting article comes from Deputy Director of the Seismological Center Central Weather Bureau (CWB) in Taiwan, Nai-Chi Hsiao, who reveals how the country's quick earthquake alert system provides notification when it comes to ensuring disaster risk reduction.

We also find out about the Ministry of Science & Technology (MOST) in Taiwan in our analysis, which details why in the age of the knowledge-based economy, science and technology has become a key driver of growth and national progress in the country.

I hope that you really enjoy browsing through this publication and that you will join us for more in the future. ■

Jonathan Miles
Editor

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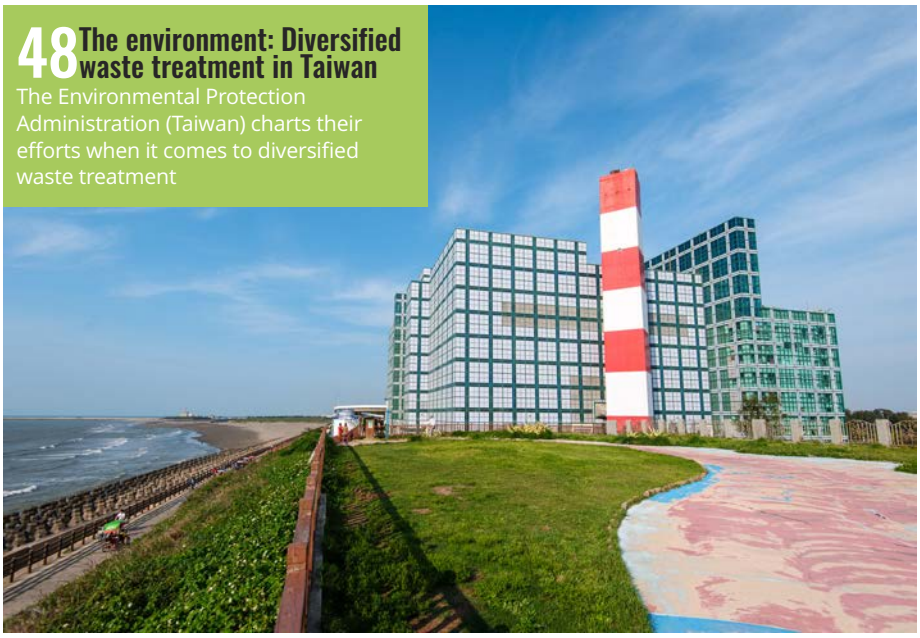
ENVIRONMENT



ENERGY

Delivering a sustainable healthcare system: Protecting health in Japan

The mission of the Ministry of Health, Labour and Welfare (MHLW) in Japan in protecting people now and in the future, as well as delivering a sustainable healthcare system, are detailed here

The mission of the Ministry of Health, Labour and Welfare (MHLW) in Japan can be summed by the catchphrase: "For people, for life, for the future." On the Ministry's website, we find out that this catch-phrase concisely summarises the notion that MHLW takes a role in protecting people and their lives – not only now but also in the years ahead.

Probing further into this most important notion, we learn that to achieve this purpose, action guidelines have, therefore, been set out for employees at the Ministry to abide by which are:

- The Ministry undertakes its tasks in a fair manner in accordance with high ethical standards.
- They supply administrative services in response to the demands of the public and times we live in.
- They also act from the point of view of individual citizens.
- They also strive for an open government approach, which is facilitated by providing information in an easy-to-understand way.

In addition, it's also important to add to put the afore-mentioned guidelines into practice, so the Ministry must be mindful of the following factors on a daily basis as they undertake their duties and take an active approach:

- The Ministry carries out their work efficiently and quickly by approaching their job with a sense of both pride and responsibility.
- They locate issues on their own initiative and work together to seek a solution.
- They also endeavour to keep up their level of ability and to remain in a state of continual improvement. (1)

"Amidst rapid population ageing, advances in medical technology, and major shifts in healthcare, a healthcare system that contributes to financial stability while engaging each sector of society to support a nation of health and well-being, where each person is empowered to realise their full wellness potential."

Prevention of heat strokes

One example of precisely how the MHLW is protecting Japanese people and their lives is the advice they give when it comes to preventing heat strokes. The important point here is that heat stroke can be prevented if the correct preventative measures are taken. The Ministry's website underlines that the individual must have a correct understanding of heat strokes and be aware of any changes in their physical condition. Added to this, it is also important to watch out for other people and as such, help prevent them from getting heat stroke.

We know that heat stroke happens under the conditions of humidity and high temperature in which case, the balance of the water and salt in the body is disrupted and thermoregulation does not function in the way it should. So, with the accumulation of heat in the body, symptoms such as fatigue, muscle aches, heavy sweating and nausea appear. In some very severe cases, the person experiences a loss of consciousness.

Going back to this point about prevention, in this case, we know that the intake of water and salt is recommended. Added to this, it is recommended that elderly people and children should follow this advice, even if they do not feel thirsty. It's interesting to note that indoor environments can create heat strokes but this can be prevented by adjusting temperatures using air-conditioning and electric fans. Other suggested measures include wearing a hat, seeking shade and not going outside during the afternoon on a very hot day. (2)

Conclusion – the priorities for healthcare in Japan

Looking ahead, the Ministry has a very clear goal to deliver a sustainable healthcare system that delivers unmatched outcomes through care that is responsive and equitable to each member of society, and that contributes to prosperity in the country and across the world. A healthcare system must be designed for all lifestyles and people – including people of all ages and providers – where each person is supported to make the life choices that are right for them. This notion is explored further as we leave the last word to the Ministry of Health, Labour and Welfare (MHLW) in Japan about their vision for the future of healthcare. This takes us back to the point made at the beginning of the article about the Ministry's role in protecting people and their lives – now and in the future.

"Amidst rapid population ageing, advances in medical technology, and major shifts in healthcare, a health-care system that contributes to financial stability while engaging each sector of society to support a nation of health and well-being, where each person is empowered to realise their full wellness potential." (3) ■

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Advancing research and developing new therapies for inherited retinal eye diseases

Takeshi Iwata, Division Director at the National Institute of Sensory Organs, National Hospital Organization Tokyo Medical Center, tells us about advancing research and developing new therapies for inherited retinal eye diseases

The Japan Eye Genetics Consortium (JEGC) was established with the support of the Japanese Ministry of Health, Labour and Welfare to investigate genes responsible for inherited retinal diseases, including inherited optic neuropathy and inherited normal tension glaucoma. Phenotypic information and blood samples were collected from more than 38 ophthalmology departments in Japan. Whole exome analysis was performed for over 2,500 DNA samples collected, resulting in a large number of gene mutation specific to the Japanese population. A number of novel disease-causing genes were also identified in this study. These novel genes will open new insight into how retina functions to maintain normal vision.

Common eye diseases, such as cataract, myopia, glaucoma and age-related macular degeneration are partly due to genetics, but the influence of a person's genotype is more profound in inherited eye diseases. Inherited retinal diseases (IRD) are a group of rare ocular disease which effects retinal function, leading to a number of eye disease including retinitis pigmentosa (RP), macular dystrophy, Stargardt's disease, stationary night blindness and 34 other diseases. These diseases are caused by gene mutation leading to the failure of cell function in the retina, such as photoreceptors, retinal pigment epithelial (RPE) cells, and bipolar cells. Inherited optic neuropathy and inherited glaucoma are caused by the failure of retinal ganglion cells (RGC), another cell type in the retina. Gene mutations are found in dominant, recessive, x-linked or sporadic forms and may change in certain ethnic groups or occur more commonly in particular ethnicities. Over 260 genes have been identified mainly in the Caucasian population but not enough studies have been conducted in the Japanese patients.

To determine the types of IRD in the Japanese population and to identify the disease-causing gene mutation, the JEGC was established in 2011. Initial members were from ophthalmology departments of National Hospital Organization Tokyo Medical Center (NHOTMC), Aichi Medical University, Nagoya University, Mie University, Teikyo University, and Kinki University and the total number now involved has increased to 38. The project was initially funded by the Japanese Ministry of Health, Labour and Welfare and later by the Japan Agency for Medical Research and Development (AMED). This was the first attempt in Japan to survey IRD patients on the scale of the entire country. Since many of the inherited retinal diseases are extremely rare, collaboration at the level of one country is necessary to collect enough patients to study the disease.

Each ophthalmologist enters a patient's phenotype information and the family pedigree into the JEGC Genotype-Phenotype Database. In addition to text-based information, fundus photo, fluorescein angiogram, optical coherence tomography, autofluorescence, electroretinogram (ERG), visual field and other phenotypic images are collected from each patient and family member. To maintain the quality of the diagnostic, JEGC designated ten ophthalmologists specialised in each retinal disease. Saliva or blood samples are sent to the National Institute of Sensory Organs (NISO)/NHOTMC for whole genome analysis. Over 1,400 family pedigrees have been collected, and the consortium aims to gather 5,000 in total. From the beginning of this project, we were surprised to observe that 80% of families studied were found to have novel gene mutations. Approximately 8% of the families were found with a potentially novel disease-causing gene of unknown function. Functional analysis is underway to characterise each of these genes in detail.

In 2015, the funding for JEGC project moved to a new government agency AMED. AMED was established in April 2015 to combine grant funding of three Japanese ministries to catalyse the process of medical innovation and overcome the barriers between ministries, connecting talented research groups in Japan and elsewhere to accelerate medical research and therapeutic development. Under the AMED funding, additional goals of identifying

the molecular mechanisms of disease onset and development of therapies for retinal eye diseases were added to the project. After genetic analysis of over 1,300 patient families, over 100 families are potentially caused by novel genes of unknown functions. JEGC has identified five novel genes for occult macular dystrophy (RP1L1), Leber's congenital amaurosis (CCT2), retinitis pigmentosa (C21orf2), cone-rod dystrophy (C21orf2), macular dystrophy (LRRTM4) and continuously works on the rest of the novel genes. We were able to show that knock-in mice from each gene also developed a patient-like phenotype which adds more proof to the disease association.

"Common eye diseases, such as cataract, myopia, glaucoma and age-related macular degeneration are partly due to genetics, but the influence of a person's genotype is more profound in inherited eye diseases."

A significant amount of information has been accumulated for how a normal retina functions, however, the biological influence of each gene mutation to a normal retina has not covered for all disease-causing genes. As more novel disease-causing genes are discovered, the mutant functional study needs to catch up. The omics, genome, transcriptome, proteome techniques are being applied to this investigation. Induced pluripotent stem (iPS) cells, from patients are generated and differentiate to neuronal cells, RPE cells or other retinal cells to observe the patient condition in the mimicked cells. We also developed mutant animal models using CRISPR/Cas9 gene editing system to prove that one amino acid substitution can lead to the onset of disease. Protein interaction studies and protein modification analysis is performed as part of the functional analysis of mutant proteins.

Takeshi Iwata

These functional analyses provide basic seed information to search for a potential drug to prevent or slow down the progression of the diseases. Such a result was achieved in our lab from functional analysis of inherited glaucoma gene optineurin (OPTN). A mutation in OPTN can lead to severe glaucoma with strong penetration in the family with the mutation. A patient carrying this mutation is likely to lose half of their visual field by the age of 40 and will progress to full blindness by the age of 80. The mutant OPTN E50K protein strongly binds to a protein called TANK binding kinase-1 (TBK1), which gave us drug target. We found that by chemically inhibiting TBK1, this protein association was greatly reduced. We further identified an FDA-approved drug Amlexanox that inhibited TBK1and tested this for a year with disease model OPTN E50K knock-in NTG mice. After one year, we showed that the drug provided significant neural protection from the precursors to glaucoma. JEGC is regularly contacted by pharmaceutical companies from around the world who are planning clinical trials. A number of clinical trials are underway in JEGC.

From the success of JEGC, Asian Eye Genetics Consortium (AEGC) was established in 2014 by four countries. In 2018, a plan to expand to Africa and South America was unanimously approved and Global Eye Genetics Consortium (GEGC) was established. GEGC China was launched in May 2018 and GEGC India in February 2019. In each of the regional GEGC meetings, JEGC has been shown as one of the successful models to maintain its structure representing the entire country. As we move towards an era of globalisation, it would be easier to share genetic eye information through similar organisations from each country. GEGC has now grown to 30 counties and is being promoted to countries throughout Asia, Africa and South America.

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Healthcare in Hong Kong: A focus on elderly health services

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The priorities of healthcare in Hong Kong are explored here, with a special focus on the delivery of elderly health services in the country

According to the Department of Health of the Government of the Hong Kong Special Administrative Region, the pursuit of health is essential for the overall development of the community, as well as the well-being of the individual citizen. The Department of Health is the government's health adviser and agency to deliver health policies and statutory functions and as such, it plays a key part in the country's healthcare system. Dr CHAN Hon-yee, Constance, JP Director of Health from the Department offers her thoughts on the health care priorities of Hong Kong.

"We safeguard the health of the people of Hong Kong through promotive, preventive, curative and rehabilitative services as well as fostering community partnership and international collaboration.

"We are committed to providing a quality client-oriented service. We also attach great importance to fostering partnership with the community and other health care professionals and bodies, both local and worldwide, in the joint effort to promote the health of the people of Hong Kong." [1]

Elderly health services

By way of background, it's worth noting that The Elderly Health Service consists of 18 elderly health centres and 18 visiting health teams. [2] Their mission is nothing but providing quality primary health care services that promote the health of their elderly population. [3]

This analysis will focus on an aspect of the Department's work, the Elderly Health Service which provides primary health care to the elderly, which, in turn,

"We are committed to providing quality client-oriented service. We also attach great importance to fostering partnership with the community and other health care professionals and bodies, both local and worldwide, in the joint effort to promote the health of the people of Hong Kong."

Image: © Rafael Ben Ari | Dreamstime.com

improves their self-care ability, encourages healthy living and strengthens family support in order to minimise disability and illness. The services offered include:

1. Public health & administration

To analyse and collect information on the elderly's health status in Hong Kong to provide a timely health intervention programme.

2. Elderly health centres

The elderly health centres in the country seek to detect diseases earlier and identify health risks to enable timely intervention and prevention of complications. Those aged 65 or above can enrol as members of elderly health centres, where they are provided with a health assessment, counselling, health education and curative treatment services.

3. Visiting health teams

Visiting health teams deliver health promotion programmes free of charge in the community to increase the elderly's self-care ability and health awareness. By making use of the train-the-trainer approach, visiting health teams provide training programmes for carers to improve health knowledge and skills when it comes to caring for the elderly. [4]

The ageing and elderly healthcare landscape in Hong Kong

The Elderly Health Service is of the opinion that ageing is a necessary stage in life, indeed with an optimistic attitude in place they believe that one can live a fruitful life and enjoy their later years.

An important point to add here is that the elderly in Hong Kong who require help with their daily lives is on the rise. As such, we know it is really important that caregivers apply the proper skills of 'lifting and transfer' to avoid repetitive strain injury. Of course, this approach instils a sense of security in the elderly person and ensures a smooth and safe transfer. This approach is vital when assisting the elderly with everyday tasks such as getting up from bed or transferring them to the wheelchair or with toileting. [5]

Other areas on the website are extensive and include issues such as healthy ageing, mental health, self-care, home safety plus common health problems such as

bones and joints, cancer, dementia and diabetes to name a few. If that was not enough, there is even a very helpful section for carers, with useful details concerning dementia care, swallowing and diet, wound care and stress management, amongst many others.

Osteoporosis

Taking one of these areas, let's focus now on a common health problem, osteoporosis, which is a metabolic disease of the bone that results in a reduction in bone density. Certainly, the affected bones become thinner and are more likely to break (fractures) which may result in pain and other complications, including a loss of independence.

While osteoporosis produces no symptoms on its own, if an osteoporosis-related fracture occurs, there may be localised pain over the fracture sites. An osteoporotic fracture often includes the site of the thigh bone near the hip joint, spine (vertebrae) and the forearm close to the wrist. While hip fracture may occur after a minor fall, the spine can fracture without any associated trauma. In addition, a vertebral fracture can result in a decrease in body height, a hunched-back and sometimes, back pain. The website of The Elderly Health Service also provides further details in this vein, such as tips on what to do if you are suffering from osteoporosis and if it is preventable. [6]

Low back pain (LBP)

Looking at another highlighted area, we know that low back pain (LBP) today is a very common medical problem. While there are many causes of LBP including injuries, diseases and degeneration, poor posture accelerates degenerative changes of the spine, so the importance of proper posture cannot be emphasised enough. Certainly, good posture helps to prevent unnecessary fatigue and injuries that can occur when the body is not in proper alignment. Those who suffer from LB should see a doctor, who can assist with individual treatment plans and can, of course, identify a specific source of the pain.

Staying on this topic, we know that the central portion of the back is composed of a bony spinal column surrounded by muscles and ligaments. Tips include standing, which is quoted below but you can also find out more about sitting, lying and many other areas in this vein. We also learn here that appropriate exercise helps to maintain general fitness and back health.

"While standing, keep your body straight with ears, shoulders and hips vertically aligned. Your shoulders should not be rounded inwards or tilted forwards. Your hips should not be flexed or hyper-extended. Tuck your abdomen in. Make sure your chin is not held too high and your head is not dropping. Use your abdominal

muscles to keep your chest lifted and your back supported." [7]

The importance of activity

Finally, let's look at just one of the many areas highlighted on The Elderly Health Service's website that concerns activity. Here, we learn that activities are an integral part of our lives and become more important for the elderly who find themselves with more leisure time after they retire.

Some elderly people think that they might be too old for joining activities but taking part in them can provide many benefits like becoming healthier by taking part in physical activities, such as tai chi, as well as dancing and swimming which both benefit coordination, mobility and cardiopulmonary function. Another example is cognitive training, which can include playing computer games, chess or board games that can improve cognitive reserve and exercise the brain.

It is said that activities like going to restaurants, singing and watching movies can help older people to express their emotion and relieve anxiety, which of course, makes them feel better. It's well worth a look at the Ministry's additional tips for engaging activities that the elderly can take part in, such as group activities, learning new things or promoting and maintaining ability in self-care. Let's leave the last word to The Elderly Health Service who explain how confidence can be increased in this valued and important group of people in society.

"Participation in voluntary work can increase confidence and offer sense of satisfaction. Elders can choose to participate in activities, such as calligraphy, painting, handicrafts according to their own interests, through which, they can make good use of their creativity and talent." [8]

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Research about Hong Kong's rapidly ageing population

Professor Timothy Kwok, Director of the Jockey Club Centre for Osteoporosis Care and Control at the Chinese University of Hong Kong, provides a fascinating insight on the challenge of the city's rapidly ageing population

Hong Kong is facing a rapidly ageing population in the coming decades. Alongside population ageing, the incidence of hip fracture, the most disabling of common fractures in old age, has been rising steadily. In 2009, the incidence was 341.7 in men and 703.1 in women, per 100,000 people aged 65 years or over per year (Chau et al., 2013). The direct costs to the public hospital were estimated to be $10,400 in 2017 (Su et al., 2018). The indirect costs which are expected to be more substantial have not been comprehensively studied. In Taiwan, the indirect costs of a hip fracture were $1760, $480 and $173 for nursing home, caregiver and outpatient clinic annually in 2010 (Chan et al., 2017).

