Research Colloquium 2022
Institut Tadbiran Awan Negara (INTAN)
Kampus Utama Bukit Kiara

Development of Extremely High Deposition Efficiency of Robust and Super-Hydrophobic Fluoropolymer Coating by Cold Spray Technology and Its Bonding Strength Improvement

LinkedIn

Presenter

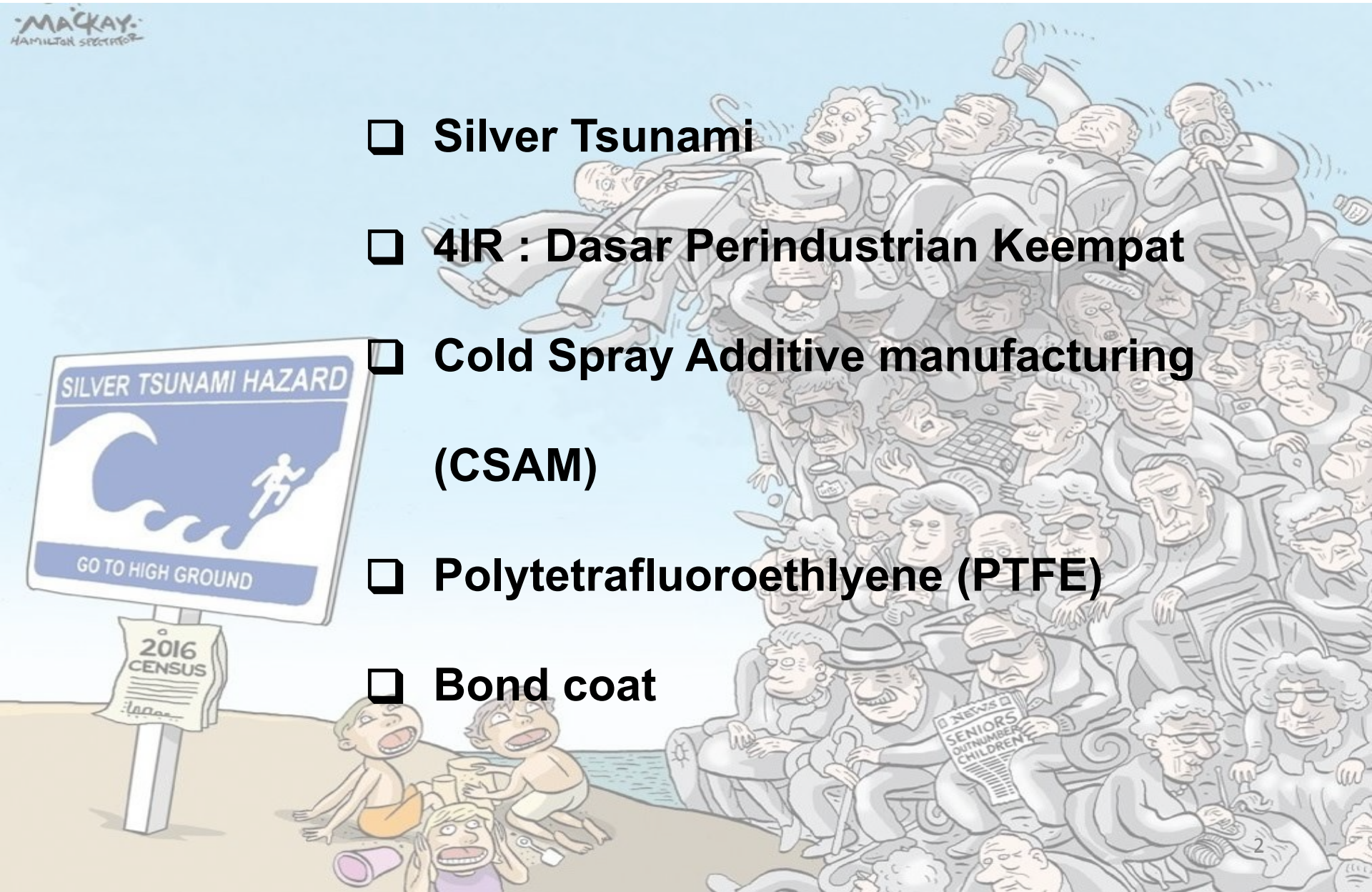
WESLEY ANAK LOCK SULEN (Ph.D, P. Eng, P. Tech)

