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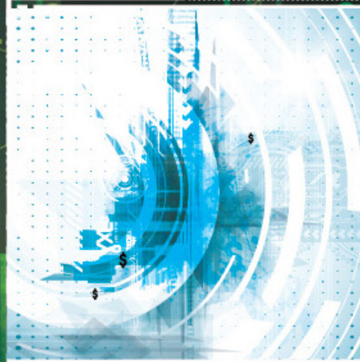
Science Technology for Development



Development of Rehabilitation Robots for Stroke Patients

Developments of Microfluidics-based Devices for Single Cell Isolation, Trapping and Culturing Single Cancer Cells for Biological Behavior Study of Canine Round Cell Tumors

Development of High Efficiency Visible-light Responsive Photocatalysts

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Editor's note

UNISEARCH JOURNAL

Science and technology are the foundation of a nation's progress, enabling the country to develop, grow, compete and keep pace with the world. To achieve sustainable economic and social development, Thailand needs to create its own knowledge-based economy by strengthening and modernizing its educational system and investing in research and innovation. This is necessary not only to increase the amount of value added in Thai products and services; establishing a strong domestic research base is also an essential prerequisite for reducing Thailand's dependence on imported goods and technologies and enhancing the country's global competitiveness.

Research capacity is the all-important foundation for driver the country towards the goals of Thailand 4.0: stability, prosperity and sustainability. A stronger research base is needed, especially in fields that are key to economic development, society and the environment. It is also necessary to foster research in areas where Thailand has competitive strengths, including agriculture, biodiversity and health, as well as the 10 priority industry sectors identified by the government.

We must ensure that our research programmes are designed to support and align with the government's long-term targets and sectoral prioritization if we are to succeed in our transition to a strong, innovation-based national economy. This development trajectory will necessitate a number of profound changes to ensure the highest calibre of teachers and researchers, with adequate funding, facilities and institutional support.

Finally, dissemination of research outcomes for use by the public and private sectors will be essential in order to create a true knowledge-based society, to develop the country firmly towards achieving true stability, prosperity and sustainability under Thailand 4.0.

The Editorial Board

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Content

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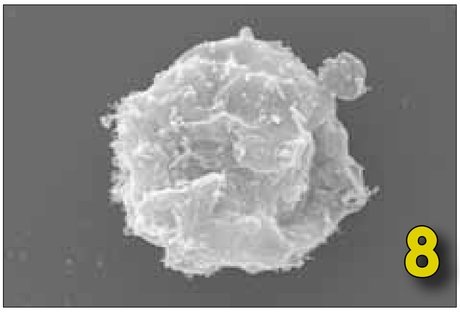

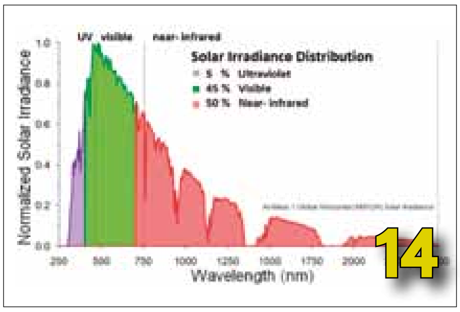

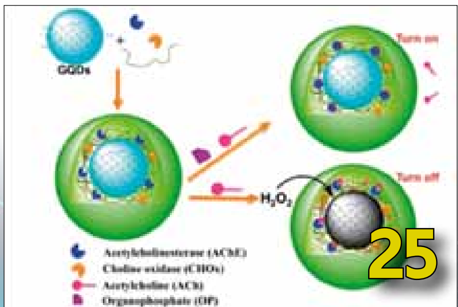

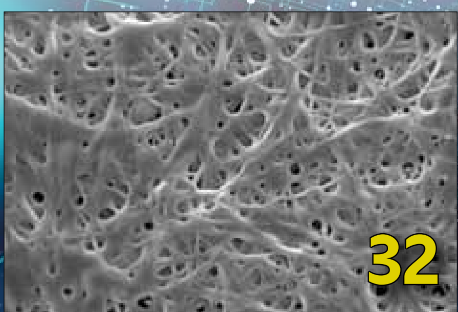

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Development of Rehabilitation Robots for Stroke Patients

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Introduction

Strokes are a leading cause of death in Thailand and across the world, and survivors are physically, mentally and socially affected. In some patients, disability becomes a burden for themselves and their family. As patients and their families may lack the ability to perform daily activities and work, they are unable to contribute to the economy or participate in social activities (Bureau of Non Communicable Diseases, Department of Disease Control, 2017)

There are several approaches to rehabilitation for stroke victims. The use of robots for rehabilitation is a currently new method allowing patients improved neurological recovery to practice repetition of the limb compared to conventional physiotherapy. The approach enables patients to build their skills based on the number of training sessions, the presence of game training and feedback, and in making training enjoyable, challenging and rewarding. Electroencephalogram (EEG) feedback as well as manipulation to control limb movement contribute to maximize rehabilitation efficiency under the assumption of increased functional change and brain plasticity. When patients have more neurological recovery, the use of robots equipped with various signaling systems enables recognition of the feedback force, as well as the position and speed of the patient's movement. These sensory inputs provide a basis for a system for supervising patient progress. It also changes the movement characteristics, as well as the force of robot created by the changing muscle force.

Game training provides the algorithmic basis for rehabilitation today. A computer rehabilitation game can offer games to stimulate and motivate patients in a stress-free environment. Given the need to find new and stimulating activities for patients, motivation in game training is a critical success factor. The game system was designed to reduce boredom and provide motivation for patients to enjoy the treatment and continue to train regularly.

There has been relatively little research into development and utility of a robotic arm (exoskeleton) covering training at shoulder, elbow, lower arm, wrist and robotic leg including the end effector. The current research will therefore contribute to Thailand's medical engineering technology to international standards. This will allow more patients to access such a new rehabilitation innovation.

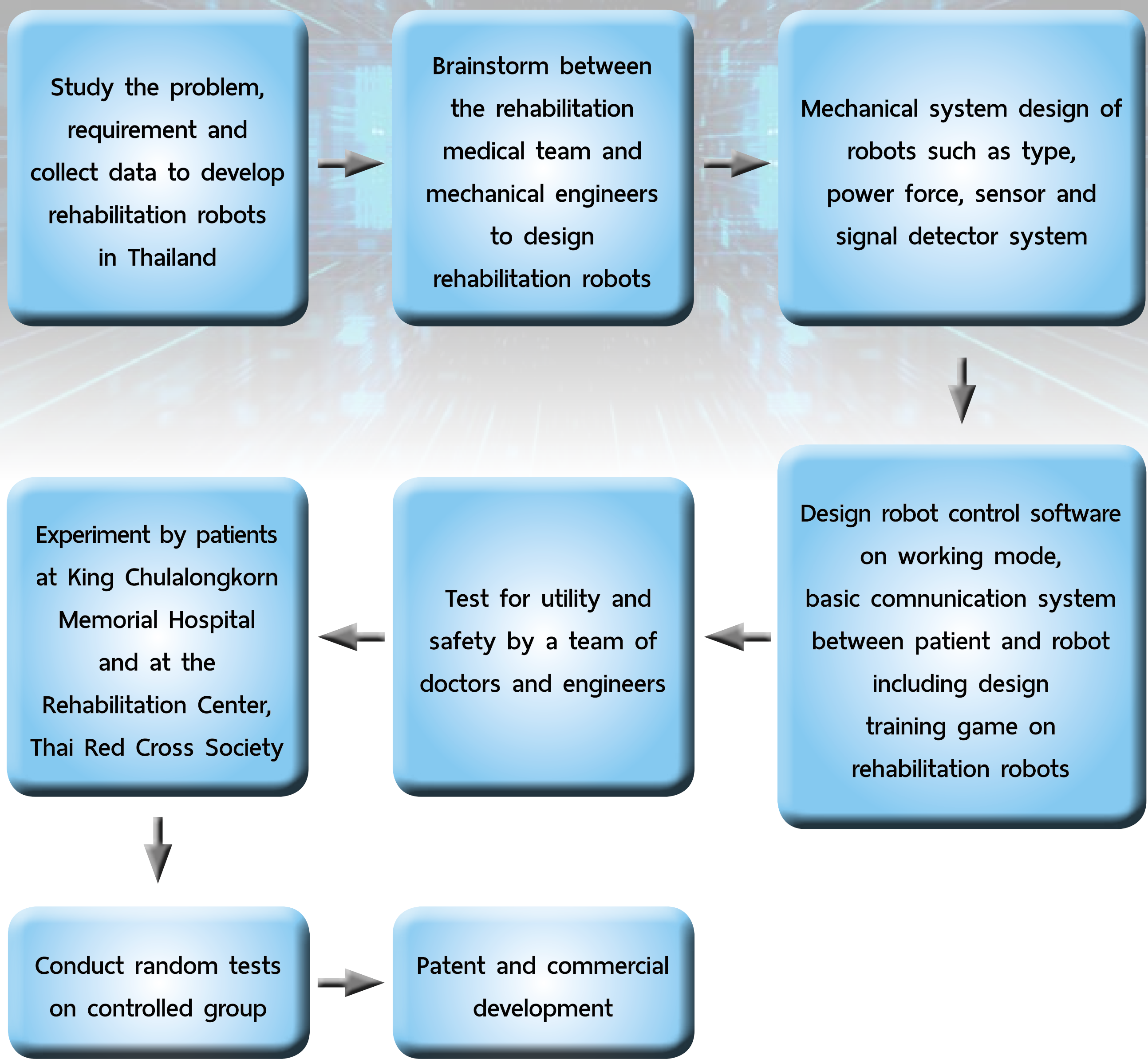

Figure 1 Rehabilitation Robot Production Process
Source: Piravej, designed in May 2018

Development of robotic arm - Chulalongkorn University Rehabilitation robotic Exoskeleton system (CUREs)

Over the past two years the research team has developed a robotic arm (or exoskeleton) for rehabilitation (the Chulalongkorn University Rehabilitation robotic Exoskeleton system or CUREs, as shown in Figures 1 and 2). The robot's active assistive feature delivers a highly secure control system and excellent patient response. Active assistive helps when the patient is incapable of independent limb movement. If the patient can manipulate the limb(s) independently, the robot will not intervene to reinforce it. The system operates as a background process, and results in limb movements as smooth as those of an unassisted person (Figure 3). Pilot test on stroke patients at the Rehabilitation Centre, Thai Red Cross Society appeared positive. The developed robotic

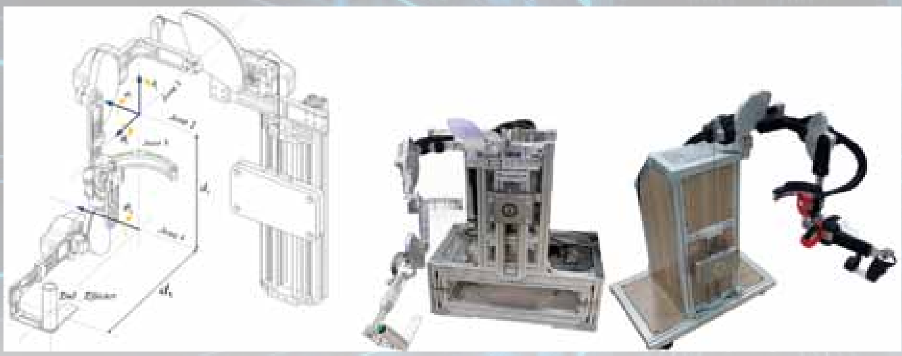

Figure 2 CUREs Robot Arm version 2 and version 3
Source: Sangveraphunsiri (2015)

Figure 3 Installing a robotic arm to the arm requiring assistance
Source: Sangveraphunsiri (2014)

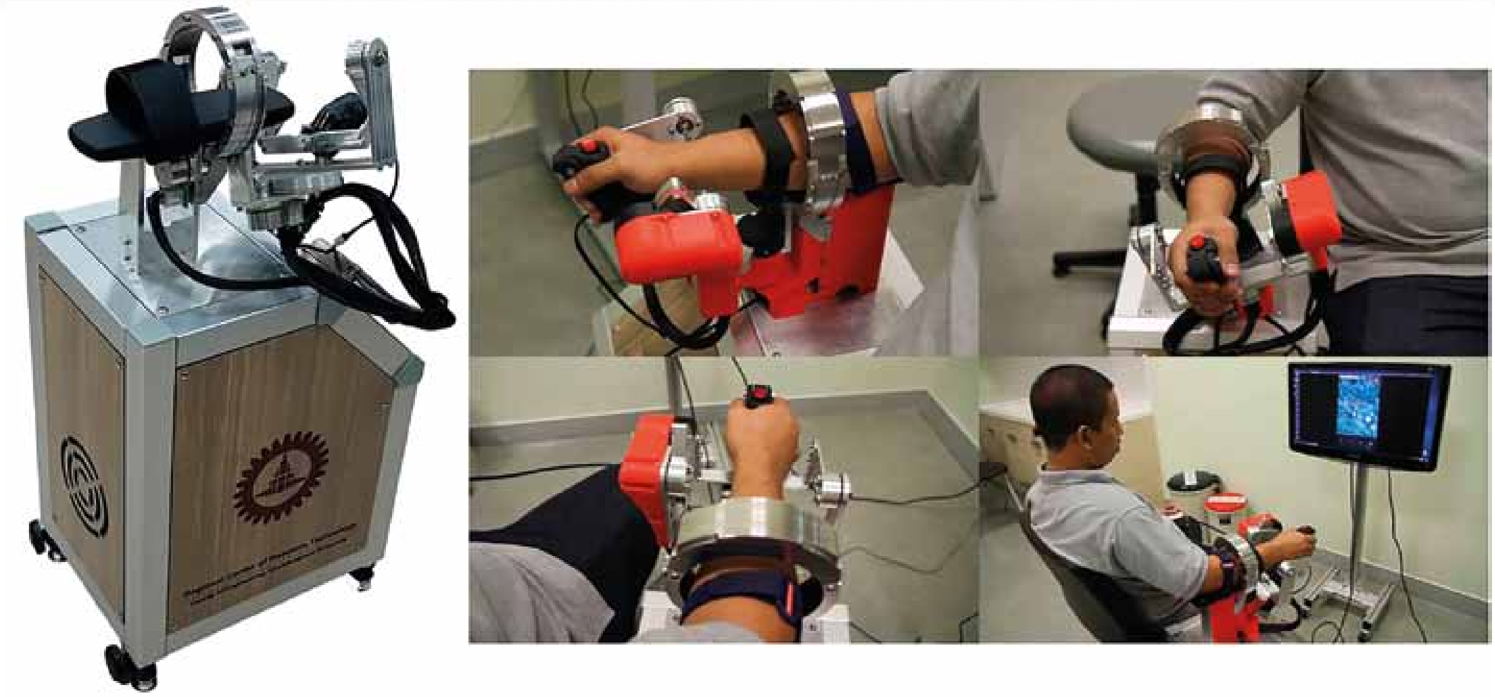

Figure 4 Wrist Rehabilitation Robot Test
Source: Sangveraphunsiri (2017)

arm is small, light and easy to transport. Though most of the robots are bulky, difficult to move and expensive, CUREs is easy to use, highly secure and cheaper compared to robotic arms developed overseas.