A cross-sectional study of 2914 fragility hip fracture patients in six hospitals in Hong Kong showed that the average age of hip fracture patients was 82.1±8.6 years. One-third of them were men, and 73.7% were community-dwelling before fracture (Leung et al., 2017). Most, if not all older people with a hip fracture have osteoporosis as defined by dual energy X-ray absorptiometry (DXA), and drug treatment for osteoporosis has been consistently shown to reduce hip fracture incidence by 40% (Kanis et al., 2013). It is, therefore, possible to prevent hip fractures if all older people are screened for osteoporosis and receive osteoporosis drug treatment. Yet in Leung's study, only 4.2% of hip fracture patients were diagnosed and treated for osteoporosis before the fracture. According to the profile of patients in our osteoporosis clinic which is the largest in Hong Kong, only 29.2% in 2017 were 70 years or more. These suggested that very few older people have DXA screening, despite the availability of DXA services in the private sector (Kwok et al., 2017).

A major reason for the very low take-up rate of DXA screening in older people in Hong Kong is the lack of specific public funding support. In collaboration with other local professional bodies, our centre is advocating the use of public funding support for a universal osteoporosis screening programme to benefit older people in Hong Kong. Universal osteoporosis screening by DXA for women aged 65 years and men aged 70 years or more has been recommended by professional bodies in the U.S., UK and European countries, and this strategy has been shown to be cost-effective for governments (Dell et al., 2010). Some Asian countries e.g. Japan and South Korea also provide funding support for osteoporosis screening (Mithal et al., 2013). With the availability of effective affordable generic drugs for osteoporosis, it is feasible to leave the long-term management of osteoporosis to primary care doctors who are mostly in private practices in Hong Kong.

Another major reason is the lack of awareness of fracture risk among older people. Osteoporosis is a common but most neglected disease (International Osteoporosis Foundation, 2000), especially in men (Haas et al., 2007). A randomised trial in the UK showed that the postage of a hip fracture risk questionnaire (FRAX) to women aged 70 years or more, together with training of primary care doctors in osteoporosis management resulted in more osteoporosis diagnosis and drug treatment and a 28% reduction in hip fracture incidence over five years (Shepstone et al., 2018). Our centre has been running a prospective cohort study of 4,000 older men and women to examine the risk factors of fractures in older people since 2001. According to our data, the combination of FRAX and a validated five-item questionnaire for sarcopenia increased the sensitivity for hip fracture incidence from 58.7% in men and 69.9% in women to 80% in both sexes (Su et al., 2019). The widespread use of this questionnaire in older people in the community may prompt more older people to seek DXA screening.

Most hip fractures occur after a fall, and fall history is a risk factor for a further fall, and can independently predict fracture in older men (Scott et al., 2007; Woo et al., 2009; Wu et al., 2013). The prevention of falls, especially in those who have fallen and

those with osteoporosis is another effective means to prevent hip fracture in older people. Randomised trials of balance exercise including Tai Chi have shown reduction in fracture incidence in those with osteoporosis and among older fallers (Gillespie et al., 2009; Sherrington et al., 2011). Fall risk assessment should, therefore, be a routine for those who are diagnosed to have osteoporosis and have had a fall within twelve months.

In a project funded by the Hong Kong Jockey Club, our centre has assessed over 1,300 community-dwelling older people who have had a fall over the past few years. Their fall risk was systematically assessed by a validated procedure PPA (Lord, Menz, & Tiedemann, 2003). According to this assessment, 36.6% were found to have moderate to severe instability. Apart from balance exercise group, we offer a home-based balance exercise programme "LIFE" which has been shown to reduce the number of further falls (Clemson et al., 2012). We have further improved on the programme by adding in- home safety assessment by an occupational therapist, which has also been shown to prevent falls (Chu et al., 2017). A randomised trial of the modified "LIFE" programme is on-going.

Last but by no means least, according to Leung's study, 26.3% of hip fracture patients were nursing home residents. Nursing home residents are at high risk of hip fractures and osteoporosis (Leung et al., 2017). Osteoporosis drugs are potentially useful in preventing hip fractures. But there is a practical problem in performing DXA in people with mobility problems, and because of disabilities and limited life expectancy, the risk and benefit of osteoporosis screening and drug treatment are finely balanced and should be assessed individually. Our centre is collaborating with Caritas College in identifying clinical risk factors of fractures in nursing home residents.

All in all, hip fracture in older people is a preventable condition. There is a lot of evidence that treatment for osteoporosis and fall preventive measures can prevent hip fractures (Chau et al., 2013, Kanis et al., 2013). But a more proactive and systematic approach directed by the government is required to translate knowledge into real impact on the incidence of hip fractures.

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Ageing and chronic kidney disease (CKD): The phosphate connection in biomedical science

Dr Makoto Kuro-o from the Division of Anti-Aging Medicine, Jichi Medical University in Japan gives a fascinating glimpse into an aspect of biomedical science that concerns the subject of how phosphate accelerates ageing, including his thoughts on chronic kidney disease (CKD)

On the subject of how phosphate accelerates ageing, my current research interest stems from my serendipitous discovery of an obscure mutant mouse strain that inherits a premature ageing syndrome in an autosomal recessive manner. The mutant was named after a Greek goddess klotho who spins the thread of life. Mice homozygous for the klotho allele (kl/kl) develop complex ageing-like phenotypes when they are around four weeks of age, including atrophy of multiple organs (gonads, thymus, and skin), sarcopenia, vascular calcification, cardiac hypertrophy, osteopenia, cognition impairment, hearing disturbance among others, resulting in frailty and premature death. The klotho allele is a severe hypomorphic allele for the klotho gene, which encodes a single-pass transmembrane protein and is expressed primarily in renal tubular cells.

Subsequently, we found that Klotho protein functions as the receptor for fibroblast growth factor-23 (FGF23). FGF23 is a "phosphaturic" hormone secreted from the bone upon dietary phosphate intake and acts on renal tubular cells to inhibit phosphate reabsorption, thereby, increasing phosphate excretion into urine. Mice defective in klotho expression (kl/kl mice) suffer from phosphate retention and develop hyperphosphatemia due to impaired urinary phosphate excretion, indicating that the FGF23-Klotho endocrine axis is indispensable for maintaining phosphate homeostasis. Importantly, restoration of the phosphate balance by placing kl/kl mice on low phosphate diet rescues them not only from hyperphosphatemia but also from the ageing-like phenotypes, leading me to conclude that phosphate retention is primarily responsible for premature ageing. Since then, the long-term goal of my research has been to elucidate the mechanism by which phosphate accelerates ageing.

CPP (calciprotein particles): The true culprit of accelerated ageing?

It has been known for decades that extracellular phosphate is toxic to the cell at high concentration. For example, when vascular endothelial cells are cultured in high phosphate medium, they undergo apoptosis. In vascular smooth muscle cells (VSMC), high phosphate medium induces calcification associated with the phenotypic transition of VSMC to osteoblast-like cells. However, high extracellular phosphate fails to exert these effects when the extracellular calcium concentration is low or when inhibitors for the formation of

calcium-phosphate, such as pyrophosphate or phosphonoformic acid, are present in the medium.

These findings indicate that it is not phosphate per se but calcium-phosphate precipitates (CaPi) that are responsible for these phosphate woes. In vivo, CaPi circulate in the blood in the form of CPP (calciprotein particles), which are colloidal nanoparticles of CaPi adsorbed by serum protein fetuin-A. CPP have the ability to induce endothelial cell damage, VSMC calcification, and innate immune responses as if they were a pathogen. Based on these observations, I have proposed "the CPP theory of ageing". Namely, CPP may be a "pathogen" that accelerates ageing through inducing arteriosclerosis and chronic inflammation.

CKD as a clinical model for accelerated ageing

Recent clinical studies have demonstrated that blood CPP levels are increased with the progression of chronic kidney disease (CKD). CKD is defined as a state of impaired renal function that persists for three months or longer, regardless of the cause of kidney damage. In many cases, however, CKD occurs as a complication of diabetes or hypertension and as a consequence of natural ageing. Accordingly, more than 10% of the total population worldwide is estimated to suffer from CKD. In CKD patients, high blood CPP levels are associated with vascular calcification, arterial stiffness, and inflammation.

Furthermore, a clinical parameter that reflects the propensity for CPP formation predicts their prognosis. Considering the ability of CPP to induce cell damage and innate immune responses in vitro, the correlation between blood CPP levels and the CKD complications may actually be causation. This notion is consistent with the CPP theory of ageing and, if proven, may justify CPP as a new therapeutic target for CKD. To obtain a proof-of-concept for the CPP theory of ageing, my collaborators and I have developed a "CPP adsorption column" that can be connected in series in the hemodialysis circuit to remove CPP from the blood during hemodialysis sessions, and is currently investigating whether the column may be effective in the treatment of arteriosclerosis and inflammation using an animal model.


Dr Makoto Kuro-o

It should be noted that CKD patients in advanced stages resemble kl/kl mice: Both suffer from high blood CPP levels, low Klotho expression, and multiple ageing-like phenotypes, including vascular calcification, cardiac hypertrophy, and increased mortality. In addition, these phenotypes can be alleviated by restriction of dietary phosphate intake both in kl/kl mice and in CKD patients. The striking similarity between kl/kl mice and CKD patients has led to the concept that CKD can be viewed as a state of accelerated ageing.

Physiology and pathology of colloids

In general, insoluble materials such as lipids and CaPi are adsorbed by specific serum proteins and converted to colloidal particles to be dispersed in the blood. Lipids are adsorbed with apoproteins, converted to colloidal particles called lipoproteins, transferred through the bloodstream between tissues, and eventually stored in the adipose tissues. However, when lipoproteins are increased in quantity and/or altered in quality (e.g. LDL vs HDL) and mistargeted to vasculature, atherosclerosis ensues. When mistargeted to the liver and skeletal muscles, lipids cause fatty liver and insulin resistance. These pathological conditions caused by ectopic lipids are correctively called "lipotoxicity".

Likewise, CaPi binds to fetuin-A to form colloidal particles called CPP. CPP may function as a carrier that transfers calcium and phosphate to the bone for storage. However, when CPP are mistargeted to vasculature, vascular calcification may ensue. Vascular calcification is the other form of arteriosclerosis besides atherosclerosis, but in contrast to atherosclerosis being treated with statins, no specific treatment for vascular calcification is available. When mistargeted to other extraosseous tissues, CPP may exert toxicity and inflammation in systemic organs and ultimately accelerate ageing. I expect that research on CPP will be appreciated as a new field of study in biomedical science as important as research on lipoproteins in the foreseeable future.

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Japan: Driving forward cancer research through collaboration

The work of the Japanese Cancer Association in driving forward cancer research through collaboration is charted here, including a push on basic and translational research

For over 70 years, the Japanese Cancer Association has supported research into all forms of the disease based on national and international collaboration between scholars

The Japanese Cancer Association traces its roots back to the Japanese Foundation for Cancer Research, which held its first Scientific Convention in April 1908.

In 1935, the foundation resolved to establish a new, independent body that could capitalise on the rapid advances being made in cancer research and play a central role in promoting further study.

Following the decision by the society's board of directors to establish the Japanese Cancer Association in March 1940, President Mataro Nagayo told the 32nd Japanese Foundation for Research Scientific Convention at Tokyo Imperial University: "In consideration of the developments of recent years, I believe it is appropriate to newly establish the Japanese Cancer Association and hold meetings under that name.

"We think that by doing this cancer research in this country, [it] will be pushed further ahead by the united cooperation of scholars nationwide."

The JCA's first scientific lecture meeting was held at Osaka Imperial University on 5 April 1941.

Since then, the association has grown to comprise over 15,000 members specialising in a wide range of basic and clinical cancer research, as well as research on public health and social medicine, who exchange information.

The association's Annual Meeting is held every autumn and approximately 5,000 research and students, members of research advocators and various other stakeholders take part.

The JCA is actively promoting the globalisation of its work and since 2007, the Annual Meeting now includes an International Session featuring speakers from abroad, particularly neighbouring Asian countries.

In addition, since 1989, the JCA has held a joint conference every three years with the American Association for Cancer Research in the Hawaiian Islands. The last event, in 2016, was held under the title Breakthroughs in Cancer Research: From Biology to Therapeutics and was attended by around 570 participants from Japan, the U.S. and other countries.

Cancer research itself has, of course, made great strides over the years and has clarified the nature of cancer biology. Remarkable progress has been made in treatment of the disease, particularly in the area of molecular target therapy based on the genomic abnormalities of individual cancers. Genomic medicine, a type of precision medicine, will allow medical care to be tailored to an individual based on their genomic information.

Indeed, genomic medicine was one of the key issues under discussion at the 77th Annual Meeting of the Japanese Cancer Association, which took place in Osaka in September 2018.

Under the title, Diving Deeper into Cancer Research, the meeting discussed developments and emerging challenges in genomic medicine in light of President Barack Obama's Precision Medicine Initiative, announced in the 2015 State of the Union address, and the creation of Japan's Council for Promoting Genomic Medicine.

Another key topic for discussion was immunotherapy, which has emerged as a fourth therapeutic method for cancer following surgery, radiation and drugs, along with how cutting-edge research in areas such as artificial intelligence and genome editing are being used in cancer research.

Innovative thinking is, of course, crucial to the continuing development and diversification of cancer research, which is why the Annual Meeting offered a number of sessions aimed specifically at young researchers.

There was also a special symposium on Advances in Basic and Clinical Medicine in the Past 10 Years, which reviewed progress in research that would have been unimaginable just a few years ago.

However, while the development of new drugs is good news for patients, there are nevertheless concerns about the high prices for these treatments and what this means for the future of Japan's healthcare system.

With this in mind, the JCA is seeking the opinions of stakeholders, including patients, healthcare professionals, governments and related academic societies to provide recommendations for the public.

As in previous years, the three-day Annual Meeting featured International Sessions covering 12 selected topics, with discussions led by prominent researchers in each area.

As the remarkable progress in the treatment and prevention of cancer continues, the JCA remains as committed as ever to its goal of using collaboration to drive forward research.

President Hitoshi Nakagama says: "JCA will work more vigorously on basic and translational research, and develop human resources, including young researchers.

"We expect to establish and strengthen cooperative relationships with foreign researchers, so that we will contribute to the development of life sciences, promote the development of new cancer prevention and treatment methods, and contribute to society through the future promotion of cancer research." ■

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Nano DDS technology contributes to next-generation cancer immunotherapy

Dr Takashi Nakamura from Hokkaido University challenges the potential of nano-tech based drug delivery system (Nano DDS) in the development of next-generation cancer immunotherapy

The appearance of immune-checkpoint inhibitors (ICIs) such as the cytotoxic T-lymphocyte-associated protein 4 (CTLA-4) antibody and programmed cell death-1 (PD-1) has revolutionised the field of cancer therapy. Dr James P Allison and Tasuku Honjo who discovered CTLA-4 and PD-1, respectively, won the 2018 Nobel Prize in Physiology or Medicine. Cancer immunotherapy is currently the hottest field in the world.

However, positive responses by the current ICIs were observed only in a minority of the treated patients and tumour types, and several resistance mechanisms have been identified. The emerging focus is on improving the response rate and overcoming resistance. One possible solution is combination therapies, namely ICIs plus other immunotherapeutic materials or cancer therapies.

Nano DDS is an essential technology in the development of cancer immunotherapy

The leading candidates of immunotherapeutic materials for enhancing combination therapy are tumour antigens (proteins or peptides), adjuvants and nucleic acids (DNA, mRNA, siRNA etc.). However, they are easily degraded, are insoluble and have a low affinity for immune cells, resulting in a failure to induce effective responses. Nano DDS, namely carrier type DDS, can protect and deliver them by incorporating them. It is an era in which the world view in Fantastic Voyage, an SF movie in 1966, can be realised. Many cells and complicated mechanisms are involved in cancer immunity in both a good and bad way.

> "We believe that nano DDS largely contribute to overcoming the resistant mechanism and we are addressing a novel nano DDS system for achieving next-generation cancer immunotherapy."

Thus, restrict control of immunotherapeutic material trafficking is an important issue for inducing desirable immune responses. The protection and delivery of immunotherapeutic material by nano DDS have largely contributed to the promotion of antigen presentation to T cells, the activation of antigen presenting cells (APCs), targeting immune cells, targeting lymphoid organs, etc. We address the control of cancer immunity by original nano DDS technologies.

STING agonist loaded nano DDS drastically enhances cancer immune responses

Stimulator of interferon genes (STING) pathway functions as an innate immune sensor of double-strand DNA in the cytosol. The sensing induces the production of type I interferons (IFNs) that is important cytokine for the activation of cancer immunity. The STING pathway, but not other innate immune sensors such as Toll-like receptors, dominated the spontaneous immune responses against cancer. Therefore, agonists activating STING pathway (STING agonists) represent promising weapon as a cancer adjuvant. DNA and cyclic dinucleotides are STING agonists.

However, nucleotides are negatively charged, which hamper their transport into the cytosol. Thus, the use of STING agonists in cancer immunotherapy has been limited. To achieve the efficient cytosolic delivery of STING agonists, we loaded original nano DDS with STING agonist (we used a cyclic di-GMP). Our nano DDS is lipid nanoparticle (LNP) containing YSK lipids (YSK-LNP). YSK lipids show pH-responsible and high fusogenic activity, leading to efficient delivery of cargos into the cytosol. STING agonist loaded YSK-LNP (STING-LNP) succeeded in inducing type I IFN from APCs, activating APCs and antigen-specific killer T cells. In addition, the treatment of STING-LNP showed a drastic therapeutic effect in the lymphoma-baring mouse model.

On the other hand, some cancer cells escape from the attack by killer T cells by the loss/down-regulation of MHC class I expression. Against such tumours, for example, malignant melanoma, natural killer (NK) cells can be a major effector cell. The intravenous administration of STING-LNP activated NK cells and significantly decreased the number of tumour

Takashi Nakamura, Assistant Professor

colony of mouse melanoma lung metastasis. The antitumor effect was NK cell dependent.

Collectively, the successes are first reported and the STING-LNP promises to be a powerful adjuvant system for building strong cancer immunity. We are currently investigating the potential of STING-LNP in anti-PD-1 therapy-resistant tumours.

Nano DDS achieves siRNA-based functional control of immune cells

It is absolutely certain that controlling the function of immune cells at gene level represents high potential and powerful technology. Of course, also in cancer immunotherapy. Controlling gene expression by siRNA can be a promising and reliable strategy.

However, introducing siRNA into immune cells is quite difficult and the uses of virus vectors and special equipment are required. We recently succeeded in the effective gene silencing in mouse and human immune cells by using YSK-LNP. When siRNA was introduced into mouse dendritic cells (DCs), YSK-LNP achieved higher gene silencing than commercially-available siRNA transfection reagent (No. 1 share in the world) and the gene-controlled DC by YSK-LNP enhanced the antitumor effect.

"It is absolutely certain that controlling the function of immune cells at gene level represents high potential and powerful technology. Of course, also in cancer immunotherapy. Controlling gene expression by siRNA can be a promising and reliable strategy."

In particular, the commercially-available siRNA transfection reagents are ineffectual against human immune cells, even if cell lines. Nevertheless, the YSK-LNP succeeded in silencing a target gene in excess of 80% at a low dose range of siRNA. The capability to introduce siRNA of YSK-LNP represent at the top level. We are currently advancing research to apply the YSK-LNP to immune cell-based therapies or control immune cells via systemic administration.

Nano DDS strategy toward next-generation cancer immunotherapy

The response rate of cancer immunotherapy is largely dependent on the immune status in tumour microenvironment. For example, the patients show a good response rate in the case of tumour microenvironment having effector immune cells and without immune suppressions.