MEXT SCHOLARSHIP

TOHOKU UNIVERSITY, MIYAGI PREFECTURE

DEPARTMENT OF OCCUPATIONAL SAFETY & HEALTH (DOSH)

Keywords



- Silver Tsunami
- 4IR : Dasar Perindustrian Keempat
- Cold Spray Additive manufacturing (CSAM)
- Polytetrafluoroethlyene (PTFE)
- Bond coat

Scope : Main Key Technologies & Key Focus Sector

4TH INDUSTRIAL REVOLUTION

Economic Planning Unit
Prime Minister's Department

Key Technologies

- Automation and Robotics
- Advanced materials
- Biotechnology
- 3D printing

Key Focus Sector

Healthcare

Introduction

The Silver Tsunami

United Nations | Department of Economic and Social Affairs

EOAD : Economic Old-Age Dependency Ratio
OAD : Old-Age Dependency Ratio (65+ / 20-64)

Singapore
22.5%
EOAD : 42.6
OAD : 36.6

Ageing % by 2030

ASEAN *1

Ageing Population in M

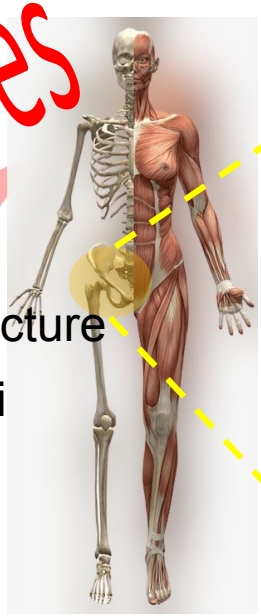
Age 80 and over
2017
(0.3 million)

Malaysia
10.0%
EOAD : 17.5
OAD : 16.4

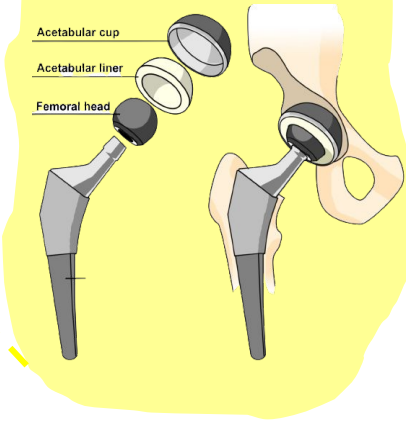
Ministry of Women, Family and Community Development

Degenerative Diseases

- Hip fracture
- Osteoarthriti
- Rheumatoid arthritis



Hip Prothesis



DASAR WARGA EMAS NEGARA

To provide affordable and holistic health care services to senior citizen

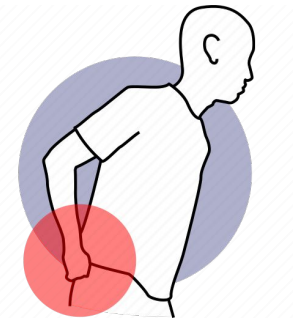
*1 United Nations World Population Ageing 2019 Highlights (ST/ESA/SER.A/430).