There are several types of exoskeleton-based rehabilitation robots used for rehabilitation in arm restoration (Figure 4) and leg restoration (Figure 5). The end-effector type is used for rehabilitation in stroke patients (Figure 6).

The robotic arm consists of the following functional components:

1) Power system and end-effector for restoration
2) Control system
3) Sensor and detection system
4) Monitor to display real-time practice and patient information for practice tracking.
5) Interactive gesture program
6) Training games incorporating both in-house games and links to external internet games.

Figure 5 Leg Rehabilitation Robot Test
Source: Sangveraphunsiri (2017)

Figure 6 The end-effector type is used for rehabilitation in stroke patient
Source: Sangveraphunsiri (2017)

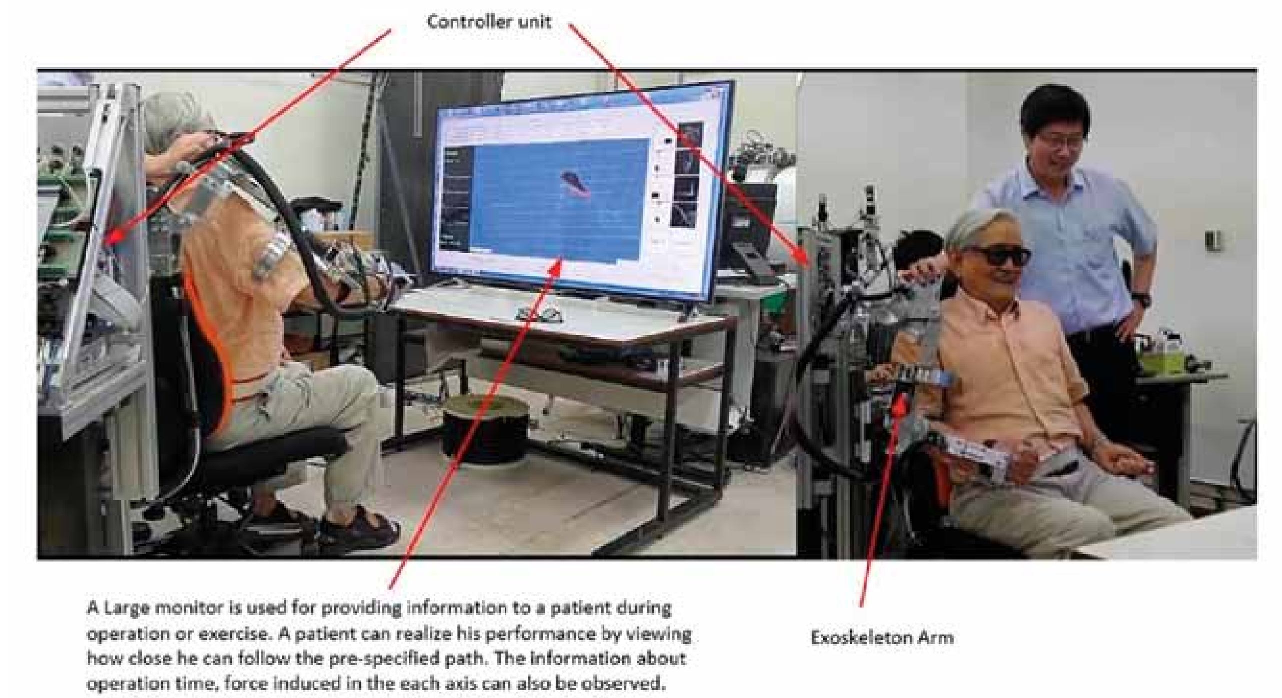

Figure 7 Robot CUREs Test
Source: Sangveraphunsiri (2017)

The CUREs robot arm and training games complement each other in the restoration process (Figures 7 and Figure 8). Robot rehabilitation games are also available for restoration of wrists and legs.

Conclusion

The CUREs Rehabilitation Robot Arm system is effective as a rehabilitation support tool. The research team plans to improve the efficiency of the rehabilitation robot, retaining the original structure to ensure compliance with the test license granted by the Medical Ethics Board and improving the training program to suit a wider range of applications and work functions. Installation of such rehabilitation robots in hospitals around the country could maximize benefits to patients at least costs.

Figure 8 Test robots arm CUREs and training game
Source: Sangveraphunsiri (2017)

Figure 9 Part of the Rehabilitation Robot Research Team
Source: Piravej (2018)

Acknowledgement

This article is part of the research project entitled *"Development of Rehabilitation Robot for Stroke Patients -3rd year"* and the project *"Development of robotic arms controlled by brain and mechanical signals in training with virtual game system for rehabilitation for Stroke Patients -2nd year"* funded by Ratchadapiseksomphot Endowment Fund, Chulalongkorn University.

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Article

Developments of Microfluidics-based Devices for Single Cell Isolation, Trapping and Culturing Single Cancer Cells for Biological Behavior Study of Canine Round Cell Tumors

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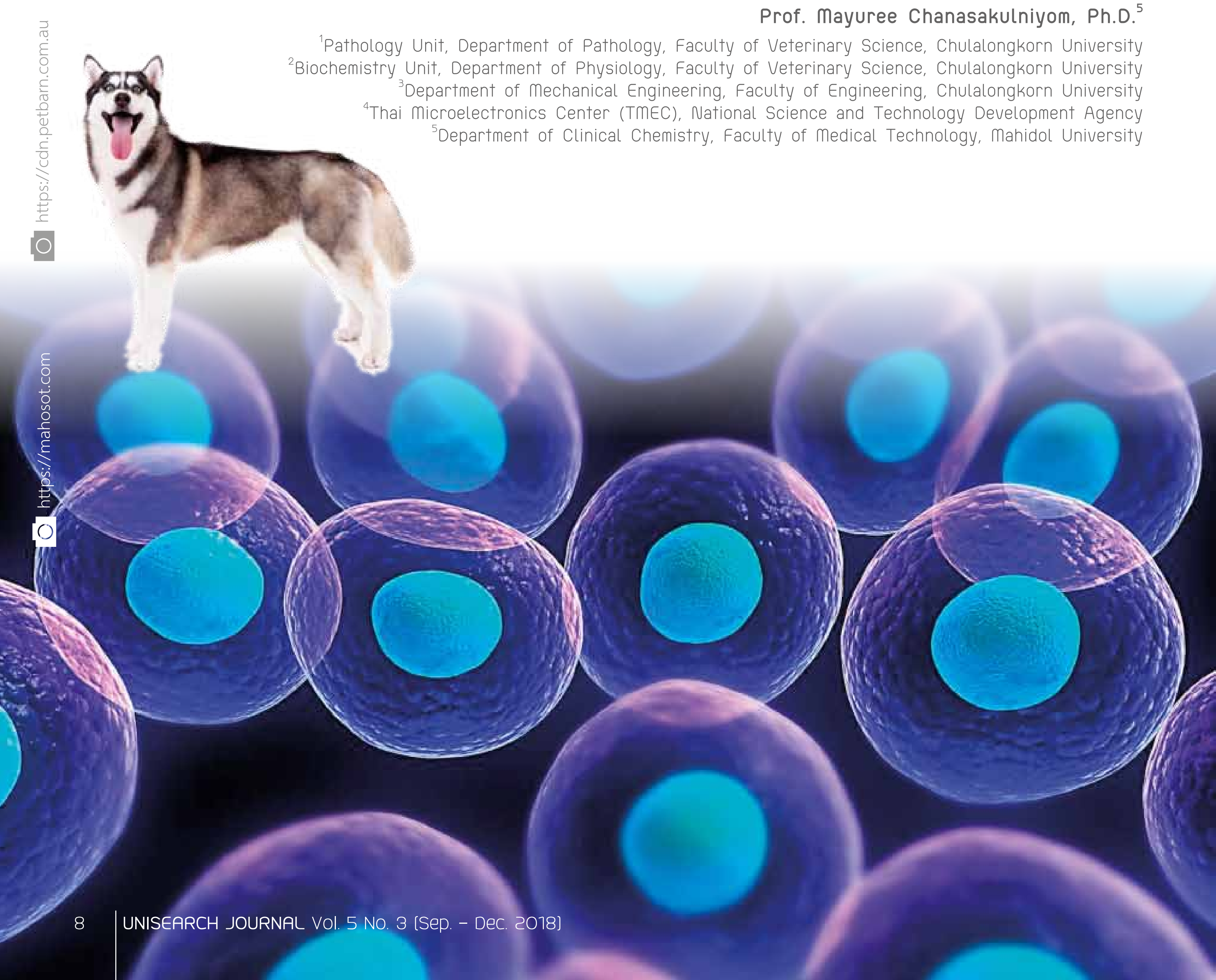

Introduction

This project studies innovative medical science applications of microfluidics and mechanical engineering in the design of microfluidics-based devices for building an integrated body of knowledge for single cell biology. Canine round cell tumors are used as the study specimen to allow the body of knowledge to be used in advance research on biological behavior of cancer cells in both humans and animals.

Tumors and cancers are diseases caused by abnormal growth and proliferation of cells in the body of an organism. Tumors and cancers are crucial issues in human and veterinary medicine, where incidence of cancer is likely to continue to rise. There is currently no permanent cure for cancer and thus, studies on cancer pathogenesis are vital.

However, cellular heterogeneity is one of the most significant obstacles in cancer cell biology, both in terms of morphology and pathophysiology, and can be presented both as intra-tumor heterogeneity and inter-tumor heterogeneity.

Obvious differences are morphological appearance, biological changes (such as mutation) and biochemical function. These differences can be seen in cancer cells sampled at different points in the same cancer bulge or sampled from the same type of tumor in different patients or animals (Heppner, 1984; Marusyk and Polyak, 2010; Michor and Polyak, 2010; Marusyk et al., 2012). This is a prominent issue hindering both cancer research and planning of treatment and therapy.

The diversity of abnormalities can cause mistakes and errors when interpreting cell change. Regardless of whether the cancer is of the same type, the mechanisms of their effects are different at cellular level. For example, in chemotherapy, chemicals are selected by interpreting results on a majority-basis from cancer cell morphology. This overlooks cells that may be smaller in number but could actually be the origin of the cancer. This limitation leads to chemotherapy destroying most of the cancer cells but not being able to destroy the original cancer-causing cells, resulting in ineffective treatment and recurrence.

The development of a body of knowledge can be applied to examine and target single cancer cells, which can help overcome this limitation. To begin, researched methods can isolate collected cells to reduce cell-to-cell-communication, which affects cell change. Unlike current methods, preparation does not require cells to undergo extensive or lengthy preparation. Current preparation procedures can impact cell change and can cause severe cell stress and cell death, resulting in errors in interpretation and analysis. Also, to effectively study single cancer stem cells and tumor-initiating cells, it is necessary to develop examination systems with the capability of sorting cells by size and trapping the sorted cells into a designated area, which cannot yet be performed by macroscopic methods. Current technologies are unable to resolve these issues and thus study results are often inaccurate.

In brief, cellular heterogeneity hinders accurate comprehension of the properties of cancer cells and underlying cancer stem cells. Macroscopic methods and current technologies, specifically automated cell analyzers and polymerase chain reaction methods, are unable to correctly identify the cancer-causing cells and unable to provide solutions for advancing cancer research. Thus, to improve understanding and reduce factors affecting target cells, studies should be conducted at single cell level. At this time, microfluidics technology is the most suitable option for application to single cell studies (Nilsson et al., 2009).

This research aims to develop microfluidics-based devices to sort and trap cells for single cell study with the capability to isolate cells in a designated area based on size. Cells must be viable and able to regenerate in order to enable further study on single cancer stem cells. The basic components of the system are for isolating and trapping cells for culture and examination of cell properties. Trapping will be performed by a spiral microchannel attached to triangular microwells as shown in Figure 1. Successful application of the device is highly beneficial for the medical and medical science industry and can be used to further advance studies on cell behavior.