On the other hand, in the case of tumour microenvironment having less effector immune cells and with strong and complicated immune suppressions, the patients have a bad outcome. That is, we have to design cancer immunotherapy based on the immune status in the tumour microenvironment. The analysis of immune status in the tumour microenvironment has found a lot of resistant mechanisms against cancer immunotherapy.

However, the current technologies such as antibodies and low molecular drugs are a heavy load. We believe that nano DDS largely contribute to overcoming the resistant mechanism and we are addressing a novel nano DDS system for achieving next-generation cancer immunotherapy.

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Industrial, trade and investment cooperation: A new era for the EU and Japan

Masanori Osumi, Japan-side General Manager and Philippe de Taxis du Poët, EU-side General Manager of the EU-Japan Centre for Industrial Cooperation, explain why a new era begins now when it comes to promoting industrial, trade and investment cooperation between the EU and Japan

The EU-Japan Centre for Industrial Cooperation[1] is a joint venture established in 1987 between the European Commission (Directorate General Internal Market, Industry, Entrepreneurship and SMEs) and the Japanese Government (Ministry of Economy, Trade and Industry) for promoting industrial, trade and investment cooperation between the EU and Japan.

With the entry into force of the EU-Japan Economic Partnership Agreement (EPA) on 1st February 2019 creating the largest open trade zone in the world which covers 600 million people, the Centre will contribute ensuring that companies in particular SMEs reap the maximum benefits from the EPA. To this end, we are mobilising several instruments, for example, the EPA helpdesk, public procurement helpdesk, and stakeholders, e.g. Enterprise Europe Network and clusters, to raise awareness, guide and stimulate SMEs.

In this context, the Centre is developing important activities regarding (i) people mobility, (ii) research and innovation, and (iii) technology transfer

- **People mobility** is one of the key elements for strengthening relations at the international level. The Centre has put in place the Vulcanus Programme, a unique internship programme involving industrial placement for European students in Japan,[2] and for Japanese university students in Europe.[3] Co-funded by the host companies and by the Centre, this one-year programme targets engineering or science students. It provides a four-month intensive language course and an eight-month internship in a host company.

- On the EU side, every year, 30–40 motivated Vulcanus participants are selected among 800 applicants to undertake industrial internships at host companies in Japan. In this vein, there is a strong signal of interest and a typical internship project includes mechanical/electrical engineering, computer science, ICT, chemistry, nanotechnology and biotechnology. Besides the technological and industrial dimension, the Vulcanus programme also helps participants gaining an in-depth understanding of culture, history and intercultural communication.

- The EU and Japan both see cooperation **in research and innovation** as necessary to promote the excellence of our research, increase the competitiveness of our industries and effectively address global societal challenges. The Centre is the National Contact Point[4] (NCP) in Japan for the EU research and innovation programme "Horizon 2020". Hence, the Centre raises awareness, disseminates information and calls for proposals, implements activities and training to support and provide guidance to potential R&D applicants in Japan. In close cooperation with the EU Delegation to Japan, NCP Japan provides information and participation support services to Japanese research institutions, companies and universities. Further expansion and development of EU-Japan relationships in science and technology are expected in the future EU research and innovation programme "Horizon Europe", including the possibility for Japan to become an "Associated Country" with this programme.

- The Centre promotes the commercialisation of technologies, and boosts innovation via the EU-Japan **Technology Transfer** Helpdesk,[5] which supports EU and Japanese companies, universities, research centres and individuals in their steps to search for and acquire available proprietary technologies, and better understand the process of tech transfer transactions. All the online services are supported by the official

website of the helpdesk, which provides general content about intellectual property rights, technology transfer, and an ever-growing database with more than 20,000 technologies potentially available for licensing deals, and more than 100 million patent documents and a wealth of information for the benefit of SMEs. Additionally, webinars, videos, podcasts, and presentations are intended to make the helpdesk's website a "must-see-and-use" for implementing open innovation practices. To favour this cross-pollination approach, research institutions can freely create an account and upload their technologies, and companies can write and publish requests for proposals to complement the existing tech offers.

"With the entry into force of the EU-Japan Economic Partnership Agreement (EPA) on 1st February 2019 creating the largest open trade zone in the world which covers 600 million people, the Centre will contribute ensuring that companies in particular SMEs reap the maximum benefits from the EPA."

The Centre also provides a six-month fellowship grant called "Minerva" for experts to work in Japan on topics of interest for researchers and businesses, including particularly creative and innovative ones, such as research into the NewSpace[6] sector in Japan and the potential for collaboration between EU and Japan New-Space start-ups. This will include a Haiku competition[7] to reach out to the public with a view of inspiring them to consider space, the theme being "Improving Life on Earth as in Space" for promoting NewSpace collaboration, by inviting artists, businesses and investors.

The EU-Japan Economic Partnership Agreement (EPA) will simplify trade and investment procedures, reduce export and investment related costs and will, therefore, enable more small firms to do business in both markets. Beyond what it includes, the EPA may also have an important triggering effect to reinforce existing and explore new areas of cooperation, such as research and innovation, space, security, investment, regions and clusters, regulation, digital economy and circular economy. It may also accelerate the current trend for joint EU-Japan business partnerships to operate together in third countries, e.g. South East Asia, Africa, Latin America, EU neighbouring countries. As stressed by the EU-Japan Business Round Table,[8] a "new era for the EU and Japan starts".

Masanori Osumi

Philippe de Taxis du Poët

In a global context with rising protectionism, where walls are being built and with geopolitical uncertainties, the EU-Japan Centre for Industrial Cooperation is also a political signal that the EU and Japan stand together for sustainable cooperation and team up to preserve the benefits of openness, ensure a level-playing field, pursue resilient economies and inclusive society. ■

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Japan: The advancement of world-class research in science

The Japan Society for the Promotion of Science works to ensure the advancement of world-class research in all fields of science both at home and in international partnerships, as this article reveals

Since 1932, the Japan Society for the Promotion of Science (JSPS) has worked to support the advancement of all fields of natural sciences, social sciences and the humanities.

In addition to directly funding scientific research, the JSPS, or Gakushin, fosters talent among young scientists, promotes science-related international exchange and supports the globalisation of Japan's universities.

While guided by the broad framework of government policies to promote science, the JSPS has since 2003, operated as an independent administrative body, allowing its programmes to be more flexible to the needs of individual researchers, universities and institutes.

As part of its aim to create diverse, world-level knowledge, the JSPS oversees the Grants-in-Aid for Scientific Research (KAKENHI) initiative, which supports research across all fields of science with an emphasis on creative and pioneering projects carried out based on researchers' free ideas.

Every year, the KEKENHI programme distributes around ¥228.4 billion, over 50% of Japan's total competitive research funding.

Projects can be proposed by individuals or groups of researchers affiliated with Japanese universities or other research institutions. More than 7,000 researchers carry out a peer review of applications, with funding awarded to those schemes judged to be of high potential and in line with cutting-edge scientific goals.

In order to ensure Japan retains its international position as a leading centre of scientific research in the future, the Ministry of Education, Culture, Sport Science & Technology (MEXT) recommended reform of the KEKENHI system to position academic research as a source of national strength.

A three-pronged reform process is underway looking at the review system in light of the rising number of applications and changing trends, as well as the research categories and frameworks to earmark funding specifically for challenging research, especially promoted research and aid for young scientists.

In addition, greater flexibility has been implemented in the use of grants with the introduction of a multi-year fund that allows researchers to carry over funds into the next fiscal year.

Following a 2012 report by Council for Science & Technology, the JSPS established a programme to contribute to advancing the humanities and social sciences in three key areas: joint research that will yield breakthroughs through close links with other fields of science; joint research aimed at making contributions to society; and international joint research. In 2017, the programme was funded with ¥208 million.

Within the programme, work is carried out in three subsets. Area Cultivation seeks research topics from different scientific fields that can spur unexpected jumps to new areas and more innovative methodologies. The second strand is responding to "Real Society", with collaboration between researchers and working-level specialists, from the planning and implementation of research to the dissemination of results. The final subset concerns global initiatives, which seeks to establish a dialogue between Japanese and overseas researchers to generate globally significant results through joint research.

In 2007, MEXT launched the World Premier International Research Centre Initiative (WPI), which sought to build a top-class research base for "super-calibre" researchers and concentrate funding for Japanese research institutes that work to achieve globally significant science.

In 2017, the ministry issued an open call for proposals for two new WPI centres and established a WPI Academy to promote the programme's work internationally.

MEXT commissioned JSPS to carry out WPI grant selection, perform evaluations and oversee project progress using procedures prescribed by the ministry. JSPS also manages the operation of the WPI Academy and supports the activities of the WPI centres with the aim of optimising the programme's output.

JSPS launched its fourth midterm plan in 2018. It is designed to respond to demands for scientific research to be highlight competitive, comprehensive, interdisciplinary and international.

Dr Yuichiro Anzai, JSPS President, says that when it comes to delivering the plan: "We will undertake to carry out our programs and operations in an ever-more efficient and effective manner toward meeting JSPS's current and new mid-term objectives".

"Concurrently, we will apply the full strength of JSPS's organization to meeting the needs of researchers and students aspiring to careers in science, while working to satisfy the public's multifaceted expectations for benefits derived from scientific advancement", he adds.

"The kind of superlative knowledge that contributes to developing a robust human society is born out of a continuum of original, cutting-edge research activities carried out by researchers ceaselessly striving to advance science across a spectrum of the humanities, social sciences and natural sciences. Such scientific thrust is the engine that drives the international competitiveness of a nation's industry and that elevates its persona within the global community. For Japan, it also plays an essential role in building a knowledge-based society.

"Scientific research lies at the wellspring of superlative knowledge creation. The fostering of talented people who can shoulder the advancement of such cutting-edge research is more important now than ever before." ■

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Chemistry and the archaeology of collagen

Takashi Nakazawa, Professor at Nara Women's University explores some fascinating aspects of chemistry and the archaeology of collagen, as well as a view point expressed on analysing ancient specimens in a collaborative way

Collagen is the most abundant protein occurring in the body of mammals. There are nearly 30 types of collagen, the majority of which are fibrous. Type I collagen has a characteristic architecture of a triple helix consisting of polypeptide chains of two α1 and one α2. This naturally occurring biopolymer is ubiquitous in bones, teeth, and skins of animals, taking advantage of its fibrous structure. The triple helix of collagen is so resistant to ageing that it can often be found in archaeological specimens as old as tens of thousands of years. Consequently, it informs us of the animal species in terms of the respective amino acid sequence, even in the absence of DNA encoding genetic information. We are using mass spectrometry to obtain information of archaeological interest.

Chemistry

As well as its triple-helical structure, collagen has a few unique features including the primary structure such that glycine (G) appears every third residue in the sequence $(G\text{-}X_1\text{-}X_2)_n$ (n > 300). Moreover, the positions X_1 and X_2 are quite frequently occupied by proline (P) or hydroxyproline (many authors abbreviate this residue as O). The post-translational modification of P to O is almost specific to collagen and catalysed by proline hydroxylase just before the formation of the triple helix. It is widely accepted that the content and position of O is closely related to the stability of the collagen triple helix[1]. Before beginning the present study of collagen in archaeological specimens, we were investigating the correlation between the role of O and the stability of the triple helix in solution using collagen model peptides[2]. Since this modification occurs enzymatically, the position of O in the amino acid sequence is not defined in the genetic code, it is very difficult to determine which P residues are modified unless protein sequencing such as Edman degradation or mass spectrometry is conducted on collagen samples.

Archaeology

Our project of protein archaeology with mass spectrometry began about 10 years ago, when we detected cow collagen in Chinese ink stick excavated from the oldest Japanese capital palace site in Nara (Heijyo-Kyo) of the mid-sixth Century AD[3]. Encouraged by such an unexpected success of finding collagen as waste disposal kept in the soil as long as 1,250 years ago, we extended the list of proteins by seeking wider area from Nara to the sites worldwide and older ages. Actually, the age of our specimens became older from the binding media of Egyptian Romano portraits (180-200 AD)[4], Egyptian wall paintings (2,400 BC) to West Asian Neolithic animal bones (5,000-8000 BC). And quite recently, we have been trying to detect collagen in Palaeolithic animal bones (30,000-35,000 BC). It is not surprising that the difficulty of analysis increases as the age of the specimens become older[5]. Nevertheless, we are excited about the challenge of solving this problem by mass spectrometry with the aid of protein chemistry[6].

> "The main target of our project of protein archaeology is collagen. This is because collagen is deeply associated with not only the evolution of animals but also the history of human culture before the invention of letters."

Note that the average lifetime of collagen to survive in archaeological specimens had been estimated to be much less than one million years[7]. It was, therefore, surprising that peptide fragments derived from collagen were found in the fossils of 8-million-year-old dinosaur bones[8]. However, another group has shown the complete match of amino acid sequences of collagen between that of modern ostrich (*Struthio camelus*) bone and those reported as of *Tyrannosaurus and Brachylophosaurus*, suggesting that there remains the possibility of cross-contamination of collagen[9]. In any case, we need to allow for the longevity of collagen, especially in the study of Palaeolithic bones for the identification of animal species.

Collaboration

Basically, we are analysing those ancient specimens in the collaborative study with archaeologists, scientists working for the conservation of cultural properties, artists, and historians, all of those who are least likely to work within our Laboratory of Biochemistry and Organic Chemistry in Nara Women's University. One of these collaborations includes a project "Culture History of Paleo Asia" organised by Professor Yoshihiro Nishiaki (the University of Tokyo), supported by a Grant-in-Aid for Scientific Research on Innovative Areas (Grant No. 1802) from the Japanese Ministry of Education, Science, Culture, and Technology. In this project, we could distinguish between a goat and sheep as the species of Neolithic bones[5]. Without these collaborations and financial aids (see "Acknowledgement"), we could not do anything so exciting as to obtain a variety of archaeological materials needed to "read" a history written in terms of the chemical structure of collagen. For this project, we welcome researchers all over the world to collaborate with.

Acknowledgement

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Surface science: A solution to shape our society that increases safety and security

Hitoshi Abe from the High Energy Accelerator Research Organisation (KEK) and SOKENDAI (the Graduate University for Advanced Studies) explains how a surface science solution will help to shape our society and increase safety and security

Infrastructure supports our modern society as bones support the body. Today's infrastructure looks very strong, made of hard materials such as steel, and millions of people put their trust when they are using it, for example, when driving over our highways and bridges and commuting by train when they have no worries about daily life. However, the materials used to build such infrastructure will not last forever, unfortunately, and the degradation and breakdown of infrastructure is a serious social problem. Steel, for example, is subject to corrosion due to chemical reactions from the surrounding environments. Corrosion starts at the surface of the materials.

If a novel material that is durable to corrosion will be invented, the infrastructure of modern society will become stronger and last longer. To design and to develop such a material, it is requested to observe and to understand the surface corrosion reactions. However, as far as we know, there is no suitable way to track such surface reactions with appropriate sensitivity. Firstly, we should develop a surface sensitive method to observe surface reactions which must meet the following three conditions:

- Surface sensitivity suitable to track surface corrosion reactions: a few nm;
- Compatibility of *in situ* measurements and;
- Ability to detect chemical states and local structures in order to understand the mechanisms of reactions.

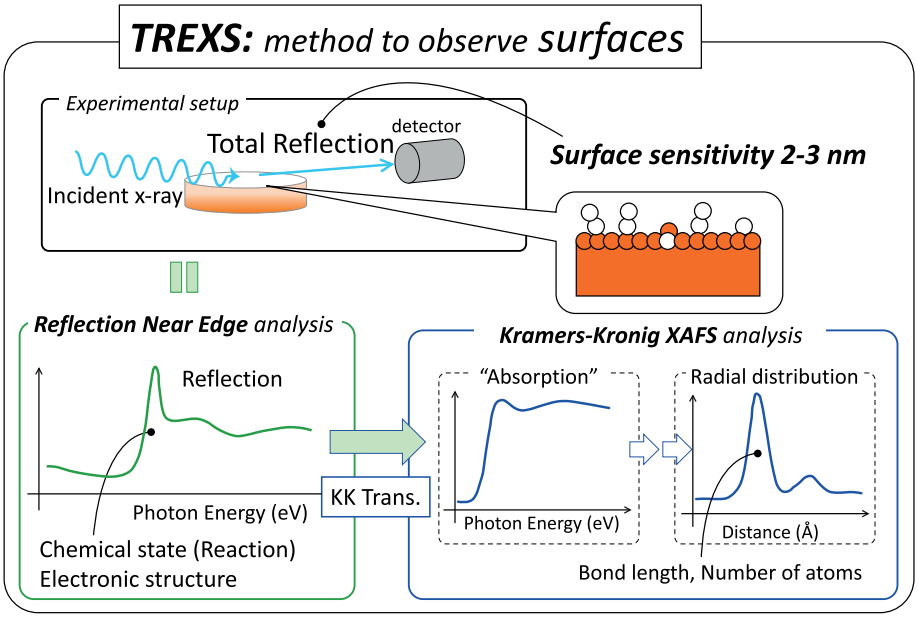

Fig. 1: TREXS (Total REflection X-ray Spectroscopy), a new surface observation method has been developed. Total reflection of incident x-ray is detected, and the surface sensitivity is as shallow as 2-3 nm

Surface can be captured by x-ray: TREXS, a new method

Traditional surface science methods usually probe a few atomic layers from topmost surfaces. They also require high vacuums and generally struggle to perform under ambient atmospheres. It is difficult for these methods to fulfil the above three conditions. Fortunately, we have a method to meet the second and third requirements. It is X-ray Absorption Fine Structure (XAFS) spectroscopy.

XAFS is widely used at synchrotron radiation facilities over the world to study local structures and chemical states. XAFS measurements can be performed under gaseous and elevated temperature conditions, and real-time chemical reactions have been observed by *in situ* XAFS measurements[1]. If the first ability can be added to *in situ* XAFS method, it can be a suitable and powerful method to observe surface reactions.

A question is how surface sensitivity will be realised. It is well-known that x-ray penetrates deeply into materials. We can see our bones by x-ray images at hospitals. But when a certain condition is met, even x-ray penetrates only very shallow regions. This is a phenomenon known as total reflection. When the incident angle of x-ray to a material is getting smaller and smaller, the total reflection of x-ray occurs at a surface. The angle is called a critical angle. The "touching depth" by the x-ray is only about a few nm[2].

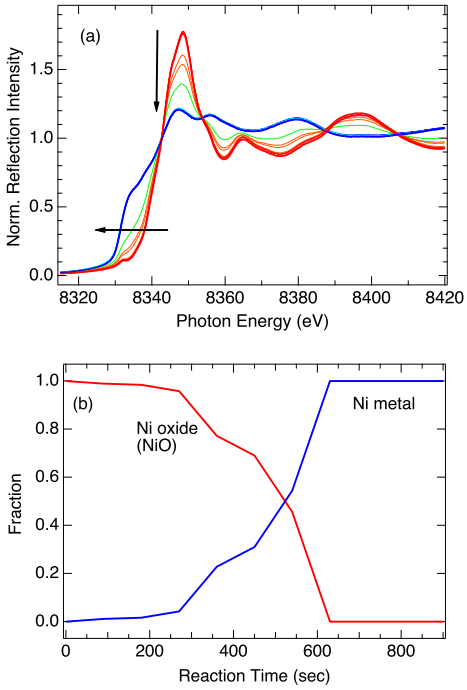

Fig. 2: (a) Reflection near edge spectra obtained by in situ TREXS measurements during the surface reduction reaction of NiO to Ni for NiO/Ni(30 nm)/Si. (b) The change of the NiO and Ni fractions during the reaction

In other words, total reflection of x-ray at surfaces probes only a few nm from the topmost surface. This surface sensitivity is perfect to observe surface corrosion reactions because the typical thickness of passivation layers of steel is several nm.