*2 Md Nor et al., Malaysian Journal of Society and Space volume 17 (3) pages 234-245 (2021)

Problem Statements

- Polymer acetabular (asɪˈtabjʊlə) liner between femoral cup and acetabular cup on a hip prothesis is always subject to wear and tear, leading to severe infection that requires an immediate replacement
- The cost of replacing increase gradually, as well as the cost to fabricate the hip prothesis itself

- The fabrication of liner and femoral head is performed separately, thus increasing the number of parts and eventually the total cost involved



Research Aim

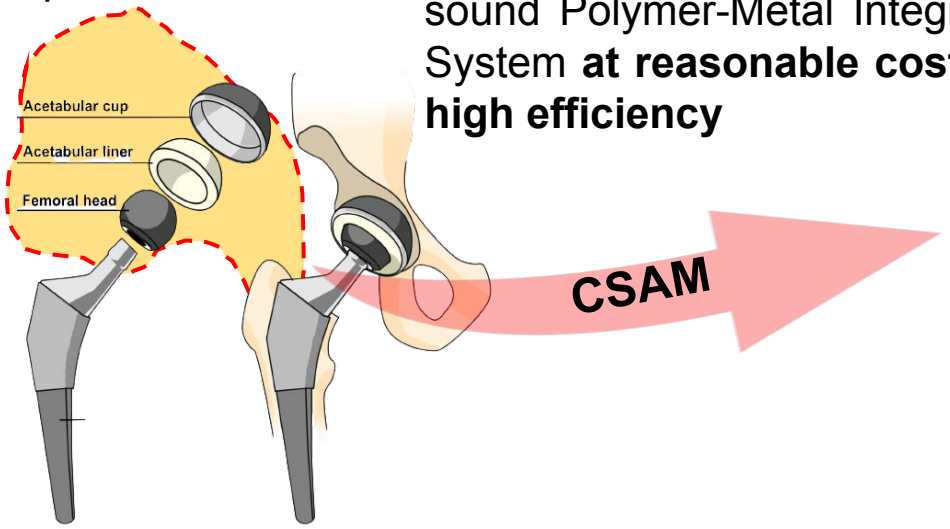
- Focus on the development of a scalable and safe way to additively manufacture polymer on metal, in a single piece

High Performance Polymer (HPP) – Metal Integration System

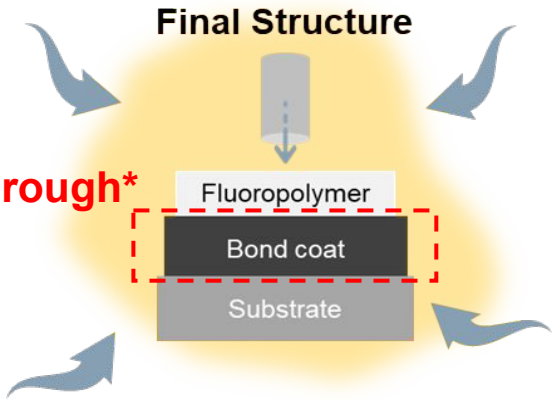
PTFE – Titanium / Aluminium*2

CSAM focuses on fabrication of a structurally and functionally sound Polymer-Metal Integration System **at reasonable cost and high efficiency**

Hip Prosthesis*1



Breakthrough*3



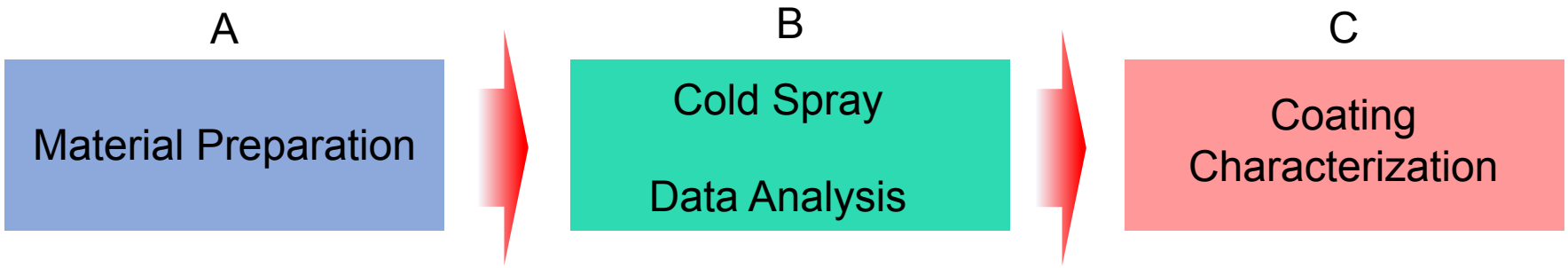
- Low abrasion / wear rate,
- Chemically inert,
- Biocompatible;
- High mechanical strength