Microfluidics-based device for isolating cancer cells according to size

The developed prototype applies fluid flow physics using controlled flow of suspended polystyrene polymers. The polymers travel in a stream depending on their size and can be accurately sorted by size. The flow channel contains a rectangular differential cross section with a height of 130 μm and width of 500 μm. The whole channel tube is twisted into 5 spirals with an interspace of 500 μm and total curvature radius of 10 mm. The tube height to target particle size is designed at a ratio greater than or equal to 0.07. The device has two inlets, with the first inlet connecting to the cell suspension and the second inlet connecting to the buffer. The suspension and buffer are injected into the device via an automated pump. The end of the final spiral is expanded by a 2 mm attachment and connected to 10 outlets (Figure 2).

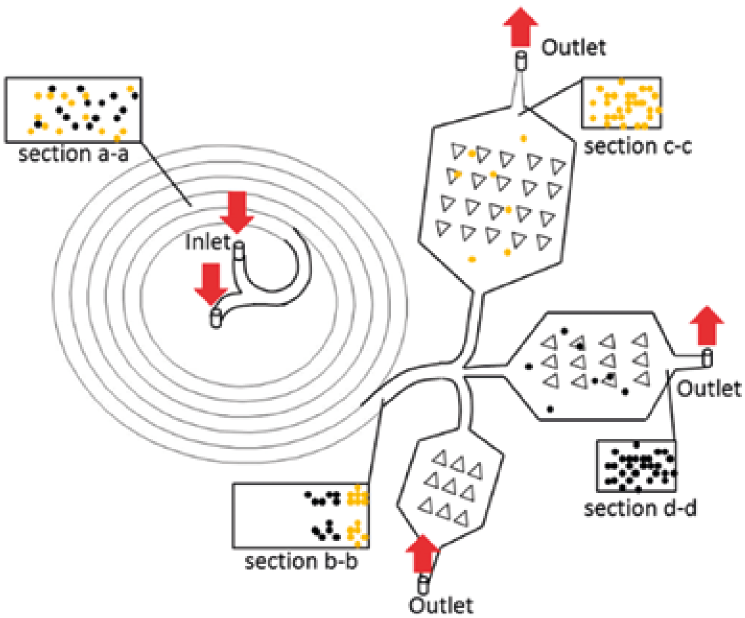

Figure 1 Microfluidics-based device for trapping and isolating cells in triangular microwells for single cell culture and examination

Source: Pimpin, designed in June 8, 2018

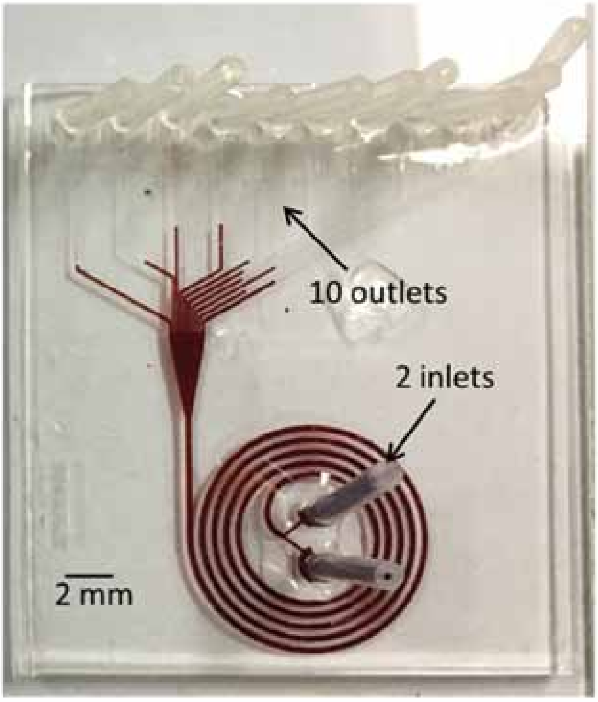

Figure 2 Microfluidics-based spiral-like device for isolating and sorting cancer cells by size
Photographed by: Pimpin, May 5, 2018

Flow velocity was set at 0.5-2 ml/min and used 5, 10, 15 and 20 μm polymers. The microfluidics-based device was able to accurately sort the polymers by size when applied to specific sizes and varied sizes (Thanormsridetchai et al., 2017). For research application, canine cutaneous mast cell tumors of 10-20 μm were used. Results showed that most cells were correctly grouped by size and in groups consistent with results from polymer testing. However, many cells were found trapped within the tube wall, including viable cells, which may have caused by a reaction between the cell membrane and tube material. Debris was also found in the suspension at the outlet. Experimental results were consistent while counting liberated cancer cells at the outlet. Cell count was decreased by approximately 50% and the percentage of viable cells after testing was reduced to just 30%. This may be caused by flow force or pressure within the channel affecting the cell equilibrium, causing cell wall damage or cell death. (Figure 3) compares a normal white blood cell and white blood cell damaged after going through the microfluidics-based device. In this regard, further study is necessary to improve overall efficacy and to reduce negative effects to the cell (Ketpun et al., 2018).

Microfluidics-based device for trapping for cancer cells

In this section, a system was designed and tested for trapping polystyrene particles and cancer cells, in which cells are directed to a microwell using physical fluid flow. The study was performed using 10 μm polymer particles and canine cutaneous mast cell tumors ranging from 10-20 μm (Figure 3). Cells are trapped by triangular-shaped microwells. The mechanism relies on force from fluid flow to direct particles towards the microwells, then relies on recirculation flow generated by the microwells to direct particles to their relevant microwell. Triangular microwells were chosen due to strong circulation and optimal trapping ability (Park et al., 2010).

The two main parts of the device are the main flow channels for particle direction and the rectangular

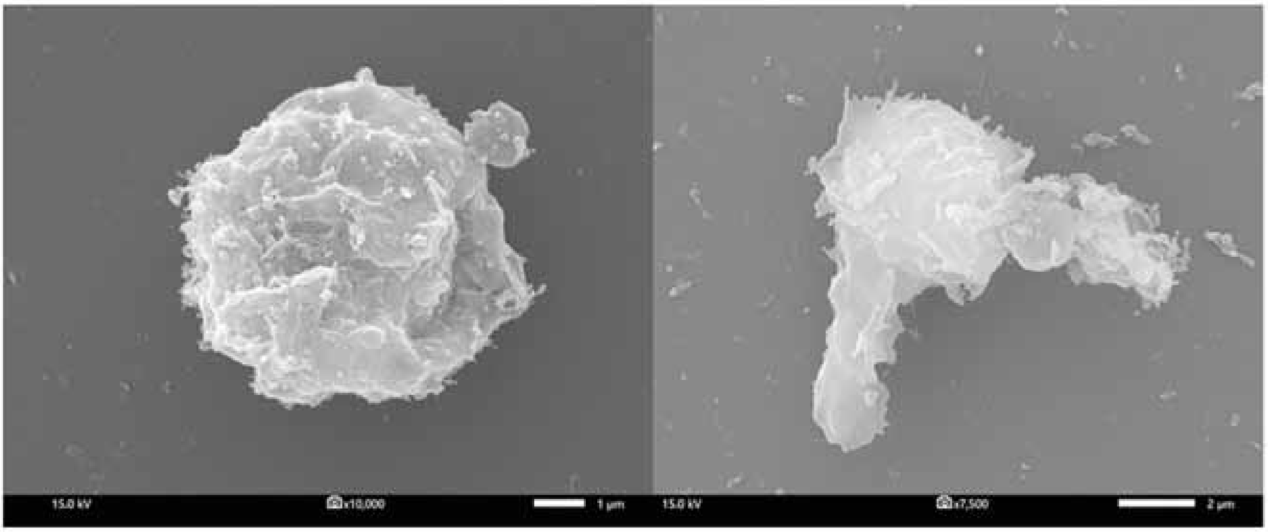

Figure 3 Normal white blood cell and white blood cell damaged from flow force
Photographed by: Suwannaphan, June 4, 2018

differential cross section with a height of 70 μm and width of 500 μm. Each end is connected to inlets or outlets and the equilateral triangular microwells are 40 μm wide and 30 μm deep.

To test its ability of trapping target particles, 10 μm polymer particles were tested at a flow velocity of 0.1 ml/h. It was then tested on cells under the same experimental conditions. Results showed that cell trapping efficacy averaged 30% of the number of microwells. The microfluidics-based device developed in this study was successfully able to trap 45% of the canine cutaneous mast cell tumors with satisfactory viability. In the future, further studies should be conducted on the parameters affecting trapping performance, such as the flow velocity and flow fluid type, which can optimize the device and further improve cell trapping efficacy.

In conclusion, the study results show that microfluidics-based devices designed using controlled flow and microparticles can be successfully applied to sort and isolate cells by size. Trapped cells in microwells were able to grow and divide by single cell culture, increasing cell count and cell viability. The cells were also able to undergo further single cell biological examinations. This knowledge can also be transferred to technological applications and in research groups needing to isolate single cells and needing to study properties of individual cells.

This study is a development for Lab on the Chip (LOC). The device is intended to sort and trap cells using microfluidics applied to cell trapping. Canine cutaneous mast cell tumors are used for initial comparative study. Cross-disciplinary knowledge from the integration of medical science and technological science is combined to develop a device that can assist single cell analysis to build a biological body of knowledge, which can be further advanced to analyze various target cells. This is especially beneficial in cancer cells, as it can provide modernized guidelines for treatment and monitoring of cancer in harmony with the Thailand 4.0 national policy.

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This article is a part of the research project entitled *"Developments of Microdevices for Isolation of Single Cells and Cancer Treatment"* funded under the in-depth strategic research

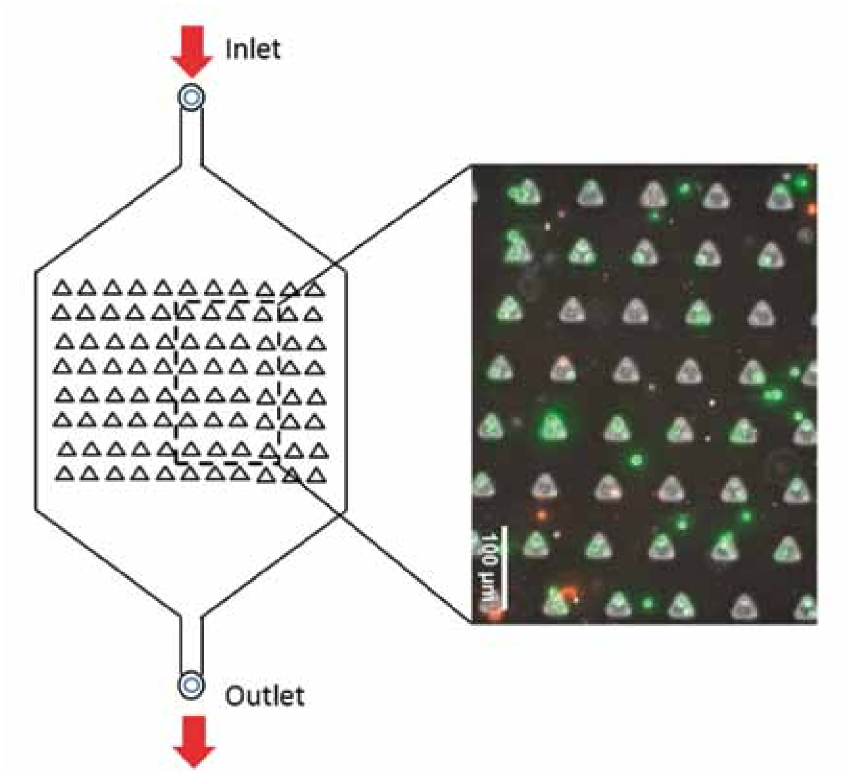

Figure 4 Microscopic triangular trapping system for cancer cells and fluorescent imaging of viable and dead cells in the microscopic reservoirs
Source: Panpattanakul and Wongpakham, designed in April 22, 2018

program 2014 of the Ratchadaphiseksomphot Endowment Fund, Chulalongkorn University; the National Research Council of Thailand, 2015 and 2017-2019; the CU Academic Development Plan to Empower 200 years of CU (Smart Medical Devices); and the Companion Animal Cancer Research Unit, Faculty of Veterinary Science, Chulalongkorn University.

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Article

Development of High Efficiency Visible-light Responsive Photocatalysts

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Introduction

Increasing levels of water and air pollution caused from human activities and especially industries detrimentally affect the environment, including the health of humans and other organisms, and have become a major problem worldwide, including within Thailand. Science and Technology development has an important role in solving these problems, both in terms of reducing the level of pollutant production and in removing already released pollutants. Thus, researchers are trying to study and develop materials to these ends. Photocatalysis is a green techonology and is a potentially highly effective process to break down toxic organic matter in the water and air using principally only light energy (except for the initial synthesis and transport of the materials) and so is a sustainable and environmentally friendly process that can be applied to reducing pollutant release and to a reduction of already released pollutants. The main and rate-limiting component in photocatalysis is the photocatalyst, which have recently started to be developed to have the capability to respond to the visable-light as well as the UV-light region, so that solar energy, a sustainable natural resource, can be used more efficiently.

Photocatalysis process

Photocatalysis occurs when the photocatalyst, a semiconductor, absorbs light that has more energy than the photocatalyst's band gap energy and so an electron (e^-) is activated and moved from the valence band (VB) to the conduction band (CB) to form a hole (h^+) at the VB. The e^- and h^+ move to the surface of the semi-conductor materials where redox reactions can occur with the absorbed molecules (such as pollutants) on the surface. During the photocatalysis process, at least two processes occur simultaneously to produce reactive oxidizing species (ROS): (i) the e^- at the CB reacts with oxygen at the surface of the semi-conductor materials to produce a super oxide radical ($O^{\cdot 2}$-), while the h^+ at the VB reacts with water at the surface to produce hydroxyl radicals ($OH^\cdot$). These two ROS have a higher oxidizing power compared to other oxidizing agents and so they have a high ability to break down volatile organic compounds at the surface of the semi-conductor materials. The final products of the reaction, shown schematically in Figure 1, are CO_2 and H_2O. However, during the reaction, recombination of e^- and h^+ can occur, which does not produce any ROS and so leads to a decreased photocatalytic effectiveness. This is currently the main efficiency-limiting problem in the photocatalysis process (Fujishima, Rao and Tryk, 2000).