We have developed a new surface sensitive XAFS method by detecting total reflection signals[3]. The method is named Total REflection X-ray Spectroscopy, TREXS. Reflection spectra can be transformed into "absorption spectra" via Kramers-Kronig relations. Then, the spectra, the same as EXAFS (Extended XAFS) specra can be analysed by common EXAFS analysis software.

Moreover, an easy and useful way of the total reflection near edge spectra is to process them like usual XANES (X-ray Absorption Near Edge Structure) analysis. The total reflection near edge spectra contain information on chemical states of elements at a few nm from surfaces, and *in situ* TREXS measurements can be performed. The TREXS method is an ideal method to fulfil the three requirements listed above and to monitor surface reactions. Figure 1 explains a schematic flow of TREXS measurements and analyses.

In situ TREXS measurements of surface reduction reaction

In situ TREXS measurements were carried out to observe a reduction reaction of Ni oxide (NiO) to Ni metal occurred at the surface of a NiO/Ni(30 nm)/Si wafer sample[4]. The sample was placed in a home-made *in situ* TREXS cell. The *in situ* TREXS cell has windows for the incident and reflected x-rays, gas inlet and outlet ports, and heaters. The cell was set on a swivel stage to adjust the incident angle of x-ray to the sample. The incident angle was set to be 2.5mrad, which is well below the critical angle[5] so that the total reflection condition could be met. The penetration depth of the evanescent wave of the incident x-ray is as small as ~2 nm at this energy range, and the surface sensitivity is ~2 nm.

The surface of the sample was reduced by gas flowing of H_2 mixed with N_2 at 540 K, and *in situ* TREXS spectra were recorded during the surface reduction reaction. Obtained TREXS reflection spectra are shown in Fig. 2(a). In the beginning, the surface of the sample was NiO. The TREXS spectrum (red) shows characteristic spectral features of NiO, such as the strong main peak at ~8348 eV and associated pre-edge peak at ~8332 eV. As the surface reduction reaction to Ni metal proceeded, the TREXS spectra continuously changed. The main peak decreased, the edge energy shifted to lower energy by ~10 eV. Finally, the surface was totally reduced to Ni metal. The TREXS spectrum (blue) shows characteristic spectral features of Ni metal. There is a shoulder peak structure at ~8332 eV and the main peak, which is not extremely strong, at ~8347 eV. The component fractions of NiO and Ni during the reaction are shown in Fig. 2(b).

Summary and outlook

TREXS can monitor surface chemical reactions with the surface sensitivity of ~2 nm, and kinetics of surface chemical reactions can be discussed. TREXS enables us to produce movies of surface chemical reactions.

We are applying the TREXS method to monitor and to understand surface corrosion reactions. We believe our way to invent a novel material that is durable to corrosion to build strong infrastructure, will help to shape our modern society by safer and more secure means.

Acknowledgements
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Taiwan: Driving forward scientific and technological innovation

In the age of the knowledge-based economy, science and technology has become a key driver of growth and national progress for Taiwan, as this article about the country's Ministry of Science & Technology (MOST) delves into

The Ministry of Science & Technology (MOST) is Taiwan's agency for driving forward scientific and technological innovation, a major pillar of the country's plans for economic growth. In the age of the knowledge-based economy, science and technology has become a key driver of growth and national progress for Taiwan.

As such, in March 2014, the National Science Council (NSC), which was originally established in February 1959, was reorganised into the Ministry of Science & Technology (MOST) with a new structure designed to strengthen the integration of academic research and industrial development.

MOST was established with three main goals: promoting nationwide scientific and technological development, supporting academic research and developing science parks.

It continues the NSC's traditional role of promoting partnerships between academia and industry and encouraging innovation, while also reinforcing the impetus for businesses to invest in research and development, fostering creativity, nurturing start-ups and supporting industrial development.

MOST formulate guidelines and policies for, as well as puts forward the overall vision and strategies of, Taiwan's national science and technology development.

The National S&T Development Plan is jointly implemented by 17 ministries, departments and agencies, the national research academy Academia Sinica, the Board of Science & Technology, the Department of Cyber Security, the National Development Fund and local government.

The plan, which covers 2017 to 2020, focuses on four goals: reviving economic dynamics through innovation; developing smart living technologies and industries; cultivating and recruiting talents with diverse career paths; and enhancing an innovation ecosystem for scientific research.

MOST also oversee national science and technology programmes. Since 1997, Taiwan's government has been promoting national-level research initiatives to address the country's social and economic needs and to enhance national competitiveness.

In 2018, the government focused on promoting the second phase of its National Energy Programme, which aims to reduce Taiwan's dependency on imported energy and to improve the international competitiveness of alternative energy industries through the development of innovative renewable and low-carbon technologies.

MOST is participating as a partner in the programme, alongside the Ministry of Economic Affairs, the Ministry of Transportation and the Atomic Energy Council.

MOST are also responsible for increasing national science and technology literacy and it actively promotes popular science. This includes funding collaborations between academia and industry to produce media content such as films, videos and animations about science and technology.

Last year, the Taiwan Railways of Popular Science train toured around the island to foster public interest in science.

In addition, the High Scope Programme helps high and

Shihmen Dam in Fuxing or Daxi District, Taoyuan, Taiwan

vocational schools to integrate the emerging science and technology of everyday life into their curriculum to fostering the development of new innovations.

Elsewhere, the Foreseeing Programme aims to translate abstract and complex science and technology into enlightening, accessible and inspiring educational resources to spark public interest in the cutting-edge. As part of this, a MOST-sponsored summer programme offers island-wide interactive science classes for students, engaging them outside the traditional classroom and showing that science is fun.

Furthermore, MOST channels corporate and social resources to fund and organise popular science activities, such as Sci-Tech Vista, an online platform for sharing popular science resources.

To promote the development of academic research, MOST has implemented a number of core facility and major instrument projects to provide first-class equipment and promote resource sharing that help researchers achieve the maximum benefit from their work.

Meanwhile, the National Applied Research Laboratories aims to further scientific research by integrating and coordinating Taiwan's national laboratories in order to translate R&D results into innovative products.

In its role as a bridge between government, academia and industry, MOST provide PIONEER grants to promote domestic collaboration between business and academia. Companies submit problems for researchers to solve.

Through the Academia-Industry Technological Alliance, research organisations are encouraged to establish service platforms centred on core technologies and SMEs are invited to participate in order to boost their competitiveness.

Finally, MOST has established three core science parks in northern, central and southern Taiwan to create a hi-tech innovation corridor to facilitate and accelerate the country's transformation into a global centre for R&D.

The three parks encourage universities and companies in their respective regions to engage in collaboration, while also establishing incubation centres to provide professional consulting and resource referral services for start-ups.

In these and many other areas, MOST is fulfilling its mission to act as a catalyst for promoting the development of science and technology in Taiwan. ■

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Robotic-assisted rehabilitation devices: A wearable hand/finger rehabilitation robot

Jen-Yuan (James) Chang, Professor at the Department of Power Mechanical Engineering, National Tsing Hua University in Taiwan, explains the essentials for robotic-assisted rehabilitation devices, including a design example of a wearable hand/finger rehabilitation robot

The development of robotic-assisted rehabilitation devices, the so-called rehabilitation robot, requires interdisciplinary synergy from both medical and engineering fields. In this article, several essential considerations in the development of a rehabilitation robot are discussed and illustrated by a wearable hand/finger rehabilitation robot developed through research funded by Ministry of Science and Technology, Taiwan. The future possibility of such rehabilitation robot will also be discussed in the context of treating the robot as a smart machine.

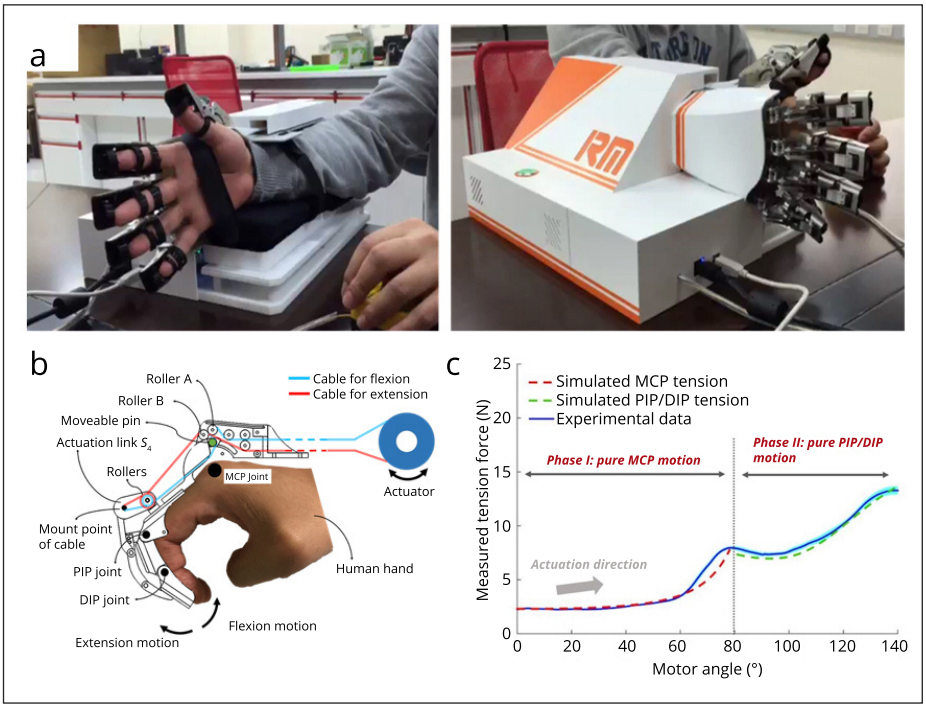

Figure 1: (a) Commercial-ready wearable hand/finger rehabilitation robot by RMTC, (b) mechanism and mechatronics designs and (c) force components of the model robot in action

Rehabilitation meditated by the use of robotic devices has been an emerging and quite interesting research topic in recent years. Due to the demographic dilemma in developed countries in which an ageing population increases while the birth rate decreases, the option of adaptation of robotic devices to assist rehabilitation treatments for an ageing and impaired population does offer social and economic advantages over the traditional human-intensive option through physical therapists and occupational therapists.

Due to such advantages, in the past ten years, more and more novel rehabilitation robots attributed by traditional therapy concepts have been developed and even commercialised in products to assist lower limb, upper limbs and even hand rehabilitation. In robot-assisted rehabilitation, patients can obtain precise, repeatable, and even reliable rehabilitation treatment through motion exercises designed by doctors. However, the biggest challenge in the research and development of robotic-assisted rehabilitation devices, or commonly called the rehabilitation robots, is the integration of interdisciplinary engineering fields with considerations from clinical requirements.

Such integration is not to the degree of complexity among medical and engineering expertise but to the level in which to offer the best solution to patients with the right combination of suitable elements for effective rehabilitation. In other words, the balance among the clinical needs and the realisation of engineering approaches is, in fact, the key to the success of the development of rehabilitation robots.

In this article, essentials for the development of rehabilitation robots will be discussed in the context exampled by the wearable hand/finger rehabilitation robot as shown in Figure 1(a) which was developed by Professor Chang's research group through research projects funded by Ministry of Science and Technology in the Department of Power Mechanical Engineering

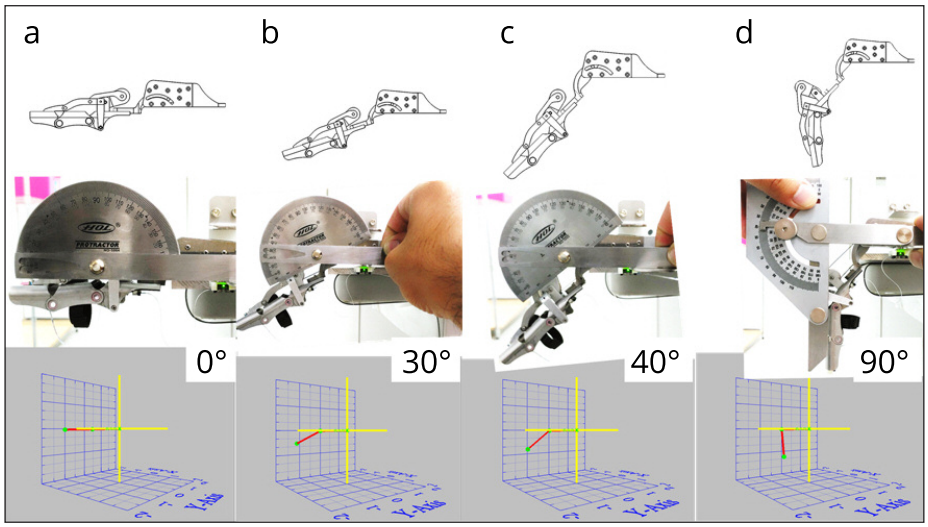

Figure 2: Finger rehabilitation robot under flexion (a) to (d) and extension (d) to (a) exercises. The bottom row shows the real-time angle measurements by IMU sensors

at National Tsing Hua University, Taiwan. Such designs were further realised in the commercial-ready product by spin-off company from the group named Rehabotics Medical Technology Cooperation (RMTC).

During robot-assisted rehabilitation, robot structures are applied upon disabled limbs with motor impairments caused by strokes, sports injuries or accidents. Driven by the robot actuators, the robot structure can then carry or move the disable limbs to perform rehabilitation exercise. As the example in Figure 1(b) shows, since the rehabilitation robot has its structure applied on a human finger, the first essential consideration is to include the human factors in the robot design. Such factors include the dimension of a human finger and thumb's proximal, middle, and distal phalanges, as well as the range of rotation for finger's metacarpo-phalangeal (MCP), proximal-interphalangeal (PIP), and distal-interphalangeal (DIP) joints. These factors will vary from race, age, gender etc. and play a significant role in the effectiveness of the robot's motion. With the human factors considered, the next essential consideration is then placed on the medical side by offering the appropriate rehabilitation exercise which will lead to the structure and mechanism designs of the rehabilitation robot. Taking the model finger robot as an example, as shown in Finger 2(a)-(d), the motions between the MCP and PIP/DIP joints are decoupled through mechanism design so that robot's movement pattern can be analogous to that observed in the human hand, as well as requested by medical doctors.

Once the robot's movement pattern is confirmed and achieved by mechanism designs, the next essential consideration is on the mechatronics integration, which includes the selection and implementation of actuators, sensors, and controller in the robot. For the model finger robot as illustrated in Figure 1(b), limited by space to accommodate for a higher degree of motion in hand/finger rehabilitation, the finger robot is not directly driven by motors but designed to be driven by cables actuated by motors which are placed away for impaired hand/fingers. The main objective of the rehabilitation robots is not only to offer repeated motion but to provide biological insight of impatiens can improve by the use of the robot.

For stroke patients, their degree of spasticity degree judged offline but can't be monitored during rehabilitation treatments. With the model robot, such online monitoring of finger joint spasticity can be achieved by the embedded force sensor data as exampled by the robot's cable force measurement as shown in Figure 1(c). Also, with the use of motion sensor, such as inertial measurement unit called IMU sensor which is embedded in the robot structure, positions and orientations of the robot movements can also be monitored real-time. Should the rehabilitation exercise be deviated from the designed path, with well-design control codes, the controller unit in the robot can alter the actuator's motion to direct the robot to move the human body back to the designed course. Since the robot possesses the capability in collecting force and kinematic information of the robot and patient, rehabilitation big data can then be established through medical trials and practices. Certainly, with such a smart machine, the rehabilitation robot, new medical knowledge in rehabilitation is thought to be generated in the near future should the data be carefully integrated and examined with artificial intelligence (AI) technologies.

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Towards mobile healthcare with medical-internet of things (IoT) devices

A move towards mobile healthcare with medical-internet of things (IoT) devices is placed under the spotlight here in an insightful piece from Prof D. Chen-Yi Lee from Department of Electronics Engineering, at the National Chiao Tung University in Taiwan

In this article, I will be looking at the impact on society when it comes to the move towards mobile healthcare with medical- internet of things (IoT)[1], technology trends, as well as an interesting example of an electrocardiogram (ECG) and my thoughts on what the future could hold in this exciting field of research.

The impact of medical devices on society

To achieve better medical services with early diagnosis and early therapy, innovative solutions for preventative medicine have been continuously investigated and promoted to both medical centres and local clinics. One of the major driving forces in exploring these solutions for mobile healthcare is to allow limited medical resources for those patients who demand in-time treatment and medical care under the coverage of national health insurance in Taiwan.

Furthermore, both medical teams and the general public need to be re-educated before these new diagnosis/therapy solutions and inherent service models can be accepted. And even some governmental regulations have to be re-adjusted or added to allow these solutions to be deployed for practical usage.