*1 Merola M, Affatato S. *Materials for Hip Prostheses*: A Review of Wear and Loading Considerations. Materials (Basel). volume 2(3), pages 495 (2019).

*2 Ravi, K. et al., Fabrication of micro-/nano-structured super-hydrophobic fluorinated polymer coatings by cold-spray. *Surf. Coat. Technol.* 373, pages 17–24 (2019).

*3 Lock Sulen W., Development of Cold Sprayed Super-Hydrophobic Fluoropolymer Coatings and Its Bonding Strength Improvement, Tohoku University (2020).

Research Methodology



Deposition Efficiency

$$DE\ \% = {Coating\ weight\ on\ sample\ after\ spray} / {Weight\ of\ spray\ poweder\ used} \times 100\%$$

Lock Sulen et al., *Journal of Thermal Spray Technology* volume 29, pages1643–1659 (2020)

Lock Sulen et al., Effects of Nano-Ceramic Particle Addition for Cold Sprayed Fluoropolymer Coatings. *Key Eng. Mater*. 813, pages 141–146 (2019).

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Wesley Lock Sulen, DOSH Malaysia Email: wesley@mohr.gov.my

Research Findings

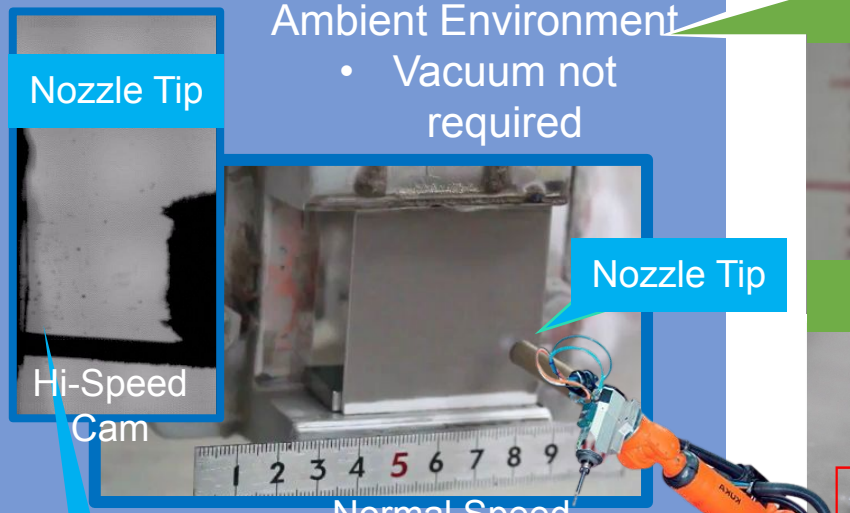
Challenges / Obstacles (since 2006*[1] - 2020*[2]):
Weak Adhesion & **Low** Deposition Efficiency (less than 10% max. DE)

Low-Oxide Metallic Bond Coat

Cold Spray Technology (CS) → Conventional PTFE + Metal → PTFE + Bond Coat + Metal