The photocatalysts currently being developed and used for treating pollution, Titania (TiO_2) is well known and widely used due to its chemical stability, low toxicity, ease to prepare, low cost, large surface area and high photocatalytic activity. However, the serious limitation of TiO_2 is that it only works with ultraviolet light ($\lambda < 380$ nm) because the band gap energy is about 3.0–3.2 eV, yet UV light comprises only 4% of the energy content of the natural light source (sunlight) at the earth's surface (Figure 2). Rather, most of the energy (more than 40%) of sunlight at the earth's surface is in the visible light spectrum ($400 < \lambda < 800$ nm). Therefore, there is a need to develop photocatalysts that are able to

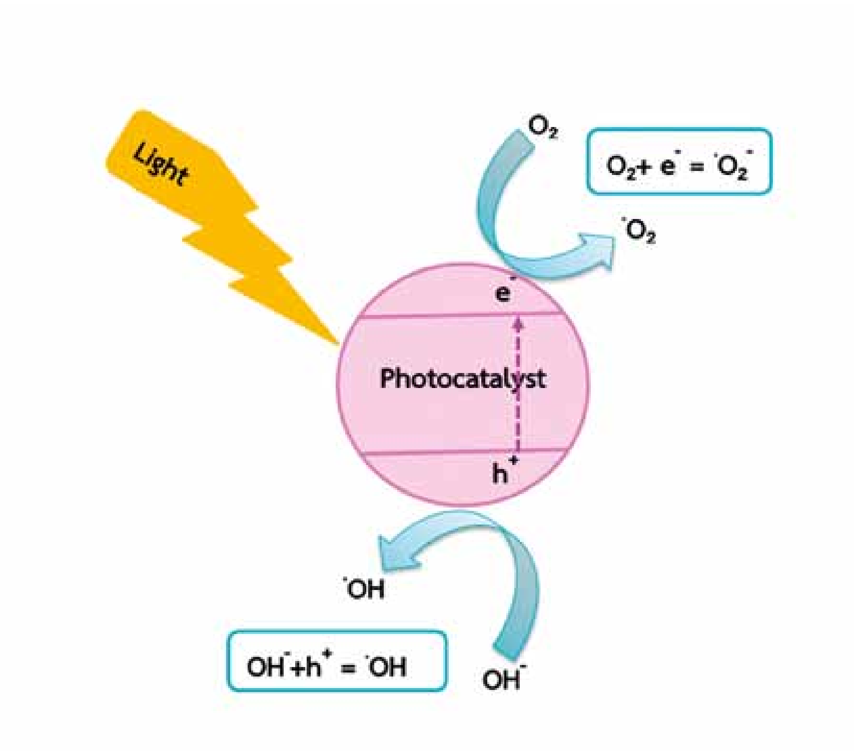

Figure 1 Photocatalysis process
Source: Prasitthikun, designed in June 2018

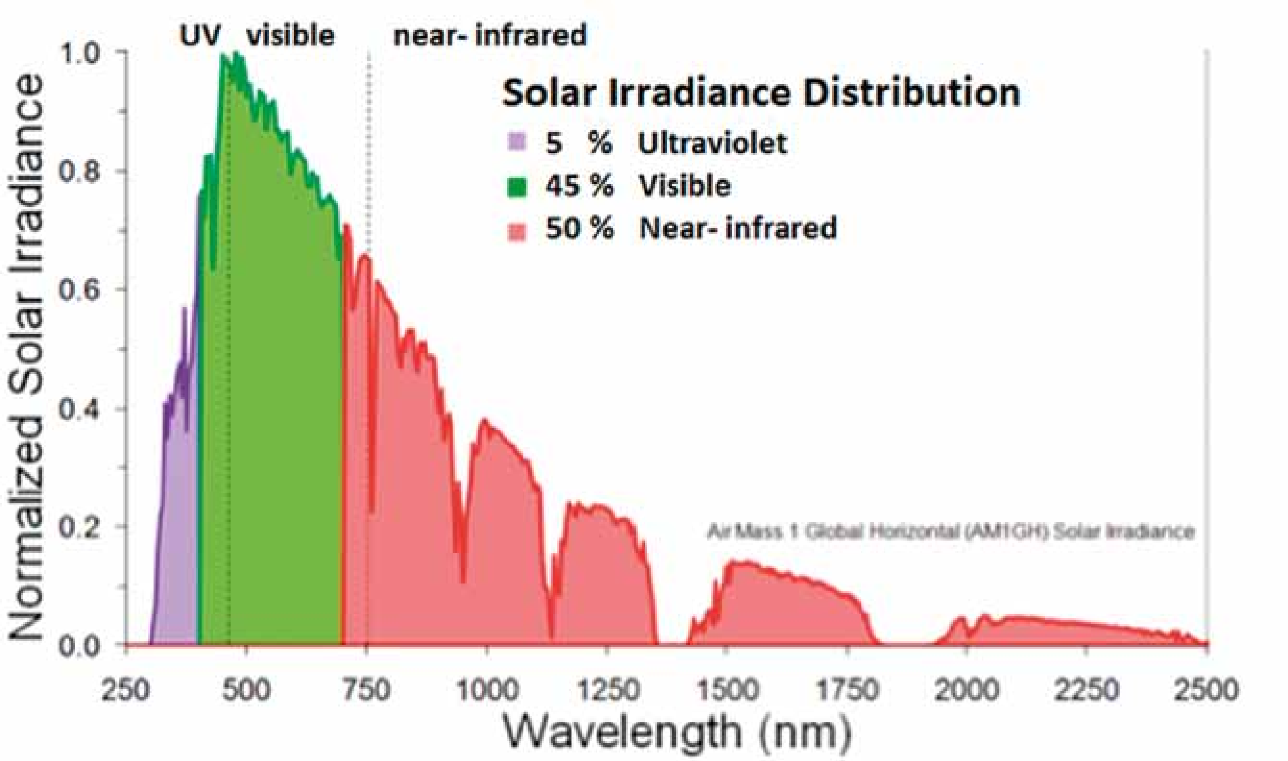

Figure 2 Solar energy in each wavelength of light at the earth's surface
Source: Cool California organizations (2000)

respond to visible light and so increase their effectiveness when using green and renewable energy sources.

Bismuth oxybromide (BiOBr)

Although modification of TiO_2 by incorporation of other metals and preparation procedures to defective crystalline forms that can adsorb visible light are being researched, many other studies have focussed on materials other than TiO_2 that can be used as a photocatalyst in different visible light spectra, especially for photocatalysts in the bismuth oxyhalide group (BiOX, where X is Br, Cl or I). These materials have been reported to be able to effectively activate light reactions under the visible light spectrum and also to break down organic matter and toxic gases (An et al., 2008) because they have a rather narrow band gap energy (2.42–2.64 eV) and are chemically stable. From current studies, it seems that BiOBr is a more effective photocatalyst than the others in the BiOX group. Factors that affect the photocatalyst effectiveness are the phase structure, crystallinity size of the particles, surface area, dispersion and light absorption.

This research studied BiOBr synthesis by hydrothermal, microwave and sedimentation, since these processes use a low level of energy. Sedimentation at room temperature is an easy process with the lowest energy consumption for synthesizing BiOBr. The BiOBr powder obtained from sedimentation is pure and distinctly crystalyized, as shown in the X-ray diffraction (XRD) analysis (Figure 3). The powders have a round shape comprised of plates in groups, as shown by scanning electron microscopy (SEM), giving a high surface area (20.663 m^2/g, as determined by BET analysis of nitrogen adsorption-desorption)

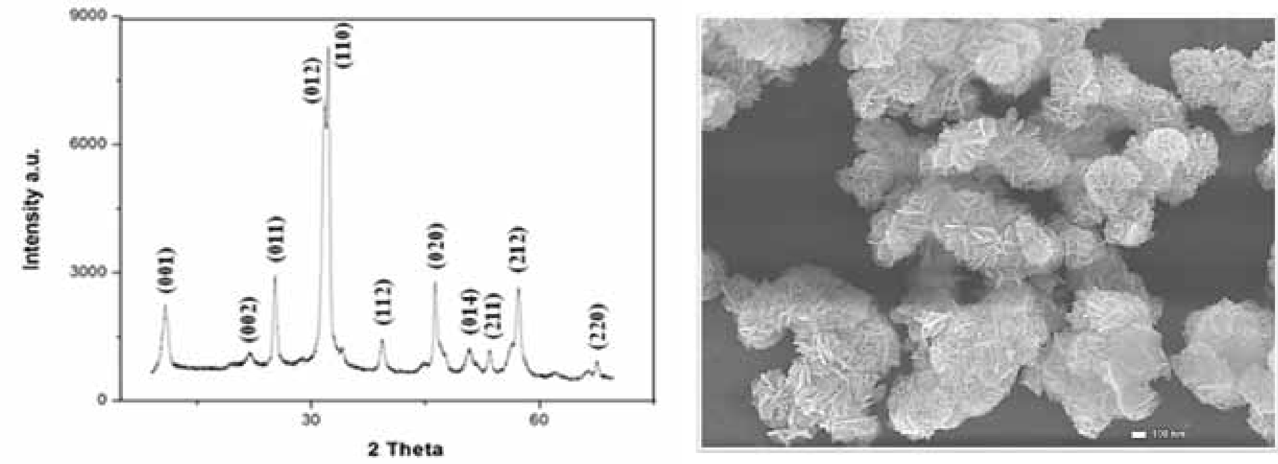

Figure 3 Representative (Left) XRD and (Right) SEM analyses of the synthesized BiOBr powders
Source: Prasitthikun (2017)

when compared to previously reported studies and are able to respond under visible light. When testing their photocatalytic ability in terms of the decomposition of organic dye, it was found that the BiOBr powder was an effective photocatalyst reducing 77% of the dye within 50 min. Likewise, the BiOBr powder could decompose NO_x under visible light with a 37% effectiveness.

However, the current preparation methods for BiOBr do not lead to a highly effective photocatalyst due to the recombination of the charge carriers (e^- and h^+) in the light-activated process. If this problem could be solved, it would increase the photocatalytic effectiveness of BiOBr. Therefore, the researcher prepared composite materials with other material that encourage electron movement and reduce the recombination of charge carriers, such as graphitic carbon nitride (g-C_3N_4).

Graphitic Carbon Nitride (g-C_3N_4)

Graphitic carbon nitride is an n-type layered semiconductor, where each layer has a triazine ring and tri-s-triazine ring structure, with a high rate of electron movement. Therefore, g-C_3N_4 is widely used in photoelectronics materials because it has high chemical and heat stabilities, low solubility in common solvents (such as water, methanol, toluene and diethy ether), and has a narrow band gap energy (2.7 eV) so it is responsive to visible light activation. Typically, g-C_3N_4 is used in composite photocatalyst materials (Zhao et al., 2015), such as with TiO_2 and other materials to increase the reaction effectiveness under both UV and visible light. It can reduce the rate of charge carrier (e^- and h^+) recombination and increase both the chemical and heat stability of the composite materials under the light-activated reaction.

Synthesis of g-C_3N_4 can be done by many different processes, including physical vapor deposition, chemical vapor deposition, solvothermal and solid state reactions. Nevertheless, the easiest process is thermal condensation of a nitrogen- rich precursors, with melamine being the most common precursor used in most research. However, due to the high toxicity of the by-product from the synthesis of g-C_3N_4 from melamine, urea was used as the substrate instead in this research. The temperature used in the thermal condensation of the substrate

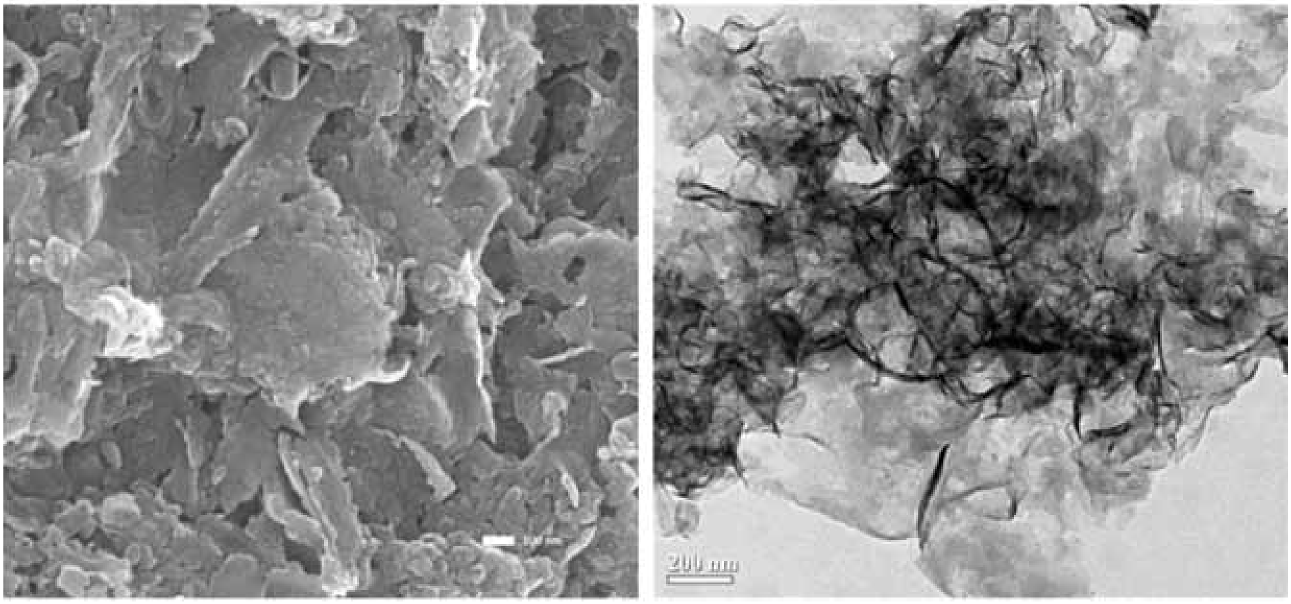

Figure 4 SEM (left) and TEM (right) images of synthsized g-C_3N_4
Source: Prasitthikun (2017)

(urea in this study) will affect the quality of the obtained photocatalyst, where 500-600 °C was found to be a suitable temperature for synthesizing g-C_3N_4, since temperatures of 700 °C or higher start to melt the g-C_3N_4 (Dong et al., 2014). Synthesized g-C_3N_4 has a flake-like structure the same as graphene (Figure 4).