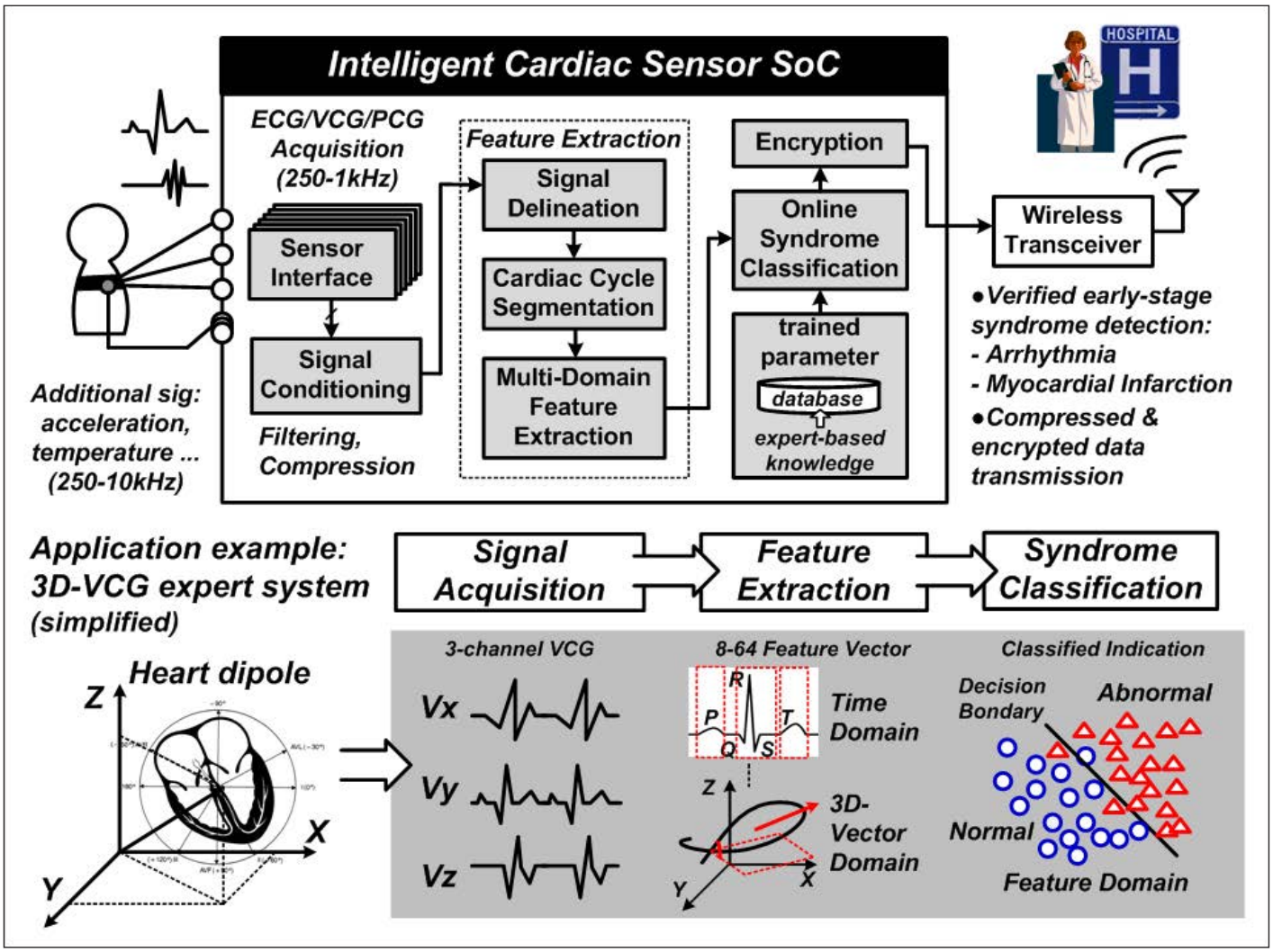
Technology trends

The advances in wireless devices and miniaturised sensors fuel the possibilities of mobile healthcare applications, where medical-internet of things (M-IoT) devices are body-worn or implanted for continuous vital signal recording. To extend the M-IoT monitoring duration, on-sensor biomedical signal processors (BSPs) can be applied to timely extract the critical information for reduced storage and transmission data. Considering the support given to versatile applications with maximised monitoring time, the BSPs should be flexible and accurate with extremely low power operation. In addition, single-type sensor or sensor-fusion solutions should be developed as well to generate valid bio-datasets for follow-up health conditions analysis. Data screening is key to enhance prediction accuracy and avoid false alarm in practical usage. Finally, data security to protect privacy leakage and personal identification to secure the quality of service should be taken into account in these M-IoT devices.

An example on an electrocardiogram (ECG)

An application scenario on an electrocardiogram (ECG) for heart disease prediction is illustrated in the following figure. To meet the requirements of mobile healthcare applications, a specific M-IoT device is demanded with enhanced energy-efficiency so that it can be operated for more than one week with one chargeable battery. In the meantime, the device should be small enough to allow user-friendly wearable usage. Thus, a specific chip needs to be designed to cover the following functions, namely signal acquisition, feature extraction, syndrome classification. In addition, data security and personal identification have to be covered as well. Wireless transmission can be leveraged by those commercial solutions, such as Wi-Fi and Bluetooth depending on how this M-IoT is deployed and used. A preliminary IRB clinical trial based on this M-IoT on the prediction of both arrhythmia and myocardial infarction with accuracy over 95% have been reported. If sensor-fusion is further exploited to cover ECG, vectorcardiogram (VCG), and phonocardiogram (PCG), it is believed that prediction accuracy can be further improved.

There are two issues to be further illustrated to avoid false alarm in practical usage. One is the input signal quality and data validation: this is a very important issue if the input signal has been affected by environmental noises, such as those from power-line, skin contact drift, motion artefact, etc. Different methods have been investigated to reduce these noise sources so that signal to noise level can be further improved. However, these noise-reduction methods may also induce human-made extra noises to signal sources, leading to worse prediction accuracy and even higher false alarm rates. As a result, new approaches to screen out valid datasets from source



signals should be further studied. The other issue is datasets collection from clinical trials. The sample volumes should be large enough to cover different test conditions in model training phase so that prediction accuracy can be accepted in practical usage. This is very important when M-IoT devices are to be deployed in different test scenarios.

However, one problem often encountered is the limited datasets collected for model training, especially in medical diagnosis based on the data-driven approach. Even test samples and procedures have been well defined and planned but it's still hard to cover all test conditions and, hence, prediction accuracy may vary a lot in practical usage. As a result, new approaches toward autonomous learning at the M-IoT device level should be further explored to enhance prediction accuracy and make it reliable for mobile healthcare applications.

A glimpse into the future

Lastly and by no means least, it is believed that with the advances taking place in M-IoT devices, including both sensing capability and autonomous learning, the penetration rate will become much fast than it is today. These new M-IoT devices, together with data-driven operation infrastructure currently under construction, will definitely provide better medical services to society. As a result, the general public will benefit more from a one-stop service platform to lead a better life while enjoying the advantages offered by those M-IoT devices, both developed and under development.

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Guard Patch: Intelligent wearable technology with Internet of Things and platforms

Professor Shuenn-Yuh Lee, National Cheng Kung University, discusses his mission to build a user-friendly development platform with smart wearable technology, in this report

I established the Communication and Biologic Integrated Circuit (CBIC) Lab in 2002. My mission is to build a user-friendly development platform with smart wearable systems, which consists of the biosignal processing integrated circuits and modules, the user-friendly websites and apps, and the artificial intelligence (AI) system on the cloud.

The goal of the Guard Patch is to develop a Low-power Long-term Wearable Body Sensor SOC for Wireless Electrocardiogram Monitor. Our team designs and implements a high resolution and low power bio-signal acquisition chip. The chip is fabricated in a TSMC 0.18 μm standard CMOS process. Based on this chip, we integrate the required circuits into a wearable system module to sense the Electrocardiography (ECG) signal from users. The communication between the sensor and the smartphone is established via Bluetooth.

The software needs to fulfil the following four principal tasks: 1) data processing, 2) analysing, 3) displaying, and 4) recording. A back-end application (APP) on Android/iOS system carries out further mathematical calculation and analysis, including demodulation and digital signal processing. With the basic monitor function (off-line bio-signal data storage), the real-time monitoring function is also developed and the real-time bio-signal can be checked on the smart device. The processed ECG signal will then be displayed on the screen. With such a wearable platform for wireless bio-signal acquisition, the user can access and monitor his own physiological condition anytime and anywhere.

For these functions mentioned above, this wireless bio-signal acquisition system will become the guard patch of the user. There are three main advantages of this system, including real-time monitoring, convenient for wear, and easy to use.

In addition, the technology of Guard Patch is promoted to other applications, including smart clothing, I-Pet clothing, TRIANSWER, intelligent medical stethoscopes, epilepsy detection and stimulation systems, portable and wireless urine detection systems and platforms, etc. The detailed has been presented in the CBIC introduction video.

24-hour arrhythmia monitoring system

Electrocardiography (ECG) is a fundamental method not only commonly used in the hospital for clinical requirement but also widely adopted in home and personal healthcare systems to obtain the electrical activity of the heart. An arrhythmia monitoring system is proposed and used in a clinical trial. The proposed system has three parts. The first is a high-resolution, low-power analogue front-end circuit for implementing bio-signal sensing circuits. The features of the circuits are low complexity, high resolution, and low power consumption.

The second part is a digital signal processor with a decimation filter and a universal asynchronous receiver/transmitter package generator. The last part is used to realise a software interface on smartphone for ECG signal recording, display, and classification. A wavelet-based classification method is also proposed to classify the rhythm. The chip used in the system is fabricated through TSMC 0.18 μm standard CMOS process. The classification algorithm is verified with data from the MIT/BIH Arrhythmia Database. The accuracy of beat detection and arrhythmia classification is 99.4% and 95.83%, respectively. Patients in Tainan hospital are enrolled in a human study to verify the performance of the proposed arrhythmia monitoring system. Results show that the system can acquire and classify ECG signals.

Smart clothing

Combining the wearable devices with the concept of the Internet of Things (IOT) to create a wearable health care system is a potential issue for an ageing society. Among the applications of the wearable health care system, smart clothing has some unique advantages. First, unlike most wearable devices such as watch and belt, clothes are necessary for every-

Shuenn-Yuh Lee, Professor

one in daily life, so the clothes-related medical wearable devices can be easily accepted by people.

Also, smart clothing has the ability to provide more variety of bio-signal monitoring than other wearable devices because they have a larger contact area to the body surface of the user. Thus, Tien Jiang Enterprise Co., Ltd. cooperates with our team in developing a system of smart clothing. The system utilises the fabric-based electrodes with a comfortable sense of touch to provide the measurement of ECG signal and respiration signal, and delivers the signal through Bluetooth to the mobile phone. At last, the physiological information such as energy expenditure and heart rate variability can be analysed.

I-Pet clothing

Through combining pet clothing and front-end sensor, the I-Pet clothing is a wireless bio-signal detecting system for acquiring ECG and respiratory signals from a pet. An algorithm is implemented to evaluate the emotion state and heart rate variability. Based on these analysis results, this system can be a reference for veterinarian and provide suggestions to pet caregivers. Moreover, the emotion index can help pet masters to understand the mental states of their pets. This work combines the concept of wearable devices and internet of things and contains the hardware implementation and software development. With a software application as a graphical user interface, users can obtain the real-time and past condition of pet. This information platform is a channel to communicate with the vet and a bridge for the pet lovers to exchange their experience.

Trianswer

Trianswer is a bio-medical evaluation module designed for wearable and IOT-based products. It not only contains several features about low-power consumption, miniaturisation and IOT-based design, but also provides the acquisition of high-quality bio-signals including Electrocardiography (ECG), Electroencephalography (EEG), Electromyography (EMG), etc. By reducing the development time and cost, developers can manufacture their wearable devices rapidly with the assistance of Trianswer.

In addition, acquiring the specific bio-signal needs its own corresponding module. Developers can combine modules assisted by Trianswer to fit their requirement. The main concept of Trianswer is to promote the development of bio-medical wearable devices.

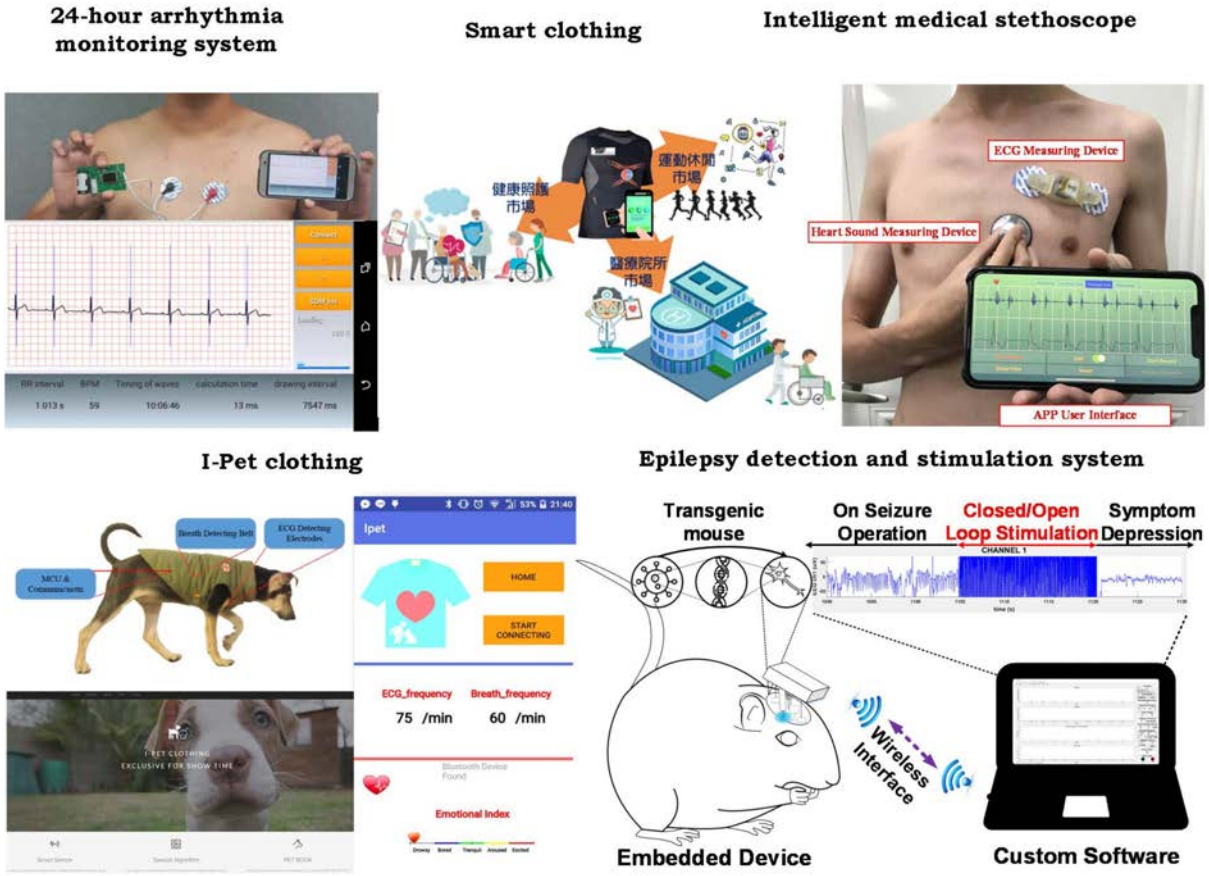
Intelligent medical stethoscope

When mentioning the cardiac auscultation in hospital, it is important but difficult to distinguish efficiently between the first heart sound (S1) and second heart sound (S2). The identification of S1 and S2 will affect the judgement of the additional heart sound and murmurs. The accuracy of auscultation relies on the experience of the doctor. In order to assist doctors in making diagnoses more rapid and accurate, our technical team develops the smart stethoscope which is capable of measuring the ECG signal and the heart sound signal at the same time. These two signals will be displayed on the smart phone and the phase of the heart sound signal can then be confirmed. To eliminate the uncertainty and reduce the demand for experience, the doctors may refer to these waveforms for diagnosing the potential heart disease by taking advantage of signal visualisation.

Epilepsy detection and stimulation system

Epilepsy is one of the most common neurological disorder. It is mainly caused by the abnormal discharge of nerve cells in the brain. The mainstream treatment for epilepsy is to take oral medication. However, conventional treatment is hard to achieve remarkable effectiveness. In recent years, many studies have focused on the development of intracranial implantable electrical stimulation.

Our team cooperates with National



Cheng Kung University (NCKU) hospital in developing the EEG sensor and electrical stimulation module. The B6 mice are selected in the animal testing at the present stage. The electrodes are implanted to collect EEG signals from mice, and the measurement module transmits the signal through Bluetooth to the computer. A custom computer software application is developed to perform a data analysis algorithm, and identify epilepsy immediately. Then, the electrical stimulation is provided to relieve the symptom. To sum up, EEG signal acquisition and epilepsy alleviation with electrical stimulation are realised in this system.

Portable and wireless urine detection system and platform

For decades, cardiovascular disease (CVD) is the top cause of death in the world and the top 3 leading causes of death in Taiwan. The statistics reveal the issue of CVD mortality awaits for a useful prevention method. Due to the high mortality of CVD, the early detection of CVD is becoming a big issue. A portable and wireless urine detection system and platform for home care and community screening is proposed. It provides a telecare platform to monitor the risks of CVD and prevent the occurrence of CVD.

The main concept is to develop a system-on-chip, a microelectrode and microchannel chip to detect the concentration of CVD-related risk factors in urine. Data will be wirelessly transmitted to a smart application platform to evaluate the user's cardiovascular status based on the outcomes in clinical research. Users will obtain the condition of CVD and the professional medical advice from the cooperative cardiovascular doctors in NCKU hospital through the platform.

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Climate change impacts and greenhouse gases in Japan: A policy perspective

The Ministry of the Environment's ambitions in Japan are detailed here, with a special focus on climate change impacts and greenhouse gases policy

The Ministry of the Environment, Government of Japan is responsible for global environmental conservation, nature conservation and pollution control and was created in 2001 from the sub-cabinet level Environmental Agency that was set up during 1971[1]. This article will look at examples of the Ministry's work around the topic of climate, including discussion of Japan's National Greenhouse Gas Emission, GOSAT (Greenhouse gases Observing SATellite), as well as climate change impacts.

Japan's greenhouse gas emissions

The Ministry, along with the National Institute for Environmental Studies released Japan's National Greenhouse Gas Emissions (preliminary figures) for the fiscal year (FY) 2017 in November 2018. These figures tell us that the total emissions in 2017 were found to be 1,294 million tonnes of carbon dioxide equivalents (Mt CO_2 eq.), a 1% decrease compared to those of FY2016; an 8.2% decrease compared to FY2013 and a 6.2% decrease compared to FY2005. The Ministry's website offers their own thoughts on these figures.

"The main factor for the lower emissions as compared to FY2016 is the decrease in energy-related CO_2 emissions due to the increase in the share of non-fossil fuels within the domestic energy supply brought by the wider adoption of renewable energy such as solar and wind power and the resumption of nuclear power plant operation.

"This is a decrease of 1.0% (12 Mt CO_2 eq.) when compared to the FY2016 emissions (1,307 Mt CO_2 eq.), mainly because of the decrease in energy-related CO_2 emissions due to the increase in the share of non-fossil fuels within the domestic energy supply brought by the wider adoption of renewable energy such as solar and wind power and the resumption of nuclear power plant operation, despite the increase in hydrofluorocarbon emissions from refrigerants that substitute for ozone-depleting substances.

"This is also a decrease of 8.2% (115 Mt CO_2 eq.) when compared to the FY2013 emissions (1,409 Mt CO_2 eq.), mainly because of the decrease in energy-related CO_2 emissions due to the increase in the share of non-fossil fuels within the domestic energy supply brought by the wider adoption of renewable energy such as solar and wind power and the resumption of nuclear power plant operation, and the decrease in energy consumption, despite the increase in hydrofluorocarbon emissions."

We also discovered that there has been a decrease of 6.2% (86 Mt CO_2 eq.) in comparison with to the 2005 emissions (1,380 Mt CO_2 eq.), primarily due to the decrease in energy-related CO_2 emissions as a result of the decrease in energy consumption, even though there has been an increase in hydrofluorocarbon emissions.[2]

GOSAT

Staying on the subject of climate, we also learn that GOSAT (Greenhouse gases Observing SATellite) is the world's first satellite designed specifically for monitoring greenhouse gases from space. This is indeed an exciting project and we know that GOSAT reveals details on the global distribution of methane (CH_4) concentrations and carbon dioxide (CO_2), as well as on where and how much greenhouse gases are emitted or absorbed. This was something highlighted in December 2018 by the Ministry of the Environment Government of Japan, as they detail below in their own words.

"Global atmospheric concentrations of CO_2 and CH_4 in all layers of the atmosphere from the ground surface to the top of the atmosphere rise yearly with seasonal oscillation.

"These results are contributing to the climate science and useful for climate change-related policies."

In addition, our attention is drawn to GOSAT-2, a successor of GOSAT, launched in October 2018 with tremendous success. Using this satellite, the Ministry of the Environment Government of Japan intends to observe whole-atmosphere CO_2 and CH_4 concentrations from space continuously. This is an activity that is carried out with high accuracy and can: "Estimate anthropogenic emissions from a large city and large-scale emission source, thereby contributing to further enhancing transparency and GHG emission reductions."