Realtime CSAM + Robot arm

Ambient Environment
- Vacuum not required

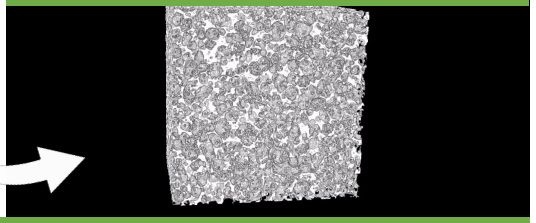


Robot arm assisted

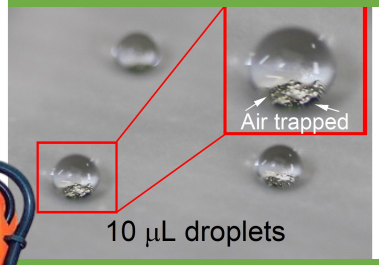
Results

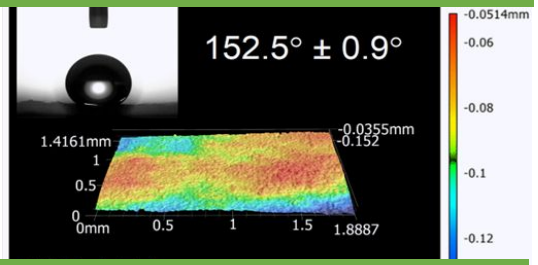
Thick PTFE on Al-substrate with patented bond coat

Dense PTFE (X-ray tomography)



DE of more than 95%





Superhydrophobic and strong adhesion*[3]

*[1] Xu et al., *Surface and Coatings Technology* volume 201, Issue 6, pages 3044-3050 (2006)

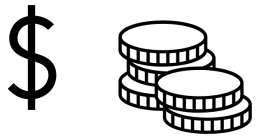
*[2] Lock Sulen et al., *Journal of Thermal Spray Technology* volume 29, pages1643–1659 (2020)

*[3] Lock Sulen et al. Effects of Nano-Ceramic Particle Addition for Cold Sprayed Fluoropolymer Coatings. *Key Eng. Mater.* 813, pages 141–146 (2019)

Research Impacts

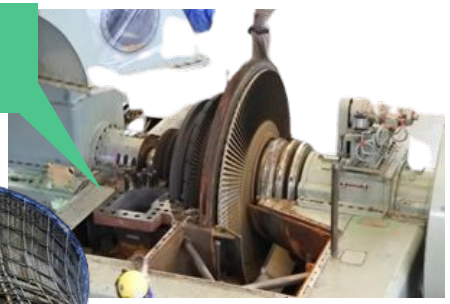
Patent Pending :
P2020069 No. 2020-157844

New potential for polymer-metal AM or CSAM



Energy Utility Sector

Matsukawa Geothermal
Iwate Prefecture



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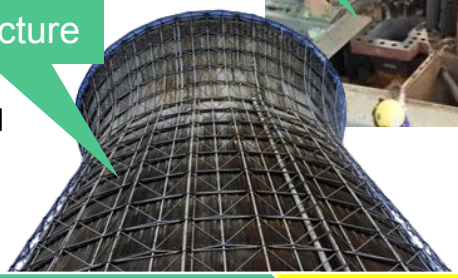
Tohoku EPCO