BiOBr/ g-C_3N_4 composite photocatalyst

The researchers are trying to develop photocatalyst composites prepared from BiOBr and thin-layered g-C_3N_4. The preparation process has a major effect on the microstructure and quantity of the obtained g-C_3N_4 in the BiOBr/g-C_3N_4 composites, which in turn affects the quality and effectiveness of the photocatalyst. Therefore, the effect of variations in the prepartion processes was evalauted so as to find the more optimal synthesis conditions to obtain an efficient photocatalyst under visible light.

In this study the photocatlyst efficency was tested in terms of the ability to oxidize the coloured cationic dye, a widely used model organic pollutant. Breaking down of dye in the composite suspension is detected by the reduction in the dye concentration, followed by monitoring the dye absorbance using UV/VIS spectroscopy, with increasing time of exposure to a fixed intensity and spectrum of visible light. The dye suspension fades in colour (and light absorbance in the spectroscopy) until becoming a clear suspension. The rate of reaction and effectiveness of dissolving the dye increased as the level of g-C_3N_4 in the composite material increased up to the optimal ratio, at which level the composite photocatalyst could degrade nearly 100% of the dye within 50 min, some 25% more effective than the pure BiOBr. The same trend in the results were found when digesting NO_x, where the photocatalytic efficency was increased about 15% for the BiOBr/ g-C_3N_4 composite material. The mechanism of the reaction in the BiOBr/g-C_3N_4 composite material is shown schematically in Figure 5, where BiOBr and g-C_3N_4 work together to promote electron transfer and separating the e^- from the h^+ to reduce the rate of their recombination. Moreover, the composite material's structure has a high ability to absorb dye, leading to an increased rate of dye absorption and degradation.

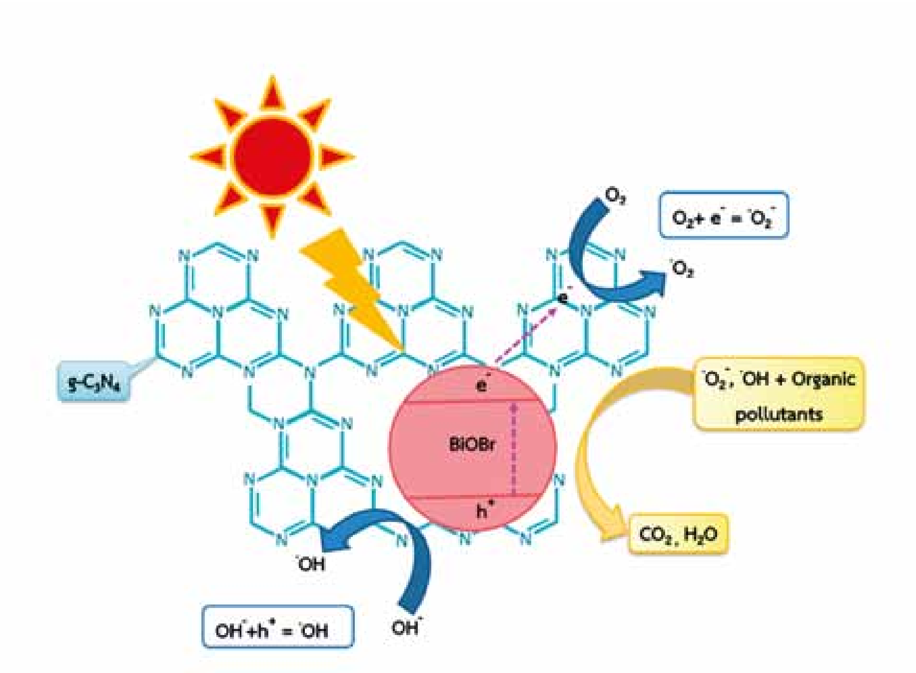

Figure 5 Schematic diagram showing the mechanism of the photocatalysis reaction of BiOBr/g-C_3N_4 composites.
Source: Prasitthikun, designed in June 2018

Moreover, the composite photocatalysts had an increased stability and recyclability compared to the pure BiOBr. After several uses, the composites still had almost the same photocatalystic efficiency as the first time, whereas that for the pure BiOBr was dramatically decreased to less than 20% of its original photocatalytic efficiency.

From this preliminary research, the BiOBr/g-C_3N_4 composite photocatalyst developed in this research has the potential to digesting toxic organics in both water and air under sunglight. The researcher is also developing other types of photocatalysts to increase their effectivness and to eventually use this knowledge for treating pollution. This research is part of a current science and technology platform that aims to improve sanitation, living quality and environment in the country.

Acknowledgements

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Development of Powder Injection Molding for Dental Ceramic Brackets

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Introduction

Dental ceramic brackets are specialized medical products that typically need to be imported from overseas at a relatively high price. Aside from reducing prices, development of manufacturing technology within Thailand will help build a knowledge base and contribute to national development, as well as provide innovative applications in material science. This can be further advanced to strengthen Thailand's industrial base and reduce the import burden. When considering shape, appearance and size, the most suitable manufacturing process is powder injection molding, recognized as the most cost-effective method for small, complex products. The method has received widespread interest for manufacturing high-quality products in large quantities. When compared with other means of manufacturing, the method reduces the amount of waste generated during the production process.

http://www.dezignlover.com/

Ceramic brackets

Orthodontics are a highly knowledge-intensive and specialized branch of dentistry relating to treatment of dental irregularities. Treatment of misalignment or occlusions can help treat oral issues, such as overbites, irregular spacing and dental relapse. Orthodontic treatment helps to realign teeth, helping improve mastication and oral hygiene by making the teeth easier to clean, resulting in improved oral health. Orthodontic devices such as dental brackets can be produced using metals or ceramics according to suitability and individual preference. Ceramic brackets are more suitable for older patients or those who do not want their braces to be prominently visible. Ceramic braces blend well with tooth color and can even be manufactured to appear translucent (Figure 1).

Powder injection molding process

Powder injection molding has many advantages in the production of small and complex pieces. The process can be performed using a relatively small amount of raw materials, conserves energy and helps reduce shaping costs as the prepared piece has a near-net shape. The main components used are the powder and binder.

Figure 1 Ceramic brackets manufactured for distribution
Source: 3M United States (2018)

Figure 2 QR Code linking to video of powder injection molding process
Source: Morgan Advanced Materials (2013)

The process comprises four main steps: feedstock preparation, injection molding, debinding and sintering. A video of the injection molding process is available at https://goo.gl/Btj5z9 or https://www.youtube.com/watch?v=0hI7wVDa9Ww, or by scanning the QR code in Figure 2. The code links to a video distributed by Morgan Advanced Materials (2013).

In general, the debinding process (removal of binder) can be performed using heat or a solvent. Selection of the binder is a crucial step in the production process. Debinding by heat alone takes a very long time, consumes energy and is costly. To find a solution to these issues, this research attempted to find a combination binder made from components that can be debinded by a solvent. Wax binders are usually debinded using organic solvents such as heptane, which is flammable. Thus, the development of a water-soluble binder is an area of interest for environmental and cost reasons.

In Thailand, the Metallurgy and Materials Science Research Institute, Chulalongkorn University, has studied the issue for the past 5 years. Water-soluble binder systems for ceramic and metal powder have been developed using polyethylene glycol (PEG) and polyvinyl butyral (PVB), with various composite materials such as alumina-tungsten carbide (alumina: Al_2O_3 - tungsten carbide: WC), alumina-zirconia (alumina: Al_2O_3 - zirconia: ZrO_2) and nickel oxide-zirconia (nickel oxide: NiO - zirconia: ZrO_2).

Thus, this project aims to develop dental ceramic brackets from alumina using powder injection molding. The procedure will be conducted using a water-soluble binder, which is clean, environmentally friendly and reduces costs. The manufacturing process is convenient, safe and has the capability to expand production capacity at the industrial level.

Development of powder injection molding for dental ceramic brackets

The laboratory powder injection molder (Figure 3) is the device used in laboratory development of the dental ceramic brackets in this study. The powder injection molder operates vertically using an air injector. The feedstock container is a cylinder with

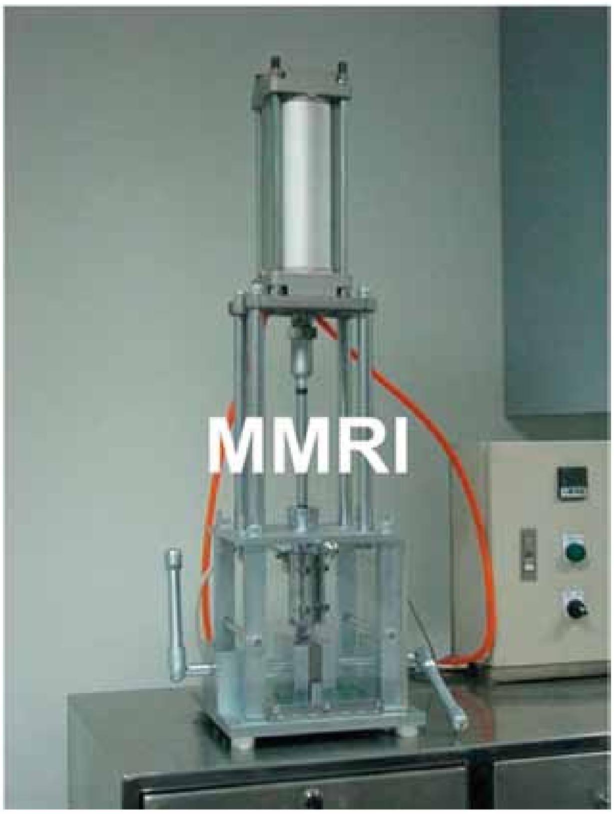

Figure 3 Laboratory powder injection molder at the Metallurgy and Materials Science Research Institute, Chulalongkorn University
Photographed by: Chuankrerkkul, 2015

a small opening at the end for adding the feedstocks to be injected into the mold. The feedstock temperature is controlled by a heating jacket, which covers the feedstock. A thermocouple is attached to the cylinder to monitor temperature during injection. An electronical control system is attached to the control box and allows the temperature and other controls to be adjusted digitally.

The experimental procedure begins with inspection of the specific characteristics of the raw materials used in the study, namely the alumina powder. Particle size and distribution is measured by a particle size analyzer and the particle characteristics are observed using a scanning electron microscope. Polyethylene glycol and polyvinyl butyral were selected for the binder and thermal properties were inspected. In the preparation step, assessments for most suitable powder to binder ratio were performed and studied with the various ratios and types of different binders. The mixture was injected and molded using the laboratory powder injection molder (Figure 4). The powder to binder ratio is reported by volume ratio (Vol%) to allow comparisons with other injection molding studies. If the ratio was reported in percent by weight (w/w), comparisons would be difficult as each material has varying density, such as the different density of metal and ceramic. The most suitable powder ratio for injection molding is usually at 50–60 Vol%, but may be reduced to 40–50 Vol% in the event that the ceramic particles are particularly small. With very small particles size, the higher surface area means a higher binder ratio is needed in order to successfully transfer the powder into the injection mold.