GOSAT and GOSAT-2 projects are promoted by the Ministry of the Environment Government of Japan, along with the Japan Aerospace Exploration Agency, and the National Institute for Environmental Studies. [3]

Climate change impacts

Finally, in recent news from January 2019 we discover that when it comes to the manifestation of climate change impacts across the world, the Intergovernmental Panel on Climate Change (IPCC)'s 1.5°C special report in October 2018 describes the future of global warming: "Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate", they said. This is indeed a challenge and the Ministry's website notes that to realise a decarbonising society, the extension of conventional efforts plus new innovation are very necessary. They believe that such innovations are now considered to be a source of growth.

"Under such situations, the Ministry of the Environment (MOE) has proceeded with technical demonstration projects of CCUS (Carbon dioxide Capture, Utilization and Storage) which can greatly reduce CO_2 from large-scale emission sources to the atmosphere." [4]

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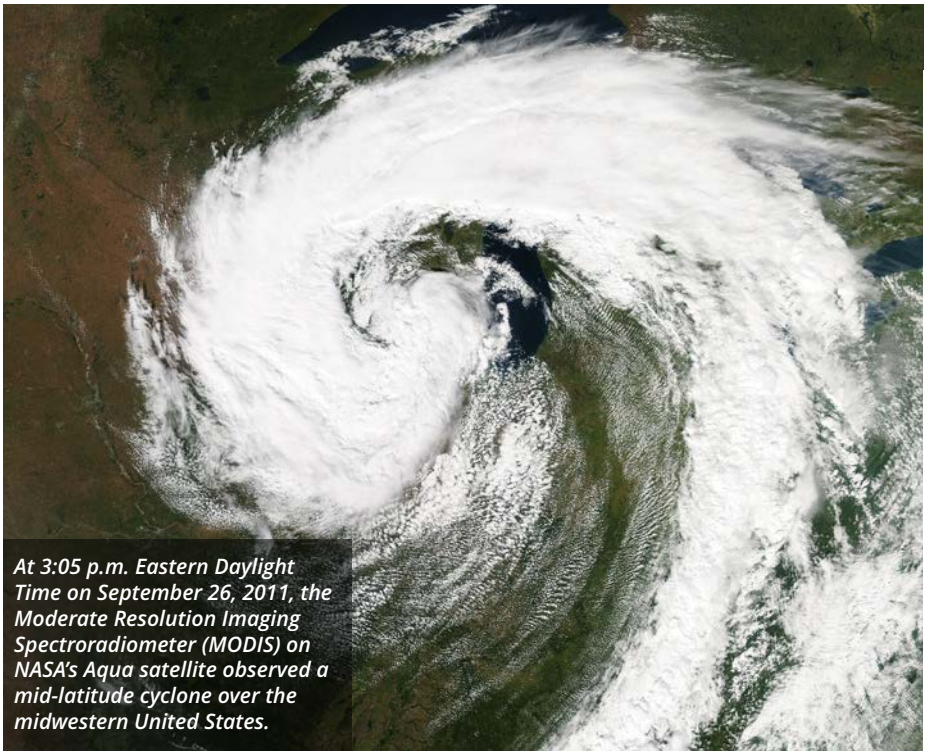
“Climatic hotspot project”: Uncovering impacts of the midlatitude ocean

Uncovering impacts of the midlatitude ocean is a part of the “Climatic hotspot project, as profiled here by Professor Hisashi Nakamura from the Research Center for Advanced Science and Technology, at the University of Tokyo in Japan

By way of background, it has long been believed that the extratropical ocean is passive to atmospheric variability and, therefore, anomalies in extratropical sea-surface temperature (SST) provide no predictability in climatic condition. In fact, the current operational seasonal prediction for the extratropics finds its basis on remote influence from tropical ocean-atmosphere variability which is typified by El Niño/La Niña. This conventional notion was established on the basis of previous findings that extratropical SST anomalies form as a response to BOTH wind and temperature fluctuations, which have been derived from SST data based on in-situ observations and output data from atmospheric general circulation models with low spatial resolution.



At 3:05 p.m. Eastern Daylight Time on September 26, 2011, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite observed a mid-latitude cyclone over the midwestern United States.

NASA image courtesy Jeff Schmaltz, the MODIS Rapid Response Team at NASA GSFC

Our challenge

However, recent satellite data and high-resolution numerical modelling have started offering a different view. Utilising such high-resolution data, our project “Hotspots in the Climate System” or “Hotspot Project”, aims to present convincing evidence that the mid-latitude ocean, especially, an intense warm current along the extreme western portion of each ocean basin, such as the Gulf Stream or Kuroshio, can exert thermodynamic forces on the atmosphere through heat and moisture release. The eastward extension of the warm current merges with a cold current, forming an oceanic frontal zone with a pronounced SST gradient. Variability of the frontal zone as a response of the ocean gyre to anomalous wind stress can, therefore, yield strong SST anomalies and thermodynamic forcing on the atmosphere by modifying heat and moisture release. We regard these warm western boundary currents (WBCs) and associated frontal zones as climatic ‘hotspots’ that must be significant in shaping the tropospheric circulation and variability.

Well-designed structure for the challenge and capacity building

Our hotspot project challenges the aforementioned established notion by exploring the climatic impacts of the WBCs and SST fronts through the effective combination of numerical, analytical and observational studies. Under five-year funding from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the project was initiated in July 2012 as the collective endeavour of 18 universities and four research institutes, where over 100 researchers and graduate students across Japan are involved. Led by Professor Hisashi Nakamura, the project consists of nine main programmes and a dozen of smaller supplementary programmes, with umbrella projects under which

crosscutting research activity is promoted for challenging four important topics: Oceanic jets and SST fronts, Pacific decadal climate variability, and air-sea interactions under the East Asian summer/winter monsoons. The project encourages close collaborations between physical oceanographers and atmospheric/climate scientists, as well as international collaboration, therefore, offering an excellent environment for capacity building. In fact, the number of PhD students in the project increased by 150% during the five years.

Unique field observations

One of the main programmes is specially designed for field observations. Experts in the programme led observation campaigns just east of Japan, including the one in early July 2012. It featured a unique strategy where three research vessels aligned meridionally at fixed intervals crossed the Kuroshio Extension and associated SST front repeatedly from the south and north over five days, while conducting GPS sonde and expendable bathythermograph observations for the atmosphere and upper ocean, respectively and synchronously every two hours. Unlike many previous attempts by single-vessel observations, our campaign was the first to unambiguously reveal a detailed vertical structure of the SST front and cross-frontal contrasts in the atmosphere, including the vertical structure of the boundary layer and low-level clouds. These findings are valuable as a benchmark for numerical models.

Outcomes and achievements

The outcome of the hotspot project was truly substantial and represented as 400 peer-reviewed papers in international journals after a five-year funding period, and new papers are still coming out. Some of them are archived in a special section of the Journal of Oceanography (2015) and a special collection of the American Meteorological Society "Climate Implications of Frontal Scale Air–Sea Interaction". Jointly with the Japan Meteorological Agency, the project has produced a new product of global atmospheric reanalysis with high-resolution SST (JRA55-CHS). We presented solid evidence that midlatitude oceanic frontal zones favour the recurrent development of cyclones and anticyclones to form regions called “storm tracks”. Moisture supply from the warm WBCs favours explosive development of cyclones. Wintertime cyclone tracks are found sensitive to the Kuroshio meanders, modulating snowfall probability in Tokyo. Recurrent cyclone development shapes low-level cloud distribution, which influences the Earth’s radiation budget, and organises large-scale rain bands along the frontal zones. Through storm track formation, the midlatitude oceanic frontal zones influence basin-scale or even hemispheric-scale westerly jet streams and their variability. For example, persistent SST anomalies in the Kuroshio/Oyashio Extensions act to force basin-scale variability in upper-level westerlies over the Pacific and semi-permanent surface low-pressure system (the Aleutian Low), whose climatic influence extends into North America. SST frontal zones in the southern oceans are found to be essential for the dominant hemispheric-scale mode of westerly variability, through which extensive climatic trends were induced over the late 20th Century by the formation of the stratospheric Antarctic ozone hole. In summer, particularly high SSTs along the Gulf Stream or Kuroshio are found to organise deep convective clouds, especially under warm, moist air flows from the tropics, which sometimes give rise to torrential rainfall in coastal regions.

Towards the next stage

Our findings mentioned above urge the international community of climate science to promote high-resolution modelling of the ocean and atmosphere to resolve narrow midlatitude hotspots and their climatic impacts. During the 20th Century, the hotspots underwent locally enhanced warming, and their climatic role is, therefore, expected to increase under future warming. In fact, recent ocean warming around Japan appears to yield enhanced surface evaporation and, thereby, increases the likelihood of torrential precipitation over Japan. The next stage of the project is under preparation to expand its scope into clarifying the role of the climatic hotspots in a future projection of the occurrence of extreme weather and climatic conditions, under on-going global warming. We will also explore similar hotspots in the Arctic, as we have found that declining sea-ice cover in the Barents/Kara Seas acts to strengthen the Siberian High and, thereby, induce severe winters over midlatitude Eurasia.

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Quick earthquake alert notification for disaster risk reduction in Taiwan

Deputy Director of the Seismological Center Central Weather Bureau (CWB) in Taiwan, Nai-Chi Hsiao, explains how the country's quick earthquake alert system provides notification when it comes to ensuring disaster risk reduction

Taiwan is located on the boundary between the Philippine plate and the Eurasian Plate. The convergence of these two tectonic plates activity causes about 100 obvious felt earthquakes per year and 100 minor non-felt events per day around Taiwan. Several hazard earthquakes have occurred during our history. The most famous one was the 1999 Chi-Chi earthquake with Richter magnitude 7.3 in the middle of Taiwan, which killed more than 2,000 and caused mass building damage as well. The threat of an earthquake is, therefore, a serious issue today in Taiwan.

The Central Weather Bureau (CWB) is the government agency responsible for earthquake monitoring and relevant warning issues in Taiwan. More than 700 seismic sensors were deployed in and around Taiwan, including some on the ocean floor in the East Offshore Marine Area. About a quarter of these stations communicate in real-time with the headquarters at CWB at any given time. Depending on these precious ground motion signals, an automatic detection system was developed which can locate an earthquake at any time.

Besides the automated system in place, there are at least three persons on duty in the Seismological Center of CWB. They have ensured the healthy operation of the Seismic Network and the computer systems all the time, and their most important mission is to verify the correctness of all information and to issue felt-earthquake reports as quickly as possible. The report is disseminated to hazard-rescue agencies, hazard-assessment organisations, earthquake research institutions, important infrastructure systems (such as power supply, communication, and transportation), and mass media. Besides the initiative disseminated, these reports will also be published on the website of the CWB to inform the general public simultaneously. For instance, 139 obvious felt-earthquake reports were issued in 2018, and the average performance of auto detect and location takes place in about 60 seconds and issues are reported within the space of around five minutes.

> "The Central Weather Bureau (CWB) is the government agency responsible for earthquake monitoring and relevant warning issues in Taiwan. More than 700 seismic sensors were deployed in an around Taiwan, including some on the ocean bottom in the East Offshore Marine Area."

Based on the millions of earthquake data recorded and the monitoring experience in place for over 25 years, the CWB had been conscious that felt-earthquake reports are useful, but only in the hazard-rescue stage after earthquake shaking occurs. Therefore, we developed the Earthquake Early Warning System (EEW) to detect significant earthquakes quickly in order to issue a warning about 10-15 seconds after the earthquake occurrs. That means we can issue alerts for the area about 60 km away from the epicentre and provide seconds to 10s of seconds warning time for an urgent response before the destructive shaking occurs.

Since 2014, CWB has provided the EEW warning directly to all the public schools, hazard-rescue agencies and other government departments in Taiwan. Since 2016, CWB has issued EEW warnings through the Public Warning System (PWS) to wireless devices of the general public. The PWS was developed and constructed by the government and communication Corp., which is based on the Cell Broadcast Service (CBS) on the 4G network. This means that all the people in a

Image: © Minyun Zhou | Dreamstime.com

high-risk area can receive an EEW warning at the same time! CWB also collaborates with TV companies to deliver instant live pop-up messages during the transmission of programmes.

However, the warning can only help people taking action to protect themselves (Drop, Cover, and Hold on) because the warning time is limited. The main benefit of an EEW is the application of industrial auto-control, slowing down high-speed communication vehicles, suspending or halting the gas-line or power-line system, auto protection for a dangerous system such as power plants, hi-tech equipment, and so on. CWB had promoted the application of the EEW, recruited more than 10 private companies and research institutes in different domains to collaborate in order to develop warning message forwarding and customised application for requirements for any hazard mitigation purpose.

No matter what the earthquake report or the EEW warning is, we focus on improving the availability, accuracy, and efficiency of earthquake monitoring. There are several tasks that need to be promoted eagerly in the future. These include expanding the coverage of the Seismic Network and installing more advanced and robust ocean bottom seismographs on the east-south ocean of Taiwan where it is most likely that an earthquake will occur. To enhance the density of the Seismic Network: upgrading more off-line to real-time stations is required – improving the algorithm of computer modules so that it will take less time for the EEW to be issued. The ultimate goal of earthquake monitoring in Taiwan is to provide useful EEW and earthquake reports to whoever needs them, to achieve practical earthquake hazard mitigation, helping to secure the civil life and properties in the country. ■

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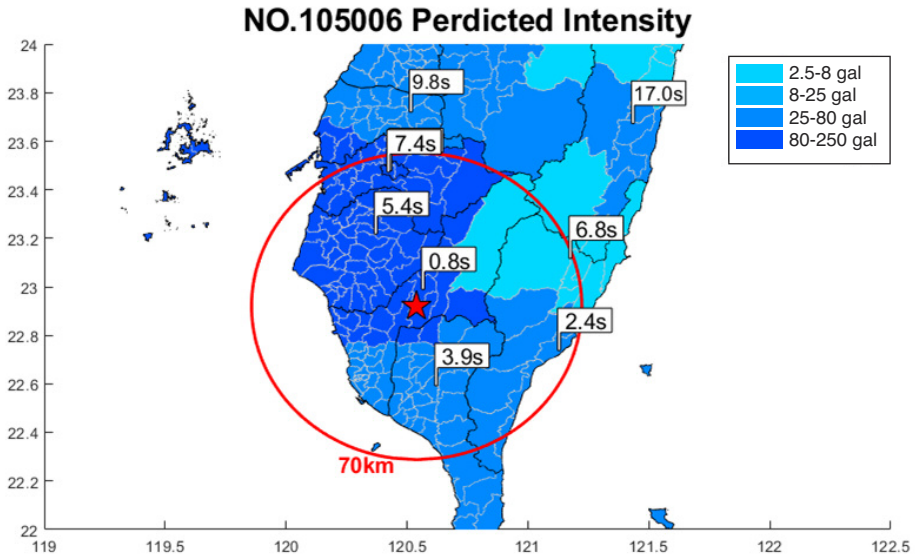
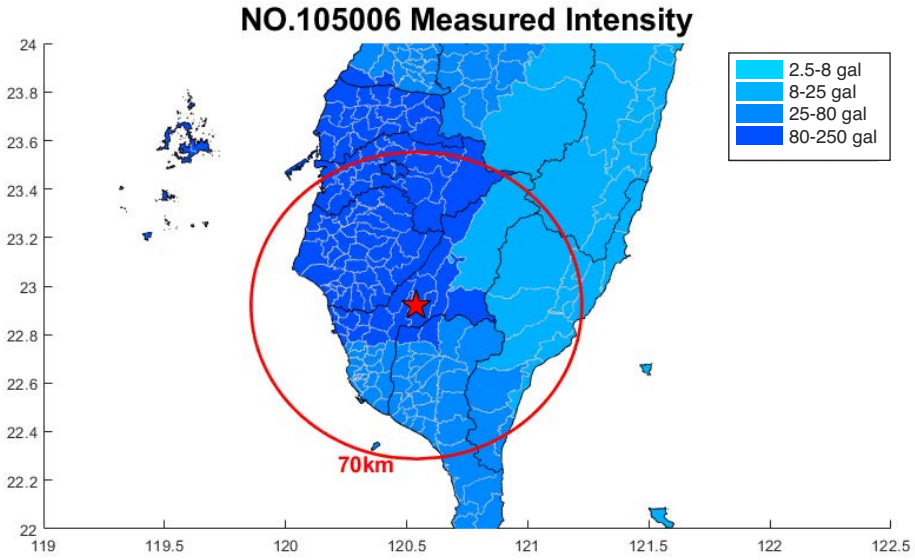
Development of the Earthquake Early Warning System (EEWS) and Structural Health Monitoring System (SHM) in Taiwan

The current status of Earthquake Early Warning System (EEWS) in Taiwan is detailed here by Pei-Yang Lin, Research Fellow at the National Center for Research on Earthquake Engineering

In Taiwan, there are two kinds earthquake early warning system (EEWS) developed for people, the first one was called the regional EEWS developed by Central Weather Bureau (CWB) and the other was the on-site EEWS developed by The National Center for Research on Earthquake Engineering (NCREE). When the earthquake event occurs, the wave propagates and the relative signal will be detected by seismometers which are closest to the epicentre and the regional EEWS collect this data to estimate the essential parameters, such as the epicentre, earthquake magnitude and intensities for influence area, etc. Then, a data centre collects the essential parameters and finally, publishes the warning information.

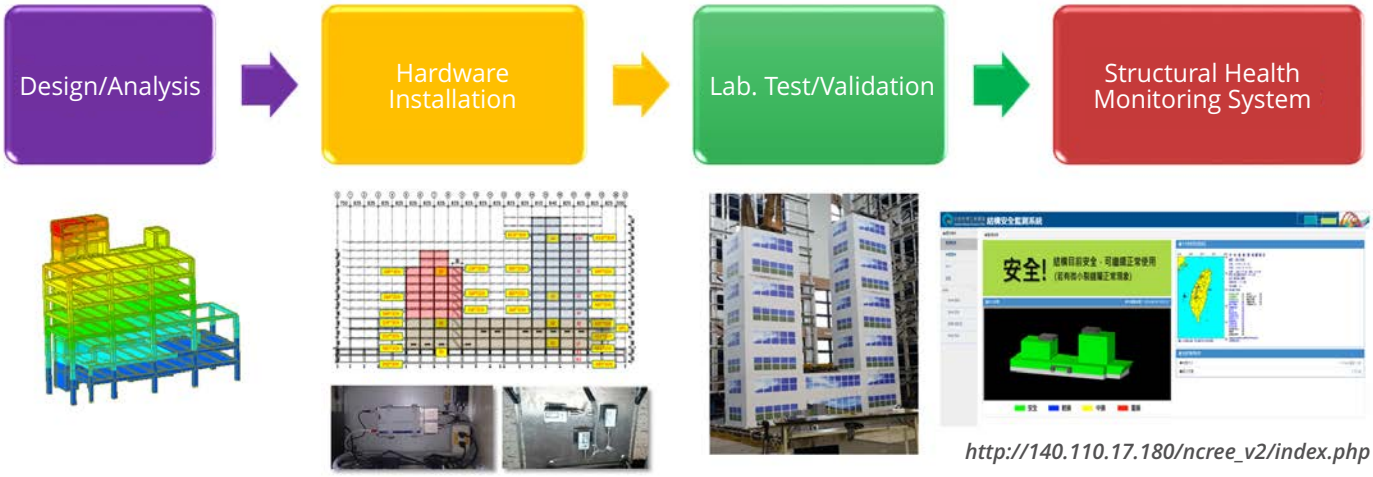




To wait for the data, transmission from seismometers and collection for analysis procedures will be costly in terms of time, in that they will delay the warning. When the earthquake event occurs inland, for example, transmission and analysis works will be about 16~20 secs when it comes to a warning. However, the seismic wave still propagating at the same time means that the influenced areas near the epicentre (influence radius small than 70 km) cannot receive the warning. Such influenced areas are also called the blind zone. The on-site EEWS was developed to reduce the blind zone, based on detecting the P-wave (1-3 secs) by only using an on-site seismometer to predict the earthquake essential parameters for publishing. Because the on-site EEWS doesn't need the transmission from several seismometers in different sites, the areas near the epicentre can receive the warning information early. The on-site EEWS can decrease the blind zone.