Patentable & Commercialization → Prototype Testing → Achievements

3 Journal Papers + 2 Papers (TBP)
Volunteering Programs
1 Int'l Exchange Program
Workshops

7 Symposiums / Conferences

1 Int'l Conference Student Committee

6 Academic

3 International

Award Intelligent Nano-Material Advanced Biomaterial, Waseda University, Tokyo

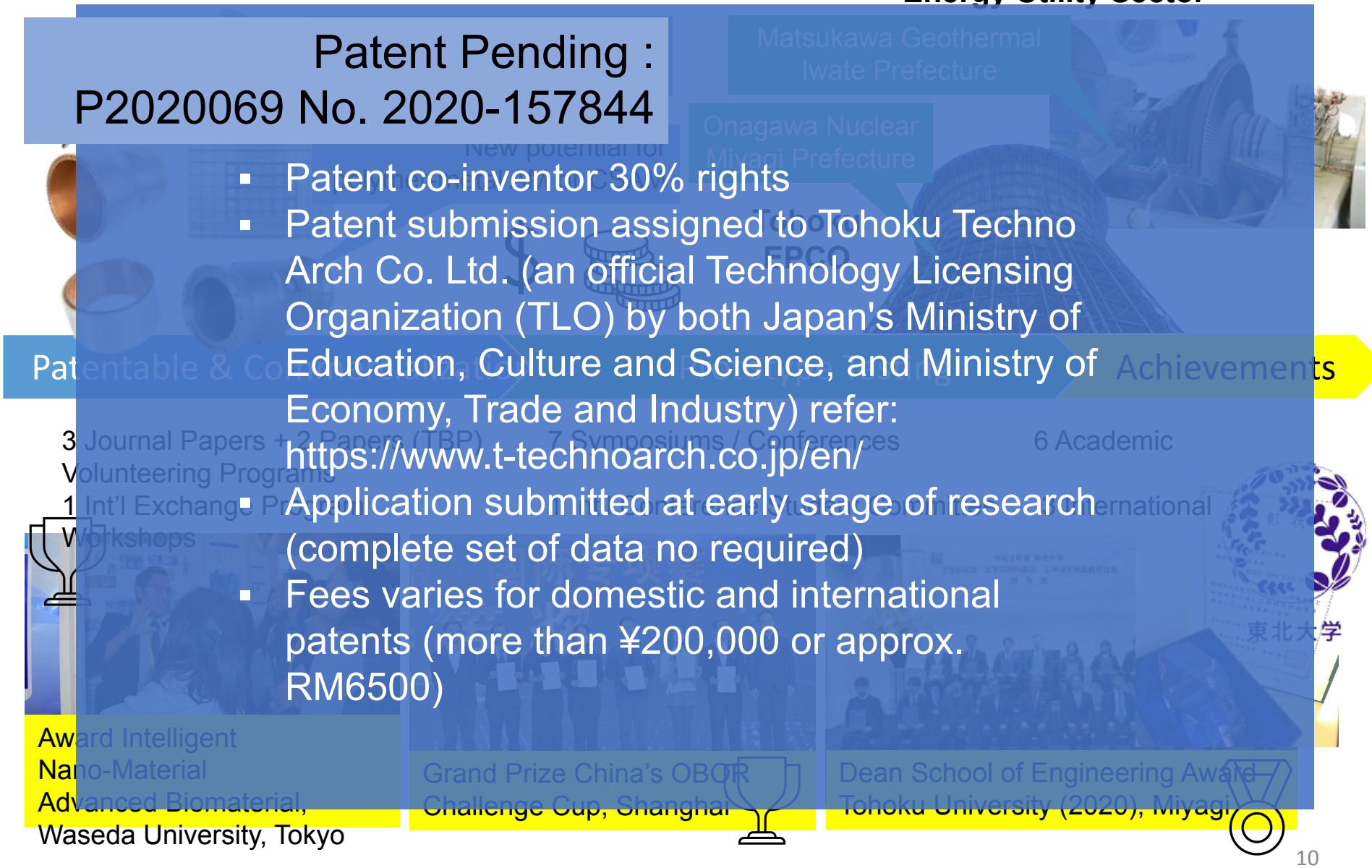
Grand Prize China's OBOR Challenge Cup, Shanghai

Dean School of Engineering Award – Tohoku University (2020), Miyagi

Research Impacts

Patent Pending : P2020069 No. 2020-157844

- Patent co-inventor 30% rights
- Patent submission assigned to Tohoku Techno Arch Co. Ltd. (an official Technology Licensing Organization (TLO) by both Japan's Ministry of Education, Culture and Science, and Ministry of Economy, Trade and Industry) refer: https://www.t-technoarch.co.jp/en/
- Application submitted at early stage of research (complete set of data no required)
- Fees varies for domestic and international patents (more than ¥200,000 or approx. RM6500)



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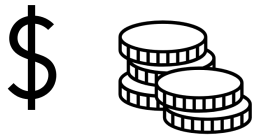