After achieving the resulting molded test product, other properties are examined such as density and

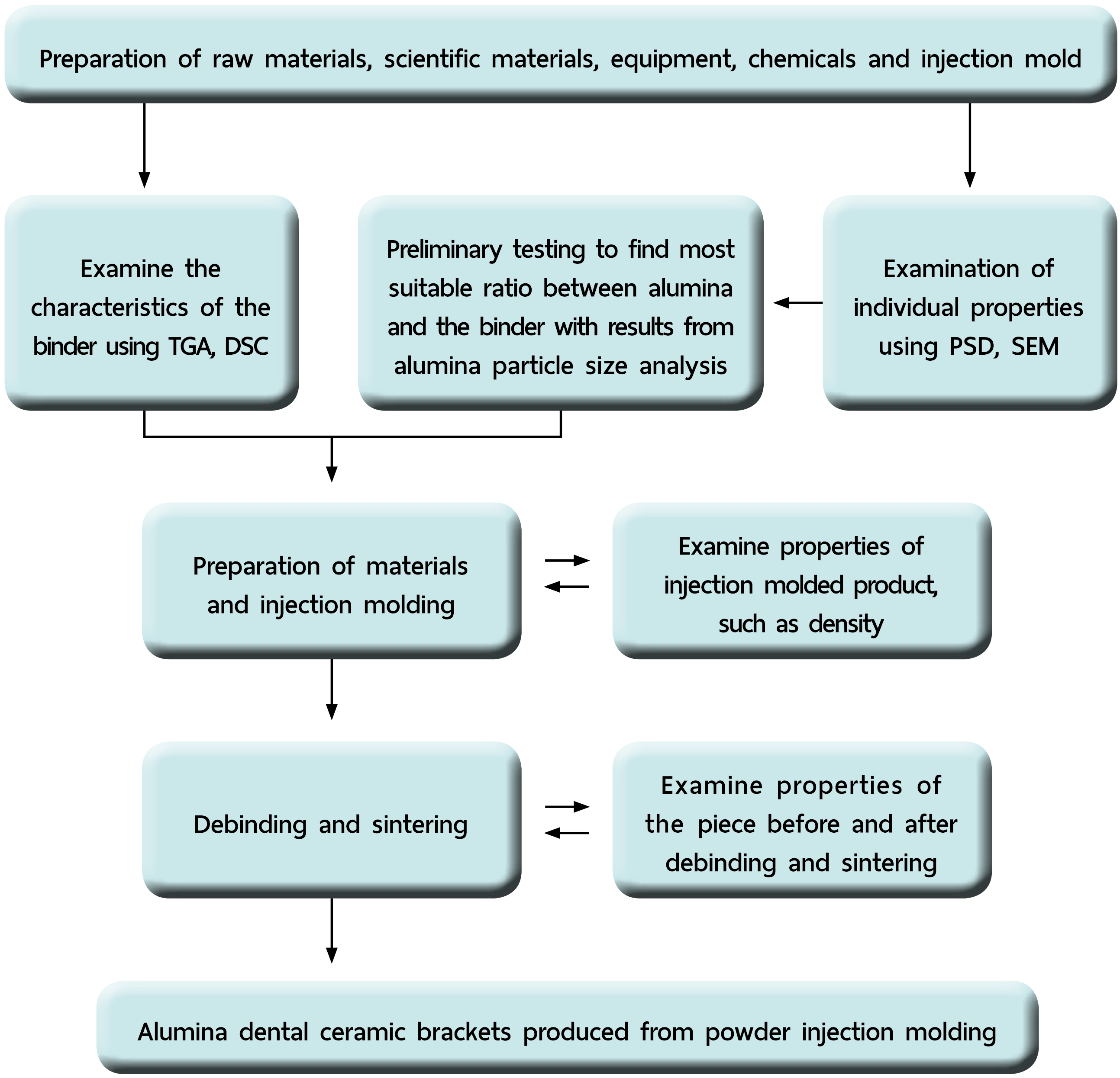

Figure 4 The powder injection molding process
Source: Chuankrerkkul, designed 22 January 2016

strength. Polyethylene glycol was used as the water-soluble binder and thus debinding was performed using water. In this step, the effect of water temperature and time on the debinding rate was also examined. The final step was sintering, in which the effects of sintering temperature and holding time at maximum temperature on the properties of the test product were also examined. A scanning electron microscope was used to examine the microstructure.

Conclusion

Using a systematic and step-by-step design, this study was able to prepare alumina powder and binders using polyethylene glycol and polyvinyl butyral that were suitable for powder injection

Figure 5 Ceramic brackets produced in the study
Photographed by: Wasanapiarnpong, 17 July 2017

molding, resulting in successful production of dental ceramic brackets (Figure 5). Nonetheless, this accomplishment represents proof of concept, and requires further study to optimize final products with the appearance and properties prescribed by orthodontists. The author hopes that this contribution to knowledge in materials science, especially in powder injection molding can help improve the knowledge base and support future studies, as well as potentially strengthening the Thai industry and reducing the need for imported goods.

Acknowledgements

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Enzyme-based Biosensors for Organophosphate Pesticide Detection

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http://infinichem.com

Introduction

The widespread and often excessive use of pesticides in agriculture presents significant health and food safety risks to consumers. A technique that quickly detects pesticide residues helps reduce these risks. In this research, a biosensor was developed to specifically detect organophosphate pesticides (OPs) using graphene quantum dots (GQDs). GQD is a highly fluorescent nanomaterial that is easy to prepare, affordable and environmentally friendly. Levels of acetylcholinesterase (AChE), an enzyme found mostly in the human nervous system, are reduced in the presence of OPs, and was therefore selected as the target for this study. Acetylcholinesterase (AChE) and cholinesterase (CHOx) reactions naturally produce hydrogen peroxide (H_2O_2). However, OPs interfere to an enzymatic production of hydrogen peroxide (H_2O_2), which in turn affects emission of fluorescens from graphene quantum dots. Observation of this change in fluorescent emission of GQD led to the study of enzyme-based biosensors to effectively detect the presence of organophosphate pesticides. The research is important to easy and rapid detection of pesticide residues in foods, water resources and other environmental resources.

http://pesticides.news

Use of Pesticides in Thailand

Pesticides are widely used in Thailand to prevent or reduce damage by insects, weeds, rats, fungi and bacteria affecting agricultural crops. According to the Official of Agricultural Economics (OAE, 2015), Thailand imported 149,546 tons of pesticides in 2015, and volumes continue to rise each year, presenting increasing risks to Thai farmers and consumers either from direct exposure through air, water or soil, or from consumption of contaminated food containing excessive residues of pesticides. The United States Environmental Protection Agency (EPA) sets maximum limits of 10 ppm for pesticides such as dichlorvos in water sources (EPA, 2012).

Organophosphate (OPs) are a group of pesticides containing phosphorus. They are highly toxic and can be absorbed dermally, by ingestion or through the respiratory system before spreading throughout the body. OPs accumulate mostly in the liver and nervous system. Once in the body, OPs create a covalent bond with the active site of acetylcholinesterase (AChE), an enzyme in the nervous system, which hydrolyses the neurotransmitter acetylcholine (Ach) to produce choline and acetate and inhibits AChE from actively functioning in the body for several hours or days (Figure 1(A), Raffa et al., 2014). As a result, the body suffers from an excessive amount of acetylcholine which led to organ malfunctions and possibly death. Therefore, early detection is crucial. Nowadays, the most common testing methods are gas chromatography/mass spectrometry (GC/MS) and high-performance liquid chromatography (HPLC). Both methods are time-consuming, expensive and require expert technicians and equipment (Blesa et al., 2003).

Inhibition of acetylcholinesterase is widely used to detect OP levels via several techniques including electrochemical methods, fluorescence spectrometry and colorimetric detection (Zheng et al., 2011). However, the biosensors used in these methods were complicated to prepare and required a large amount of enzymes. Moreover, some research required environmentally toxic reagents. Therefore, creating a new biosensor that is easy to prepare, affordable and environmentally friendly is crucial to resolve these constraints. The GQDs/AChE/CHOx biosensors were developed in this study by incorporating graphene quantum dots based on our knowledge

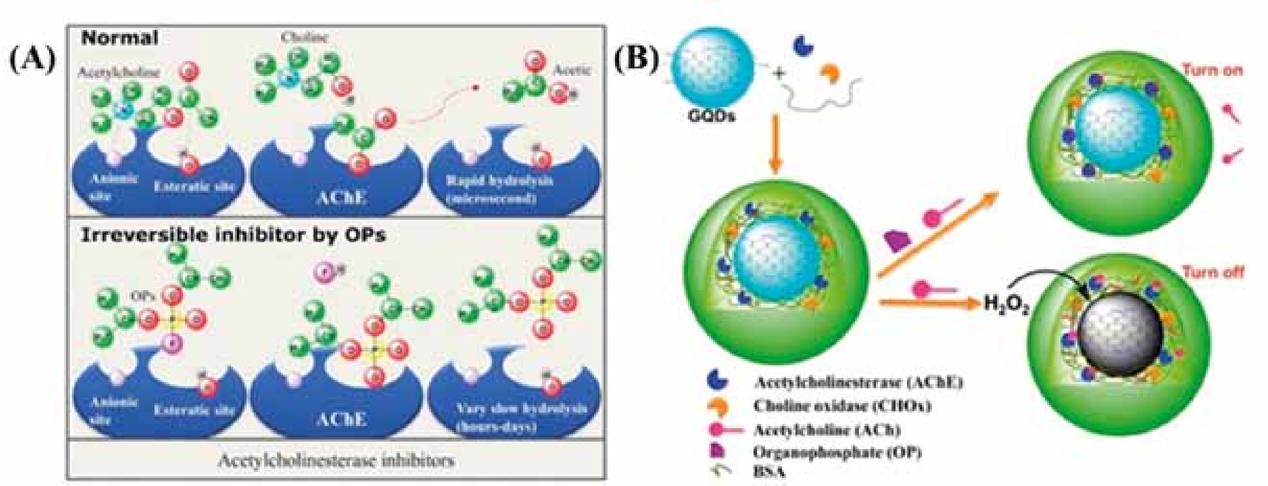


Figure 1 (A) Organophosphate pesticides inhibit AChE from the rapid hydrolysis process
(B) Preparation of GQDs/AChE/CHOx biosensors for organophosphate detection
Source: Sahub et al. (2018)

of the enzyme-based reaction (Sahub et al., 2018) via fluorescence spectroscopy technique. This method is faster and cheaper than other standard methods mentioned above. It is also affordable and accessible even for farmers and consumers. It is hoped that this research will lead to a high-quality method for detecting organophosphate residues in fruits, vegetables and processed food products, soils and water sources.

Nanotechnology used in the graphene quantum dots

Nanomaterials, materials of which a unit is measured between 1 to 1000 nanometres, are widely used as catalysts to accelerate reactions, as a transmitter, in drug delivery (Sahub et al., 2017) and in fluorescence microscopy images of cells and tissues. Nanomaterials can be categorised by size and shape, and include structures such as nanocones, nanofilms, nanotubes, nanoparticles and quantum dots.

Graphene quantum dots (GQDs) are a type of nanographene-constructed carbon sheet with unique characteristics such as a high and stable fluorescence emission, easy and inexpensive synthesis, low toxicity and environment-friendly. Adjusting the surface area and boundary characteristics of GQDs triggers changes in energy levels (Dong et al., 2012) and enables creation of GQDs with specific detection of target molecules by fluorescence spectroscopy technique.

Biosensor preparation process

The GQDs/AChE/CHOx biosensors were prepared from GQDs and both AChE and CHOx enzymes. The biosensors were coated with bovine serum albumin (BSA) Figure 1(B). During the biosensor preparation process, AChE and CHOx were added to the solution of graphene quantum dots and 1% bovine serum albumin solution in Tris buffer (pH 8). The solution was kept at $5\,^{\circ}C$ for 24 h before making the portion series by adding the various concentration of organophosphate or water samples (as applicable). The solutions were continuously stirred and then left to stand for 15 min. Acetylcholine was added to the solutions and stirred continuously for 30 min. The quantity of organophosphate was measured by monitoring the fluorescent signal at 467 nm under excitation at 362 nm. A graph was plotted to show

the relationship between the acetylcholinesterase inhibition efficiency (I%) (Zheng et al., 2011) and the concentration of organophosphate (ppm).

Morphological characteristics of GQDs and GQDs/AChE/CHOx

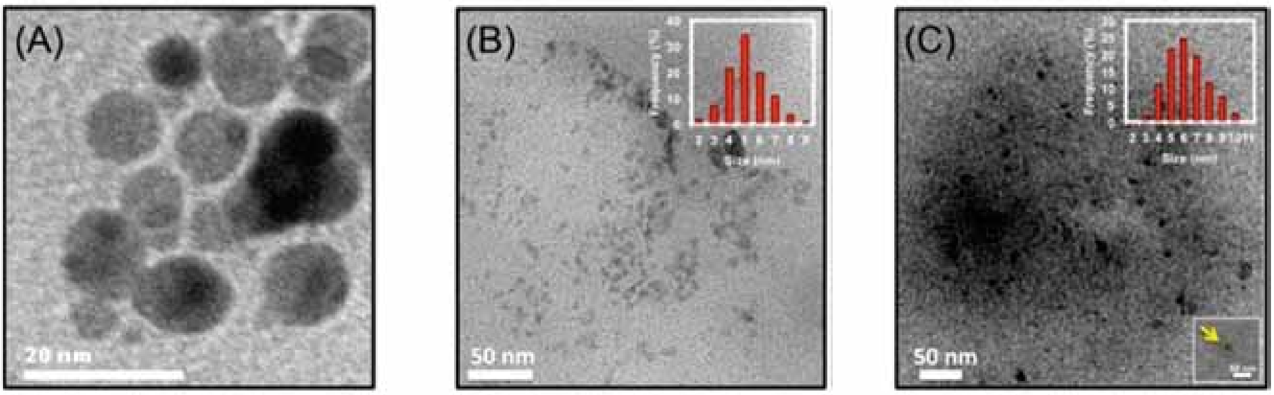
The morphological characteristics of GQDs were studied using transmission electron microscopy (TEM). Figure 2(A) and 2(B) reveal spherical plates at approximately 5 nm (measured with the ImageJ programme from 200 GQD particles). Following the biosensor preparation process, the GQDs/AChE/CHOx biosensors in Tris-BSA solution at pH 8, the core particles of GQDs, (approximately 6 nm in size, Figure 2(C)) were coated with layers of proteins and enzymes which enlarged them to approximately 20-30 nm (yellow circle). The results were in accordance with the infrared spectroscopy study (Sahub et al., 2018) which confirmed that the GQDs were coated by layers of enzymes and BSA.

Peroxide group as catalysts

Hydrogen peroxide (H_2O_2) is a crucial oxidising agent in biological systems, and has been widely utilzed in several biological-related processes such as identification of the amount of glucose required for diabetic patients. Song et al. (2010) and Zheng et al. (2013) used graphene oxides and graphene dots to improve the oxidation efficiency of hydrogen peroxide toward 3, 3, 5, 5- tetramethylbenzidine in determining the amount of glucose.