According to the earthquake events data during 2013-2018, the influence radius was reduced to less than 30 km.

Structural Health Monitoring System Construction Process



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And there were several successful cases which can be found in a database of on-site EEWS, which can activate the broadcast system in schools to notify people automatically to respond in the event of an emergency.

"During the past few years, NCREE provided the total solution of seismic disaster reduction."

Customised on-site EEWS

The proposed on-site EEWS can further serve the users with vibration-sensitive equipment, by providing more local, detail and accurate seismic vibration prediction and the automatic disaster reduction control system in advance. It cost $160,000~$200,000, and the target users include high-tech plants, high-speed rail, power plants ...etc. In the 2016 Meinong earthquake, the on-site EEWS succeeded in providing the famous semiconductor company in Taiwan an early warning and activated the related emergency responses to reduce seismic loss.

Considering the high costs of the on-site EEWS, NCREE developed another business model for EEW service. People or government can install one on-site EEWS and message server in a small area (~20 km radius). As the seismic intensity is similar inside the area, thousands of users inside the area can share the same early warning message with a low-cost receiver. This kind of application is suitable for the seismic hazard area which needs a warning system urgently. Only after several months of installation, can the EEWS serve thousands of users.

Applications of EEW for smart-technology

During the past few years, NCREE provided the total solution of seismic disaster reduction. Before the main shake, the EEWS can provide the warning info and activate the disaster reduction control, such as shut-off the gas, open the door, stop the elevator... etc. During the shake, the seismic-proof table and safety area provides people with a strong shelter. After the shake, the structural health monitoring system (SHM) can provide the structure healthy condition and safety report to help people carry out the post-earthquake response (return or leave the damaged structure) quickly.

In 2017, NCREE applied the on-site EEWS and SHM and in an office building in central Taiwan science park. The whole system also had been validated on the full-scale RC building shake table test. In 2018, NCREE cooperative with CWB to apply the EEWS +SHM to 10 building structures. We want to use these demonstrations to promote the proposed disaster-privation system, and wish it can be widely deployed in the near future.

NCREE

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Incinerator for municipal waste in Hsinchu, Taiwan

The environment: Diversified waste treatment in Taiwan

The Environmental Protection Administration (Taiwan) charts their efforts when it comes to diversified waste treatment

For general garbage disposal in Taiwan, nearly 60% is recycled while 40% goes for incineration. Challenges include declining efficiency of incinerators as they approach the end of their service lives, offshore island garbage disposal and adequate diversified disposal channels for kitchen waste. In an attempt to improve the efficiency of old incinerators and to diversify treatment options, in June 2017 the Executive Yuan approved the Diversified Waste Treatment Plan proposed by the EPA. It is to be implemented over six years with a budget of NT$15.342 billion from central and local governments.

The Plan has six focus areas: upgrades of incinerator equipment; promotion of regional cooperation; offshore garbage disposal; improving the effectiveness of environmental installations; supervision of garbage clearance and; circular economy policies.

Introduction of new garbage disposal technology and incinerator upgrades and improvements

On 15 May 2018, the EPA held the Symposium on Garbage Incineration Disposal Technology. Professionals from enterprises in relevant fields were invited to talk about incinerator upgrades and improvement, as well as new waste treatment technologies. It was decided that regional platforms could be established to facilitate cooperation in addressing waste treatment problems. Diversified treatment facilities would be set up and the effectiveness of existing facilities improved through economic incentives and other assistance provided to help with the adoption of new technology.

Significant results since 2017 are as follows:

1. Assessment and planning for incinerator upgrades and construction

During the first half of 2018, the EPA invited regional bureaus, operators, and supervising units to attend meetings to promote overall equipment upgrades for incinerators and go over application procedures for future upgrades and needed construction. So far assessment and planning budgets have been approved for nine incinerator upgrades.

Plans for transporting waste from three offshore island counties were approved as well. The EPA also helped counties without incinerators to set up their own diversified disposal facilities.

2. Promotion of regional waste reutilisation facilities

(1) An NT$1.8-billion project is in place to establish, from 2017 to 2022, at least three bioenergy plants using kitchen waste, which is expected to raise kitchen waste disposal capacity to 180,000 tonnes/year and reduce carbon emissions by 17,400 tonnes/year. The project is already in motion with six regional governments, including Taipei City. In addition, construction of Waipu Green Energy Eco Park in Taichung City started on 24 October 2017, with a trial run set for September 2018.

(2) The Environmental Protection Facility Efficiency Improvement objectives of the Plan aimed at lightening incinerator loads by utilising wastes as resources and for energy through measures such as kitchen waste dehydration in pre- and mid-treatment. The EPA approved the establishment of pre-treatment facilities for dehydrating and breaking down kitchen waste, located in Tainan City, Yunlin County, and Yilan County in 2017, and in Kaohsiung City in 2018. This year a high-performance compost treatment facility was also approved to be set up in Lienchiang County. Through these measures, the EPA hopes to increase the efficiency of kitchen waste recycling and reuse, and effectively solve garbage disposal problems. In addition, they should lead to positive carbon reduction outcomes, and keep Taiwan up with international trends.

3. Bottom ash disposal and reuse

Regarding bottom ash disposal and reuse, the EPA completed trials for the reutilsation of granular materials used in the maintenance and construction of road pavement in logistics and storage zones. The Information Management Center for Reutilization of Granular Incinerator Materials has been established to ensure thorough source-to-end controls. Each government department is also asked to start using or to increase the usage of granular incinerator materials in infrastructure projects in order to expand channels for the reutilisation of waste products and promote resource recycling and reuse.

4. Promoting reutilisation of livestock waste as farmland fertilizer

Currently, 211 farms have been approved to send livestock waste for anaerobic fermentation before it is used on farmland as fertilizers. This reduces organic pollution by 5,574 metric tonnes/year, and NT$10.1 billion is also saved as this is equivalent to building 101 gravel contact oxidation treatment facilities. A total of 921,000 metric tonnes of fertilizers are used per year on 819.7 hectares of farmland, including 287 metric tonnes of nitrogen. Together farmers reduce costs on chemical fertilizers of up to NT$13.92 million. To link reutilised products with farmers' needs, the EPA has held meetings and set up an online platform, that can match over 50,000 tonnes of fertilizers with 468 hectares of usable farmland.

Future outlook

Continuing to carry out the Diversified Waste Treatment Plan, the EPA estimates that after all incinerators are overhauled, the combined increase in treatment capacity will be equivalent to an incinerator that is able to treat 900 metric tonnes/day of waste. The following tasks will also be continually promoted:

- Counties without incinerators will be assisted first to set up diversified local self-operating waste disposal facilities.
- New technology and treatment facilities are encouraged through economic incentives to raise treatment efficiency.
- Industries and new technology are combined to promote industry upgrades and open overseas markets.
- Regions are assisted to set up treatment facilities that utilise kitchen waste for bioenergy in order to improve kitchen waste disposal, open up channels and markets for reutilised products, and promote circular economy policies. ■

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Science and technology innovation including energy: A crucial driver for economic growth

Science and technology innovation is a crucial driver for economic national progress and growth in Taiwan. As an example of National Sci-Tech Programmes in the country, we take a look at the National Energy Program and the call for the country to achieve 100% renewable by 2030

In the knowledge-based economy of today, science and technology (S&T) innovation have become a crucial driver for economic national progress and growth. In light of this, the Ministry of Science and Technology (MOST) in Taiwan was created in March 2014 and the organisational structure was geared to facilitating stronger links between research in the academic and industrial development. Prior to this, the equivalent organisation was known as the National Science Council (NSC) of the Executive Yuan, which dates back to February 1959.

In addition, we know that MOST will carry on the NSC's tradition of innovative programmes and measures – and bringing academic research a step closer to the needs of industry. MOST believe it can boost Taiwan's industrial and academic competitiveness at the international level, by employing an entrepreneurial and innovative spirit, as well as encouraging creativity in S&T.[1]

One of the National Sci-Tech Programmes in Taiwan that the MOST website draws our attention to is the National Energy Program (NEP-I)[2]. By way of an introduction, we know that Phase I of the NEP-I was set up by a Resolution from the Energy Policy & Technology Development Working Group of the Executive Yuan. In addition, 15 energy technology-related development programmes were drafted during November 2007.

The website of NEP-I draws our attention to the four focus areas for future energy programmes, as well as the 2011 disaster at the Fukushima nuclear power plant and also, the global financial crisis.

"NEP-1 established four directions for future energy programmes: energy efficiency, energy usage & energy sustainability, renewable energy development & utilisation, and formulation & evaluation of energy technology development strategies.

"In March 2011, the unfortunate disaster at the Fukushima nuclear power plant saw a major change in dealing with energy and energy projects.

"In addition, the global financial crisis of the European Union, the U.S. subprime mortgage calamity, etc., along with the constant political threat of terrorists and an increasing demand for energy and material resources in Asia as well as the burst of the bubble from the overinvestment of photovoltaic and LED industries, have forced a new paradigm shift with regards to energy and energy resources allocation."[3]

We know that when it comes to energy policy in Taiwan, there are a number of goals, such as improving energy efficiency and reducing dependence on imported energy. Another is to improve the international competitiveness of alternative energy industries. Helping build a smart grid system and developing a smart grid technology industry in Taiwan is also a priority.

While there are a number of other goals for energy policy, let's just focus on one here that concerns developing smart offshore wind power and ocean energy technology industries. In the view of NEP-I, they want to strengthen the development of offshore wind and ocean power and, "realise a domestic power production of 2.1 billion kWH and carbon reductions of 1.3 million tons by 2020."

The vision of the Offshore Wind Power and Ocean Energy Master Program is, "increasing national energy independence, reducing emissions and damage and establishing Taiwan's offshore wind power industry

chain." This vision combines university, research and industry resources, plus it integrates concepts for pioneering applications and builds industry consensus to propose development targets for offshore wind power industry, break new ground in the development of offshore wind power and ocean energy technologies, and coordinate solutions from academic and research institutions.[4]

Achieving 100% renewable energy by 2030

Perhaps this vision will help with the recent recommendation that Taiwan should introduce more policies to accelerate its energy transition, with the suggested goal of achieving 100% renewable energy by 2030. An internationally renowned energy and climate advisor advised this back in August 2018. Hans-Josef Fell, Founder and President of the Berlin-based Energy Watch Group says, "transiting to 100% renewable is not a faraway target. It is the main strategy in many nations."

We know that President Tsai Ing-wen has promised to decommission the country's nuclear power plants, which currently generate 9.3% of electricity. By 2025, the plan is to achieve an energy mix that is 50% liquefied natural gas, 30% coal and 20% renewable energy, which today accounts for 4.9%. Fell draws our attention to the example of Germany who has done remarkably well in the move towards renewable energy. "Now renewable energy is cheap and goes faster. If this doubling goes on, we will have 100% renewable energy by 2030 in Germany. It's possible. I believe it will come", he says. Fell underlines the need to diversify sources of renewable energy to balance fluctuating power supply, based on wind and solar power.[5]

> "Transiting to 100% renewable is not a faraway target. It is the main strategy in many nations."

In closing, it's worth relating the energy areas discussed in this article as an excellent example of science and technology (S&T) innovation becoming a crucial driver for economic national progress and growth which is a key policy aim of the Ministry of Science and Technology (MOST) in Taiwan. ■

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A focus on green energy Taiwan

Dr. Gwo-shyh Song, Associate Professor at the Institute of Oceanography, National Taiwan University and Senior Consultant with Global Aqua Survey Ltd provides an in-depth look at green energy in the country

Taiwan, an island-type country with a population density ranked second in the world, must be provided with approximately 42GW electricity autonomously each year. In 2017, power distribution for coal-fired power generation was 39.2%, gas power generation 43.4%, nuclear power generation 9.3%, hydroelectric power generation 8.1% (plus a few percentages on renewable energy). Recently, a rise in the awareness of environmental protection, under the anti-nuclear policy of the Taiwan Government ruling by the Democratic Progress Party, and peoples' awareness of anti-air pollution resulting from thermal power generation, wind power seems to be the major antidote to this impasse in energy distribution. Due to land wind turbines, in addition to its poor efficiency, its development has also been limited by land use and the turbine's low-frequency noise. Hence, since 2012, the government had promoted the so-called offshore wind power scheme for thousands of turbines. Coupled with the mature development of offshore wind farm in Europe, such as the significant reduction of costs due to the maturation of development technology, Taiwan has now become the most important area in the world to develop offshore wind power generation.

The wind field in Taiwan Strait is blessed in the world, for instance; the average density of wind fields near the coastal zone of Changhua is 7m/s or equal to 750W per square metre of power generation. According to C-Offshore reporting, Taiwan Strait ranks among the highest wind farms in the world. The development of offshore

wind power in the Strait area has the following characteristics:

1. Wind speed greater than 10m/s, a good rate of more than 60% in 7.5 months during the autumn and winter season; even a proper rate of more than 20% in 4.5 months during the spring and summer season. More importantly, the direction of the wind is stable.

2. Water depth of less than 50 metres can be developed in a wide area of up to 5,600 square kilometres.

3. More than 80% of wind farm positions have a moderate offshore distance to reduce the impact on the inshore environment.

4. With the exception of some inshore wind fields, most of the wind farm geological conditions of the excellent seabed are covered by more than a hundred metre thick layers of a medium or coarse grain of sands without the occurrence of active faults.

5. The government is encouraging a push to reduce fisheries disruption.

Promoting green energy is the main mechanism to solve the environmental impact in the development of modern world inspections, and while it is expensive, Taiwan cannot stay out of it. However, the development of offshore wind power based on national economic considerations must also take into account the following shocks:

1. Impact and myths of the environment

Is it time to use nuclear energy but it this causing much disturbance in Taiwan because it is a relatively cheap and stable base power in energy distribution? Many people are opposed to nuclear power because of Taiwan's location in earthquake zones – combined with the incidence of Japan's Fukushima tsunami nuclear power plant disaster and nuclear waste which has not been resolved – so this makes the residents who live around power plants feel unsafe. The government has, therefore, decided to gradually reduce the power supply ratio of nuclear energy, with the intention to denuclearisation the country in 2025.

The supply ratio of thermal power generation must be increased in a short period of time without the use of nuclear power. Although the cost of thermal generating electricity is cheaper – especially coal-fired power generation, releasing pollution particles also called particulate matter (PM) 2.5 – makes almost all major metro-cities with bad air quality such that people choose against the additional development of so-called coal-fired power plants during the 2018 referendum.

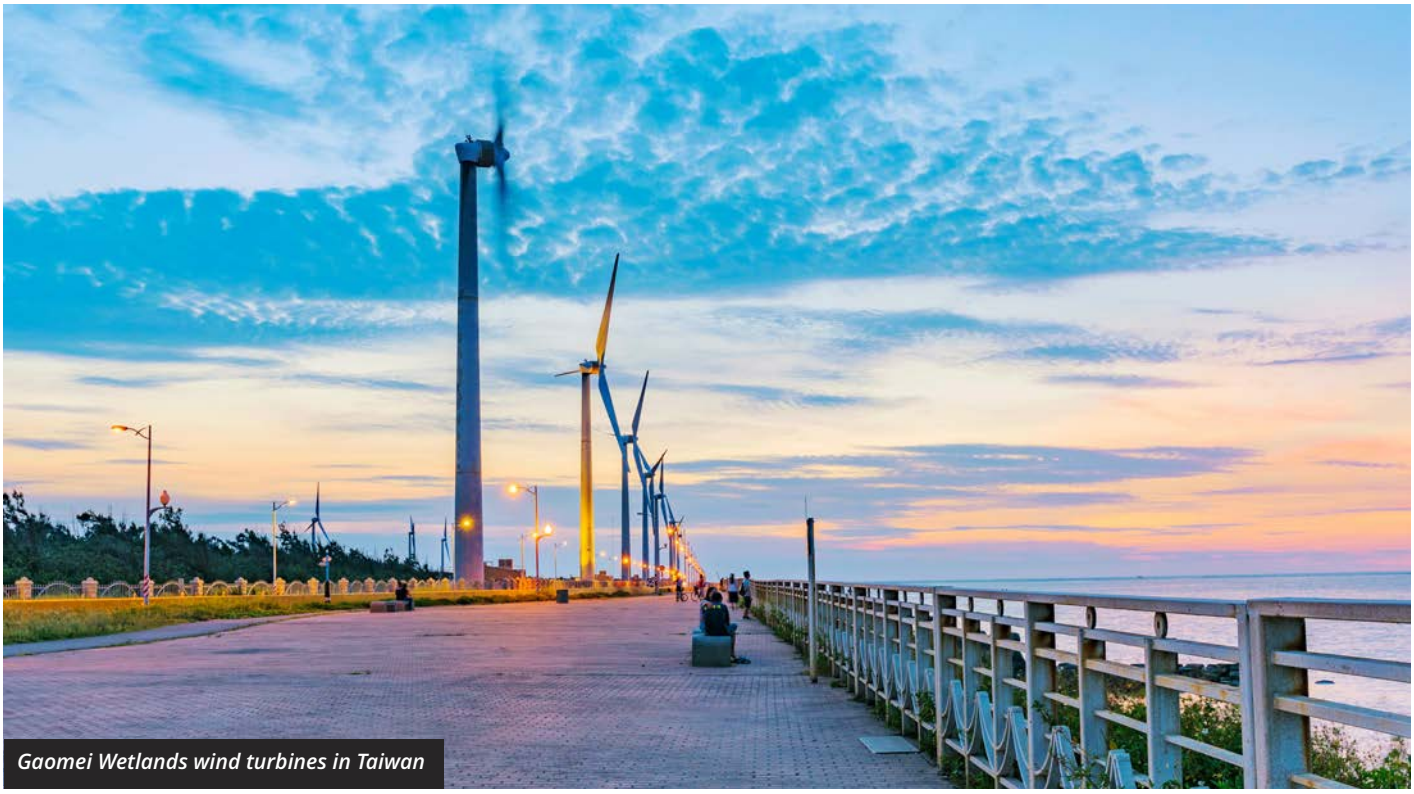
As for the construction of hydroelectric power or reservoirs, it has caused the destruction of the natural environment or results in reservoir siltation and river ecological damage, and even coastal erosion phenomenon. The establishment of terrestrial wind turbines in recent years because of the low-frequency noise has been generated but its development has been limited.

So, it seems that offshore wind power is the antidote to environmental killers compared with other types of power resource. The impact on the migration of migratory birds and the restrictions on fishing activities were the most discussed when I was on the Environmental Impact Assessment Committee; however, it had also been suggested that the agglomeration effect of the foundation of the turbines based on the seabed may have a positive effect on the increase in catches.