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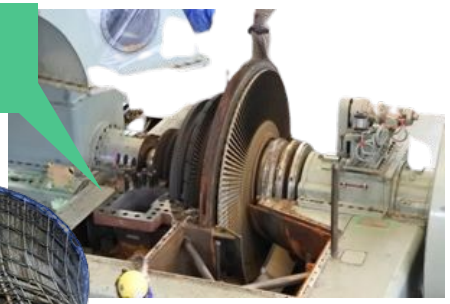

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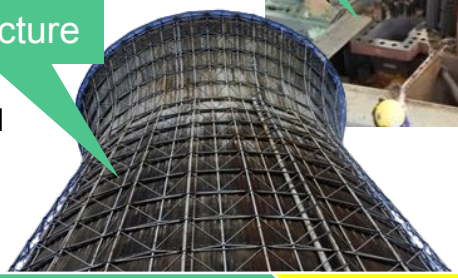

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Research Impacts

Prototype Testing

- Functional coating (High Performance Polymer)
- High temp. resistance 350℃
- Superhydrophobic
- Anti-scaling, anti-corrosion
- Testing Sites:
  - Water treatment pipeline coating at Onagawa Nuclear Power Plant
  - Geothermal turbine blade coating

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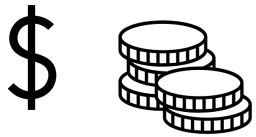

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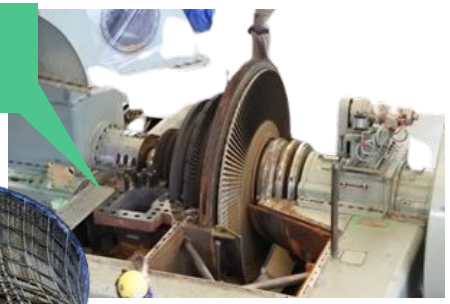

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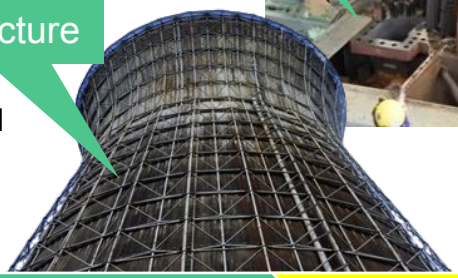

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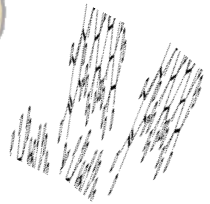
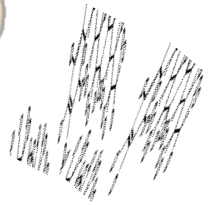
Implications on Society, Businesses and Government

- Improved quality of life by providing quality product (hip prothesis) at reasonable price
- Sustainable environment by reducing carbon footprints through the fast, scalable and safe fabrication method using CSAM
- Offers competitive and innovative business opportunities at a global scale as AM is becoming inevitably important across the globe
- Reduce medically related expenditure borne by the government and help to focus on prudent spending



My hope to policymakers

- The government through MITI to give tax incentive to bring in this technology and its application in niche sectors such as Health Ministry and Defence Ministry
- The government through the Ministry of Higher Education to provide conducive R&D environment especially research funding to boost the level of innovation and competitiveness amongst research institutions including patent registration



Acknowledgements

Organizations

Embassy of Japan in Malaysia, Kuala Lumpur

Ministry of Education, Science and Technology (MEXT), Japan

Public Service Department (JPA), Malaysia

Department of Occupational Safety and Health Malaysia (DOSH)

Japan Society for Promotional of Science (JSPS)

FRI Fracture and Reliability Research Institute


Prof. Dr. Kazuhiro OGAWA


Assoc. Prof. Yuji ICHIKAWA


Assist. Prof. Chrystelle BERNARD


Assist. Prof. Hiroki SAITO

MatéIS MATERIAUX INGÉNIERIE ET SCIENCES


Assoc. Prof. Nicolas MARY


Post. Doc.Researcher Kesavan RAVI

Thank you for your time and participation

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