This study focused on direct interactions between GQDs and H_2O_2 from the two enzymes. The results revealed that the decrease of fluorescent intensity of GQDs was proportion to the concentration of H_2O_2 addition (Sahub et al., 2018). This was expected as a result of the electron transfer process from the surface area of GQDs to H_2O_2 according to equations (1) and (2) (Song et al., 2010; Umrao et al., 2015).

Moreover, the decrease of fluorescence emission from GQDs/AChE/CHOx biosensors after



(A) Magnification TEM image of GQDs (B) Regular TEM image GQD biosensors (C) GQDs/AChE/CHOx biosensors

Figure 2 TEM images of GQDs showing frequency (%) and sizes
Source: Sahub et al. (2018)

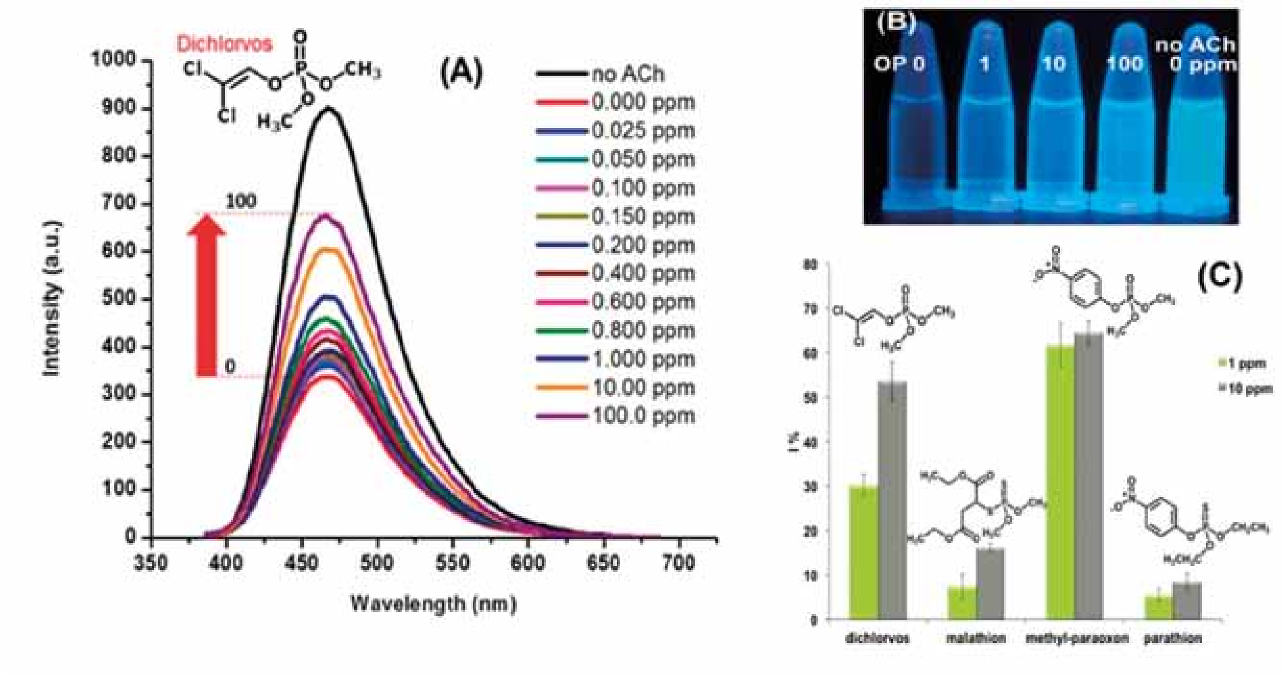


Figure 3 (A) Photoluminescence of GQDs/AChE/CHOx after adding dichlorvos at different concentrations between 0-100 ppm (B) Colorimetric of GQDs/AChE/CHOx biosensors in visible UV light at different concentration levels of dichlorvos between 0-100 ppm (C) %Inhibition efficiency (I%) towards GQDs/AChE/CHOx biosensors of four different types of organophosphates at 1 and 10 ppm
Source: Sahub et al. (2018)

adding acetylcholine also confirmed that AChE and CHOx enzymes reacted within the biosensors to convert acetylcholine to H_2O_2 as shown in equations (3) and (4). Further study on pH effect and reaction time revealed that pH 8 and reaction time of 30 min was the most appropriate condition for the fluorescent sensing application in the presence of the concentration of AChE and CHOx at 1 and 0.125 U/mL respectively. The mechanism of reaction are shown in equations (2) - (4).

$$\text{GQDs} \longrightarrow \text{GQDs}^{+} + e^{-} \quad (1)$$

$$H_2O_2 + 2e^{-} \longrightarrow 2OH^{-} \quad (2)$$

$$\text{acetylcholine} + H_2O \xrightarrow{\text{AChE}} \text{choline} + \text{acetate} \quad (3)$$

$$\text{choline} + O_2 \xrightarrow{\text{CHOx}} H_2O_2 \quad (4)$$

Determination of the amount of organophosphate

The principle for detection of organophosphates is based on its ability to inhibit AChE enzyme activity resulting in reduction of H_2O_2 amount which in turn allowed a strong fluorescence emission. The effect was similar to that produced by addition of dichlorvos organophosphate to the solution (Figure 3(A)). The effect of three other organophosphates (methy-paraoxon, malathion and parathion) was also studied at concentrations of 1 and 10 ppm. The results revealed that at 1 ppm concentration, the inhibition efficiency of methy-paraoxon, dichlorvos, malathion and parathion were 62±5%, 30±2%, 7±3% and 6±1%, respectively (Figure 3(C)).

At different concentration levels, dichlorvos and methy-paraoxon reacted differently in terms of their inhibition efficiency. The linear range of dichlorvos

Table 1 Measuring the amount of dichlorvos in water samples using GQDs/AChE/CHO biosensor in comparison with the UHPLC-MS technique

Samples	Spiked dichlorvos (ppm)	GQDs/AChE/CHOx Biosensors			UHPLC-MS		
		Measured (ppm)	%RSD	%Recovery	Measured (ppm)	%RSD	%Recovery
Tap water	0	-			-		
	2	2.23	2.27	111.59	1.84	0.15	91.83
Water from a pond in CU campus	0	-			-		
	2	2.03	5.87	101.33	1.83	0.16	91.67
Water from the reservoir in Roi Et	0	-			-		
	2	2.08	5.54	104.01	1.83	0.62	91.83

Remark: n = 3
- = dichlorvos was not found

was between 0.1-10 ppm at I% = 27.173 + 22.488 log[dichlorvos], R^2 = 0.9882 while n = 3. The limit of detection for dichlorvos was 0.172 ppm or 0.778 micromolar. The linear range of methyl-paraoxon was between 0.1-1 ppm at I% = 53.846 + 36.881 log[methy-paraoxon], R^2 = 0.9725 while n = 3. The limit of detection for methyl-paraoxon was 0.084 ppm or 0.342 micromolar. The results were below the US EPA maximum residue limit (MRL) at 10 ppm. Moreover, the presence of dichlorvos could be detected using only visual examination under UV light (Figure 3(B)). In the normal state, the biosensors emitted blue fluorescent light which was visible in the solutions. However, non-bright solutions were observed after adding acetylcholine as shown in the left tube in Figure 3(B) (OP = 0 ppm). Moreover, when dichlorvos was added at 1, 10 and 100 ppm, the solutions emitted bright blue fluorescence.

In order to transfer this research to the general public, it is crucial that shared water sources are tested for contamination. The research team used biosensors to test for dichlorvos in water samples using the standard addition method. The water samples were taken from 1) tap water from Chulalongkorn University; 2) sampled water from a pond located inside Chulalongkorn University; and 3) sampled water from a reservoir in Ban Nong Khuan, Pho Thong sub-district, Phon Thong district, Roi Et which was surrounded by agricultural areas. The ultra-high pressure liquid chromatography mass spectrometer (UHPLC-MS) was used as a comparison test (Table 1). Dichlorvos was not found in any of the samples. Dichlorvos was then added to the samples at 2 ppm. Both techniques were then used to detect dichlorvos by measuring % recovery of dichlorvos from the samples. Recovery ranged between 80-110% for the 0.1-10 ppm range. The relative standard deviation (RSD) was limited to 14% at 2.0 ppm (Gustavo González and Ángeles Herrador, 2007). Therefore, this research was found that % recovery results were 101-112% for the using GQDs/AChE/CHOx biosensors and 91.5-92.0% for the UHPLC-MS technique. The results were in accordance with % relative standard deviation (%RSD) at 2.3-5.9% for the GQDs/AChE/CHOx biosensors and at 0.15-0.16% for the UHPLC-MS technique. Therefore, the GQDs/AChE/CHOx biosensor technique is suitable for practical use.

Conclusion

This research has illustrated the successful use of enzyme-based graphene quantum dots (GQDs/AChE/CHOx) to specifically and easily detect organophosphate pesticides. The research could be applied to detect dichlorvos in real samples without prior preparation of the samples. More importantly, the biosensors are easy to prepare, affordable and environmentally friendly. It is suitable for further development to detect pesticide residues in fruits and vegetables prior to exporting.

Acknowledgements

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Production of Modified Bacterial Cellulose Nanocrystals for Cancer Drug Delivery

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Introduction

Cellulose is one of the most abundant polymers in nature and has received prominent interest for its potential role in development of sustainable, renewable and environmentally-friendly materials. While biomass from crops and trees represent the most significant and familiar sources of cellulose, bacterial cellulose (BC) has become increasingly noteworthy; its higher purity levels reduce the need for additional processing to remove contaminants. BC has a distinct ribbon-like 3D network structure of cellulose microfibrils that are 2-4 nm in diameter. In addition, BC has many attractive properties, such as high tensile strength, high porosity, high water-holding capacity, high biocompatibility and low toxicity. These properties are highly beneficial in medical and pharmaceutical applications, as well as a raw material for producing cellulose nanocrystals. Thailand's main source of income is agriculture, which generates immense quantities of crop residues from crop harvest and food processing. This biomass represents a major potential cellulose feedstock; however, extraction requires research on converting agricultural waste into advanced value-added materials that can contribute to local livelihoods and the national economy.

The cellulose nanocrystal (CNC) is a nanosized rodlike particle obtained from the BC crystalline region isolated from the amorphous region of BC by acid hydrolysis. The type of acid used in acid hydrolysis affects the properties of the resulting CNC product. For example, if sulfuric acid is used, the CNC rod is a shorter and negatively charged nanocrystals (due to the sulfate group). Consequently, colloidal suspensions can be highly stable due to its electrostatic repulsion force. If using hydrochloric acid, the CNC rod is longer, and the surface charge is less negative. Therefore, sulfuric acid is preferred over hydrochloric acid for producing CNC.

Medical utilization of CNC has become increasingly popular due to CNC's unique small dimensions, strength, and abundant surface hydroxyl groups, which makes CNC highly hydrophilic and bio-compatible. Surface hydroxyl groups are useful for CNC development as they react with other substances via chemical and physical reactions, which can then influence CNC to develop specific properties. In addition, nanoparticles are superior to spherical nanoparticles when permeating cells, resulting in CNC having the capability to act as a drug carrier. CNC may offer an alternative to the carbon nanotube, which has low biocompatibility.

The objective of this study is to develop CNC for use in drug delivery using the method presented in Figure 1. The CNC produced from BC are bacterial cellulose nanocrystals (BCNC). Acid hydrolysis will be applied, in which sulfuric acids will be used to obtain sulfated BCNC. Sulfated BCNC will be able to undergo physical reactions with

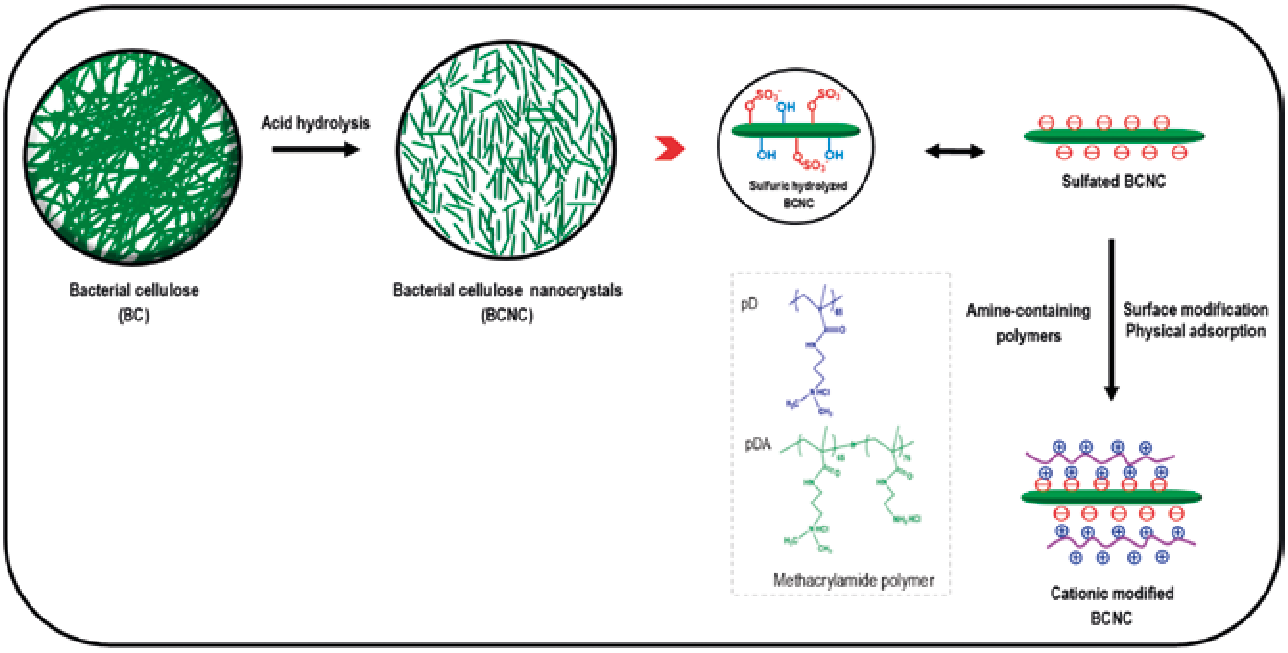

Figure 1 Diagram of the production process of modified bacterial cellulose nanocrystals for cancer drug delivery
Source: Adapted from Singhsa, Narain, and Manuspiya (2018a)

cationic substances, which can help BCNC avoid chemical reactions that are complex and require numerous chemicals. Methacrylamide polymer is chosen as the cation substance for testing. The negative charges of sulfated BCNC binds the positive charges of the polymer, undergoing physical adsorption by ionic interaction and resulting in cationic BCNC. In the next step, small interfering RNA (siRNA) is formed, which is a short-chain genetic material that interferes with the genetic process of various cells, including cancer cells. This results in the effective delivery of these nucleic acids into cancer cells, which can benefit cancer treatment. However, the negative charge of siRNA interferes with cell permeability. Thus, the objective of developing the nucleic acid delivery system is to reduce the negative siRNA charge and to prevent against attacks from the body's immune response against foreign substances. Thus, the use of cationic BCNC with siRNA (cationic BCNC-siRNA complexation) in the development of a delivery system provides two simultaneous benefits in which the hydrophilic properties of BCNC helps to improve compatibility with the body, reducing toxicity and improving delivery efficacy.