2. Power generation efficiency and cost

Regardless of whether wind power can be used as base power, the demand for existing electricity in Taiwan was 42GW in 2018. If the average generating capacity per turbine is 8 MW, then half of the wind field area of 5,600 square kilometres for offshore wind power generation is used and spacing between the turbines is 1 km. 22.4GW power of electricity can be generated in ten years which is more than half of the amount of power required in Taiwan.

Wind turbines can generate power at a wind speed of 3m/s. It indicates that there will be 97% of the time period in the Strait Wind Power can be generated. With larger wind energy based on higher wind speed, we can predict that it can generate 60% of the total electricity that is produced by offshore wind turbines during the autumn and winter; or at least 20% of the total wind-generated electricity in the summer season. It indicates that in 2030, with the total wind-generated power at 22.4GW, there is 13.44GW which can be generated or accounts for about one-third of the electricity demand during winter, and 4.5GW can be generated or accounts for 11% of electricity demand in the summer. This amount of power generation can replace the electricity generated by nuclear power in Taiwan or reduce the amount of air pollution emitted by coal-fired power generated by 30% in



Gaomei Wetlands wind turbines in Taiwan

the summer when the air is more heavily polluted.

To encourage skilled developers to assist in the initial development of offshore wind electricity, Taiwan has provided approximately the purchase price of NTD 6 dollars per degree (exchange ratio between NTD and USD is 31:1). This electricity price is much higher than the average cost of generating electricity for the Taiwan Power Company (TPC) itself, NTD 2.2. As a result, many groups of people have questioned the offshore wind power policy which will greatly raise the cost of power generation and, therefore, cause prices to rise and will impact on the overall economic development of Taiwan.

But will the development of offshore wind power really end up like this? Before we can come to this conclusion, we must first observe the following two phenomena:

a). This initial pricing was only applicable to the development of demonstration wind farms, a price that would slowly decline with the status of development. The 5.5GW wind farm granted to date, of which 3.3GW has been used in terms of the average purchase price that has to be supplied before 2025 has fallen to NTD 5.4- NTD 5.8 per degree. The remaining 2.2GW wind farms granted with the open bidding has dropped to a reasonable price of NTD 2.2 - NTD 2.5 per degree. It comes to the average purchase price of 5.5GW for wind farms, dropping to around NTD 4.5 per degree.

b). The ratio of power energy types in the Taiwan Power Company has a different energy cost structure. With the removal of environmental costs, coal-fired power generation cost is NTD 1.6, gas power is NTD 2.7, nuclear power is NTD 1.2, hydroelectric power is NTD 2.7, and terrestrial wind power is NTD 0.8 degree (above of them is non-procurement costs).

Hence, when considering the different costs at various times and in terms of the different energy structure of power supply, the costs of power generation in Taiwan will be increased by between 12%-15%, based on the use of offshore wind power calculations. Finally, it will be reflected in the pricing of electricity.

So, let's make a preliminary budget estimate. Nuclear power generation in Taiwan was around 4GW in 2018 as part of the government's strategy: offshore wind power is used to replace nuclear power generation. The remainder of wind power should replace high-pollution coal-fired power generation. According to the time schedule of offshore wind power development, 5.5GW of wind power can be supplied by 2025, and 10.8GW (EIA obtained by existing developers) by 2030. Let's assume the generating costs of offshore wind power are NTD 4.5 per degree for the first 5.5GW, and NTD 2.3 per degree for the remainder of 5.3GW, then electricity generation costs will be in between NTD 2.47 and NTD 2.53 per degree. Compared with

the costs of NTD 2.2 in 2018, an increase of between 12%-15% in the pricing of electricity is predicted.

In summary, under the condition that 10.8GW wind power can supply 5.4GW electricity by assuming there is 50% proper rate in a year – wind power can totally replace the nuclear power used or one-third of high-polluted coal-fired power in Taiwan between 2025 and 2030. However, electricity prices will rise by at least 10% which will impact individuals in the country.

3. Benefits for local industry

The purchase price for high-priced wind power proposed by the government in Taiwan totals USD 160 million worth of investment for 3.3GW of power by foreigner developers, who were asked to come up with a so-called home-grown industry chain mentoring programme. This means that requiring local industries to participate in the construction process is necessary. Projects include work on the fan tower, turbine and its components, the underwater foundation, basic power facilities, the electric cable and the laying, underwater construction, hydrographic and geological site surveys, as well as the manufacture of ship and tools which all must be done locally.

The plan aims to utilise hundreds of millions of investment to increase the country's economic growth by providing employment opportunities for thousands of people in Taiwan. Besides that, its final goal is to ensure the localisation of wind power industrial technology.

Because the development of offshore wind power concerns the cost of generating electricity in Taiwan, the increase in NTD 0.3 per degree was predicted on the total at 42GW of the power supply. It means that the country will spend more around NTD 110 billion (USD 3.3 billion) per year; therefore, the plan has been criticised by many since the 20 years' wind power supply plan will cost the people of the country around NTD 2,200 billion of extra money (USD 70 billion). The rise of local industries and the roots of technology have become the major antidote to this controversy.

So far, developers from all over the world are DONG Energy (or Orsted) from Denmark, Yushen from Singapore, Northpower from Canada, Macquarie Capital from Austria, Copenhagen Infrastructure Partners (CIP) from Denmark, WPD from Germany; and includes some local businesses, such as Swancor Holding Co, China Steel Corp and Asia Cement Corp. This is because the development of green energy has already reached a global consensus.

In addition, this is the best time for Taiwan to develop offshore wind power. Since the development of wind power in European counties for many years, the accumulation of this huge breadth of experience is such that Taiwan could fall into the trap of not taking the right approach. Together with strong support from the Taiwan Government, it then brought the wind power developers from all over the world successively.

Based on the protection of the Earth's environment, although the cost of offshore wind power construction is relatively high at this stage, in recent years, with mature technology in place, experts predict that the costs per degree of offshore wind power in Asia will be less than NTD 2 dollars. Of the top 20, Taiwan Strait has been blessing by the 16 best wind fields in the world; therefore, the promotion of offshore wind power in the face of non-nuclear homes and a reduction of air pollution, I believe that Taiwan is on the right track.

Whether this precious energy, located in Taiwan Strait, can give Taiwan a bright future in the next few years as a model for the world's environmental leader, let's wait and see.

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Enhancing industrial technology and addressing energy and global environmental problems in Japan

The aims of the New Energy and Industrial Technology Development Organization are detailed here when it comes to enhancing industrial technology and addressing energy and global environmental problems in Japan

The New Energy and Industrial Technology Development Organization (NEDO) was established after the two oil crises of the 1970s when the requirement for energy diversification in Japan increased. In essence, NEDO is a governmental organisation that since 1980, promotes the introduction and development of new energy technologies. It's interesting to note that research and development (R&D) when it comes to industrial technology was later added to the remit of NEDO. In addition, NEDO is one of the largest public R&D management organisations in the country.

The mission of NEDO is two-fold – raising the level of industrial technology – and addressing energy and global environmental concerns.

On the first aspect, we know that NEDO undertakes projects to explore future technology seeds as well as mid- to long-term projects for industrial development. NEDO also supports research related to instances of a practical application.

On the second aspect, NEDO actively looks at the development of new energy, such as wind power, biomass and waste, as well as photovoltaic, wind power, geothermal power, thermal utilisation and fuel cells. Energy conservation technologies form another part of the organisation's remit. Promoting a greater utilisation of new energy and improving energy conservation are important aspects of NEDO'S work.

Promoting the demonstration of new energy, energy conservation, and environmental technologies abroad based on knowledge obtained from domestic projects are ways in which NEDO contributes to the resolution of global environmental problems and a stable energy supply. [1]

Contributing to society by accelerating innovation

Hiroaki Ishizuka, Chairman of NEDO believes that they are contributing to society by accelerating innovation and achieving results in a timely manner. In a recent message, he keenly observes that NEDO's Technology Strategy Center was established back in April 2014, more of which he explains in his own words.

> "Technology development strategies utilising Japan's competitive advantages will also be formulated by anticipating innovation trends faster and more accurately than in other countries. NEDO will then plan and carry out industry-academia-government collaborative projects."

"It is designed to formulate technology development strategies with a mid and long-term perspective, and plan and propose new projects which incorporate its strategies. In addition, a new project manager system has also been introduced not only to improve management capabilities but also to enhance NEDO's role as an intermediary to facilitate the commercialisation of innovative technology seeds."

He also highlights that NEDO's Fourth Five-Year Plan began in April 2018, which considers today's trends in the fields of industrial technology, innovation, energy,

and the environment. He explains how the Plan will be carried out.

"NEDO will carry out the plan with a focus on its three pillars of achieving results for practical use through technology development management, fostering technology-based start-ups, and providing a new direction for mid- and long-term technology development.

"First, as a specific effort to achieve results for practical use through technology development management, NEDO is striving to further strengthen its management capability to promote challenging research and development activities based on technology strategies.

"Second, NEDO will develop and implement various support measures to foster human resources and technology-based start-ups, including assistance in formulating project plans, thereby creating innovative new industries."

Hiroaki goes on to explain that with the ambition of facilitating open innovation from R&D projects, NEDO will set up a system that provides consistent support from the seed phase right up to practical applications. "NEDO's aim is to serve as a public-private support hub for venture businesses through cooperation and the exchange of information with other public support organisations", he adds.

Third, Hiroaki reveals that a new direction will be taken when it comes to mid- and long-term technology development, something that will lead to cultivation and the practical use of innovation in the years ahead. He develops this third point in his own words.

"Technology development strategies utilising Japan's competitive advantages will also be formulated by anticipating innovation trends faster and more accurately than in other countries. NEDO will then plan and carry out industry-academia-government collaborative projects."

Having looked at what NEDO aims to do now and in the future, we leave the last words to Hiroaki who believes that technological innovation currently being developed during the Fourth Industrial Revolution will help to establish new energy and industrial systems. Let's not forget that NEDO will continue to play a crucial part in Japan's industrial and economic and policies, with its two-fold mission of enhancing industrial technology and addressing energy and global environmental problems.

"Society 5.0 [3] is also expected to be realised. To this end, NEDO will continue to make every effort in accordance with its Five-Year Plan so as to contribute to society by providing opportunities to produce innovation through industry-academia-government collaboration and achieving results in a timely manner." ■

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Research focus: Exploring novel energy-harvesting materials

Yuzuru Miyazaki, Full Professor at the Department of Applied Physics, Graduate School of Engineering, at Tohoku University in Japan enlightens us on his fascinating research on exploring novel energy-harvesting materials in this special question and answer interview

In this interview with Yuzuru Miyazaki, Full Professor at the Department of Applied Physics, Graduate School of Engineering, at Tohoku University in Japan, we learn about exploring novel energy-harvesting materials, such as thermoelectric materials, cathode materials for secondary batteries and photovoltaic materials, amongst a number of other exciting areas of research in the field.

The focus of this compelling interview includes Yuzuru Miyazaki's research, his work on high-quality structure analyses using neutron and X-ray diffraction, and the challenges around thin-film thermionic multilayers and organic thermoelectric materials, amongst other areas.

Can you introduce your work when it comes to exploring novel energy-harvesting materials, such as thermoelectric materials, cathode materials for secondary batteries and photovoltaic materials?

I studied basic materials science during my bachelor course. Just before my graduation, a scientific fever of cuprate superconductors occurred. I was, therefore, deeply motivated by this positive impact and began to study pursue novel cuprates during my Master and PhD courses at Tohoku University. Fortunately, I was able to find several cuprates which possess interesting structural units. Some of them actually exhibited superconductivity. From this successful experience, I decided to explore novel functional materials which exhibit special properties, in particular, generating electricity based on a knowledge of solid state chemistry. At that time, the 21st Century was approaching and the energy crisis was one of the critical issues in academic research.

Thermoelectric (TE) materials can generate electricity from the temperature difference by means of the Seebeck effect. TE materials themselves do not generate noises or vibrations and do not emit toxic gases and, therefore, they can be regarded as clean energy sources. However, apart from bismuth telluride-based and lead telluride-based materials, both comprise quite rare and toxic elements, indeed, there are quite a few compounds that can be used as potential TE materials utilising the waste heat of our surroundings. In our research, we focused on oxide materials as they are stable at high temperatures and the constituents are abundant.

My experience on oxides (cuprates) was also quite helpful when it came to studying oxide TE materials. We discovered several cobalt oxide-based TE materials, which are quite stable even at a high temperature up to 1000 K. The crystal structure of them is quite similar to that used as a cathode of the lithium-ion battery. So, we have also begun to explore cathode materials for secondary batteries in layered cobalt oxides that do not contain lithium. We are also studying photovoltaic materials in relation to layered oxide materials.

What is the current focus or themes around your research?

Our main focus when it comes to our research is the waste heat recovery from automobile engines. Currently, the waste heat of around 46 peta calories is emitted annually from automobiles in Japan. The temperature range here is 600-1000 K. If we can recover electricity from such waste heat by the efficiency of ~10%, a number of large thermal power plants can be scrapped and CO_2 emissions can, therefore, be greatly reduced.

Higher manganese silicide, HMS ($MnSi_{\sim 1.7}$) is one of the potential TE materials, to be used at around 800 K. HMS consists of naturally abundant elements and is chemically stable up to 1000 K. Typical samples exhibit the dimensionless figure-of-merit, zT~ 0.3 around 800 K, which needs much improvement. As the zT value roughly corresponds to the thermal-to-electric conversion efficiency, zT~ 0.6 at 800 K is at the very least, necessary. To practically generate electricity, tens or hundreds of p- and n-type TE materi-

als (legs) should be joined electrically in series and thermally, in parallel. We call such a device a pi-type TE module. Electrons (holes) are major conducting carriers for n- (p-) type TE materials. As the HMS is a p-type material, a corresponding potential n-type TE material is necessary. The first choice should be another silicide, Mg_2Si-based material. Currently, we are financially supported by the NEDO/TherMAT project, Japan.

Tell us about your work when it comes to high-quality structure analyses using neutron and X-ray diffraction, combined with first-principles calculations?

Generally, the functions of materials are highly dependent on their electronic structure. The electronic structure is derived from the crystal structure of materials. Hence, a deep knowledge of the precise arrangement of atoms is critical to understand their properties. Such an arrangement can be determined from diffraction experiments of X-ray, neutron and/or synchrotron X-rays. We generally use the first-principles calculation to elucidate electronic structures and, hence, the precise arrangement of atoms in a material is crucial to predict its properties. Unfortunately, many researchers today do not care about having a deep understanding of the crystal structures.

How many novel materials have been discovered based on your guiding principles?

It depends on how we define the difference. If we define the difference as the distinctly different crystal structures, the number should be around 20. Some examples are strontium cuprate oxycarbonate $Sr_2CuO_2CO_3$ and its relatives $Sr_2(Y,Ca)Cu_2O_x(CO_3)$ and $Sr_2(Y,Ce)_2Cu_2O_x(CO_3)$, and so on. The latter two cuprates are based on $Sr_2CuO_2CO_3$ but another structural unit of either (Y,Ca)Cu or $(Y,Ce)_2Cu$ is inserted. If we expand the definition to include the same crystal structure but different components, the number could be more than 40. They are like P2-type Ca_xCoO_2, Sr_xCoO_2 and Ba_xCoO_2, all derived from the solid-state ion-exchange from the layered cobaltate Na_xCoO_2.

What challenges are there concerning challenges on thin-film thermionic multilayers and organic thermoelectric materials?

We have quit these studies but instead, we have started to fabricate new types of TE modules, tilted-multilayer TE modules, which can exclude the problem of electrodes. The electric current flows parallel to the temperature gradient in conventional pi-type TE modules and, hence, electrodes are necessary in between every p- and n-legs.

However, the new type TE module utilises the off-diagonal Seebeck effect, which generates electricity perpendicular to the temperature gradient. In such a module, multilayers of TE materials and metals are simply tilted to an angle of 30-50 degrees to the temperature gradient and electrodes are only necessary at the uppermost and the opposite sides of the multilayer. Currently, we are financially supported by The Japan Society for the Promotion of Science (JSPS) project in our country.

What are your research priorities for the future?

We should expand other fields of energy-relating materials. One possibility could be to explore potential cathode materials for calcium-ion batteries to make use of our accumulated experience. We have discovered several unopened layered materials suitable for the diffusion of calcium-ions and hope that they will exhibit superb electrochemical performance.

Is there anything you would like to add?

In five years' time, our university will construct an ultimate synchrotron radiation facility, named SLiT-J. This facility will herald a new era when it comes to investigating the static and dynamic crystal structures of matter with a high degree of accuracy. We are, therefore, very keen to commit to SLiT-J, so that we can bring much insight when it comes to producing superb energy harnessing materials.

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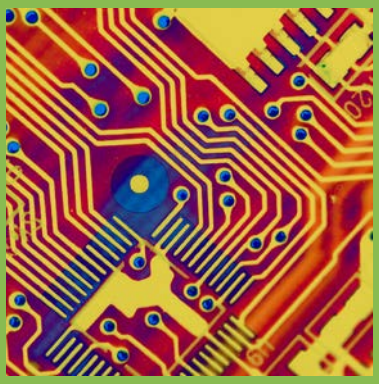





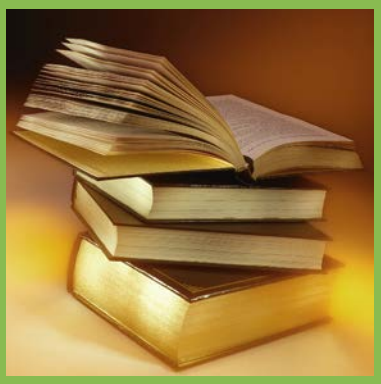

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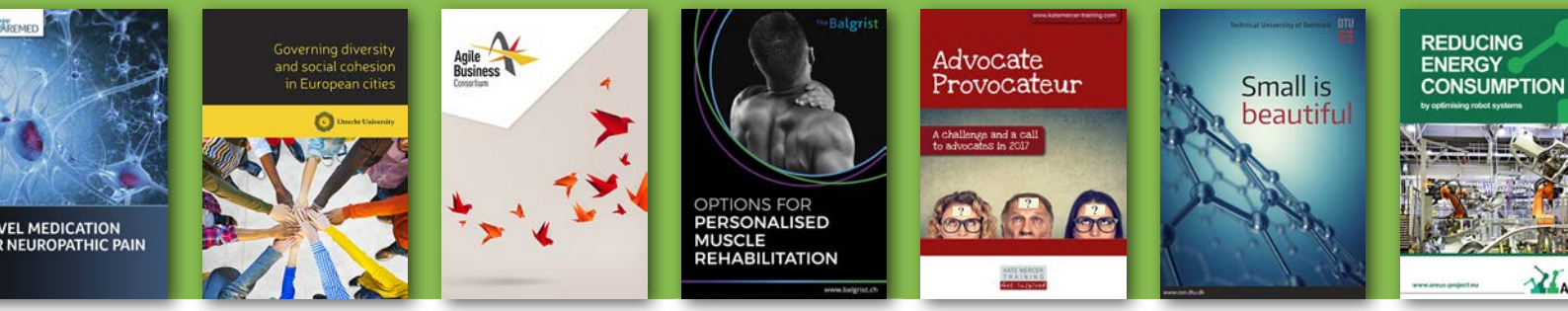

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