Production of bacterial cellulose

Bacterial cellulose (BC) was produced by *Komagataeibacter xylinus* TISTR 975 obtained from the TISTR Culture Collection, Thailand Institute of Scientific and Technological Research and cultured in culture media comprising 50 g glucose and 5 g yeast extract in 1 L water. The pH was adjusted to 5 using hydrochloric acid and alkaline sodium hydroxide, then incubated at 30 degrees Celsius for 7 d. BC was form as a film-like sheet separate from the culture media. The sheet was rinsed with distilled water then boiled with 2% w/v alkaline sodium hydroxide at 80 degrees Celsius for 1 h, then rinsed again until neutral pH (pH 7) was obtained. This yielded the resulting BC pellicle also known as the K9 pellicle, a white, jelly-like sheet with a dry weight of 1.6 g/L growth medium (Singhsa, Narain and Manuspiya,

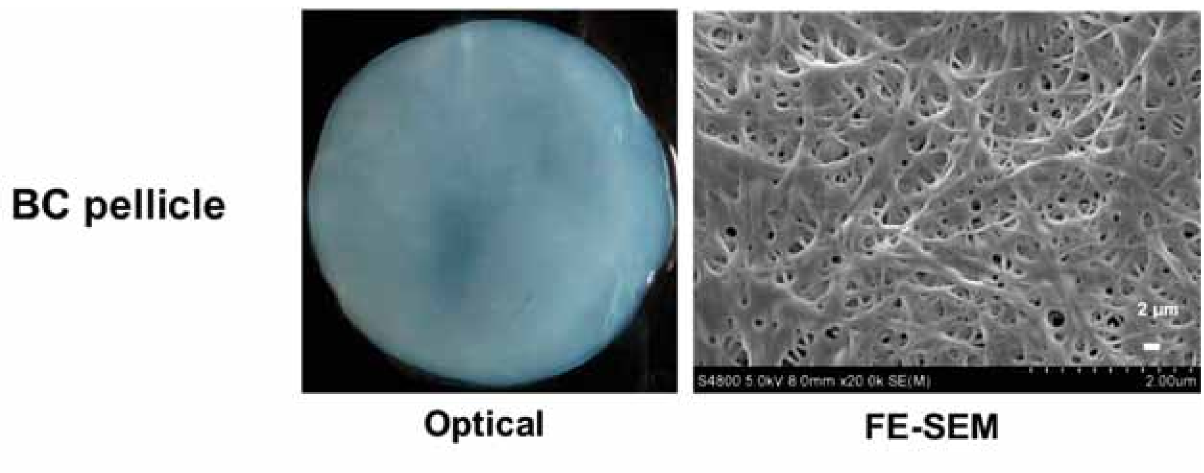

Figure 2 Field emission scanning electron microscope (FE-SEM) images of the BC pellicle
Source: Adapted from Singhsa, Narain, and Manuspiya (2018a)

2018a). The structure resembles a 3D interwoven structure, as shown in the field emission scanning electron microscope images (FE-SEM) (Figure 2).

Production of nanocrystals from bacterial cellulose

BC nanocrystal production was initiated by disintegrating the K9 bacterial cellulose pellicle from the previous step in a laboratory blender at 5000 rpm for 20 min. The blended pellicle was then filtered through a 60-mesh strainer and squeezed to remove as much water from the bacterial cellulose as much as possible. 40% w/v sulfuric acid was added to 10 mL aqueous sulfuric acid/1g damp BC, then incubated at 60 degrees Celsius for 2 h to allow reaction. After 2 h, the reaction was stopped by adding cold water at 10x the amount of aqueous sulfuric acid and centrifuged at 12,000 rpm for 10 min to remove water. The residue was rinsed to remove acid and contaminants were removed by distilled water dialysis then freeze dried.

The resulting BCNC (sulfated BCNC: K9-S) resembled a white powder. Examination via Transmission Electron Microscopy (TEM) showed that the granules were short 190–220 nm rods (Figure 3) with a surface zeta potential of -35 millivolts, indicating the negative charge from the BCNC surface sulfates. From analysis of the crystallinity index (CI) by X-ray diffraction (XRD), the BCNC had a CI of 87%. The CI of the bacterial cellulose was initially 80%, which shows that CI was improved due to the increase of the crystalline region after acid hydrolysis of the amorphous region.

Development of nanocrystals from negatively-charged bacterial cellulose for cancer drug delivery

The aqueous negative-charged 1% w/w BCNC suspension was modified to become

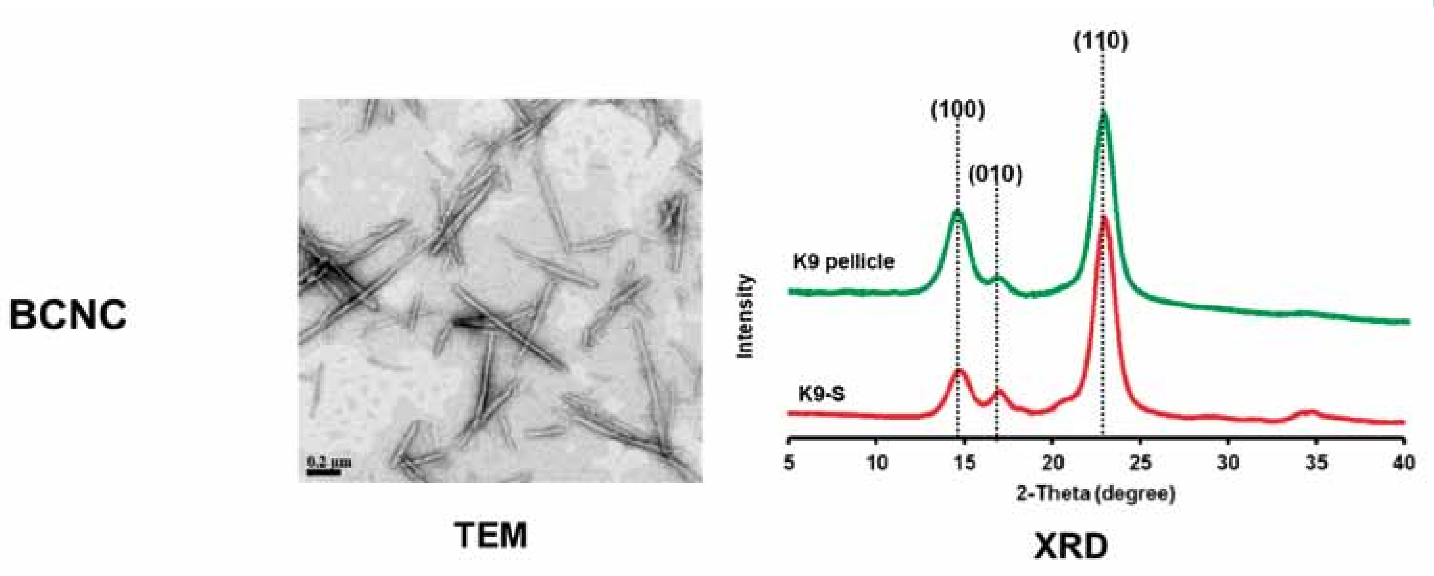

Figure 3 Transmission Electron Microscope (TEM) and X-ray diffraction (XRD) of bacterial cellulose nanocrystals (BCNC)
Source: Adapted from Singhsa, Narain, and Manuspiya (2018a and 2018b)

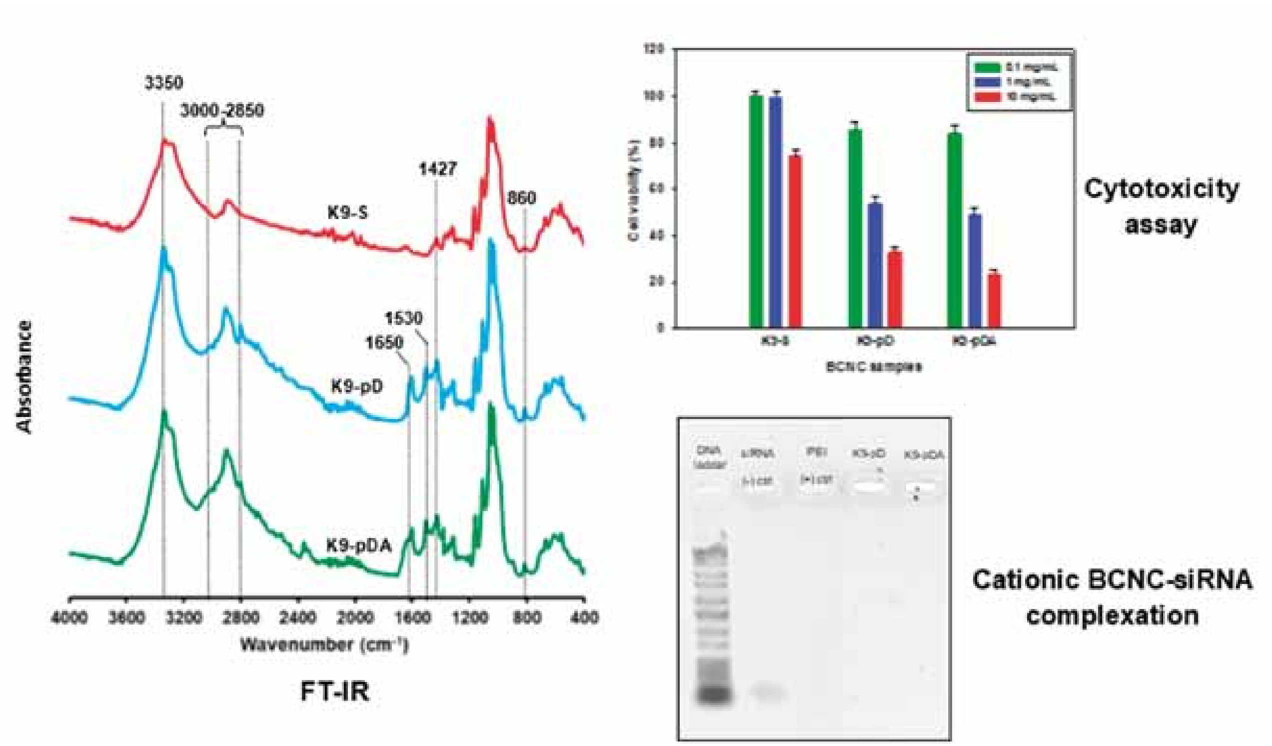

Figure 4 Cationic BCNC FTIR analysis, cytotoxicity assay and cationic BCNC-siRNA complexation
Source: Adapted from Singhsa, Narain, and Manuspiya (2018a)

cationic by physical adsorption of methacrylamide polymers, which are amine-containing polymers (Singhsa, Manuspiya, and Narain, 2017), namely poly[*N*-[3-(dimethylamino)propyl]methacrylamide hydrochloride] (p(DMAPMA·HCl_{65}), pD, M_n = 13500, M_w/M_n = 1.21) and poly[*N*-[3-(dimethylamino)propyl]methacrylamide hydrochloride-co-(2-aminoethyl)-methacrylamide hydrochloride] (p($DMAPMA_{65}$-b-$AEMA_{76}$), pDA, M_n = 27500, M_w/M_n =1.34) (M_n refers to number average molecular weight and M_w refers to weight average molecular weight), using 2% w/w aqueous polymer solution carefully added to the BCNC suspension and incubated for 6 h. Unwanted contaminants were removed from the resulting product by rinsing with distilled water and multiple centrifugations until neutral pH was obtained.

The cationic-modified BCNC from the ionic polymerization of pD and pDA shows increased surface charges of +31 and +34 millivolts respectively. Analysis of the K9-pD and K9-pDA by Fourier Transform Infrared Spectroscopy (FTIR) is shown in Figure 4. Results showed the addition of amide functional groups that were not present on the initial BCNC structures, confirming that these methods were successful in BCNC modification.

As the cationic BCNC is intended for use in cancer drug delivery in humans, cytotoxicity is an important factor. MTT assays of human cervical carcinoma cells or HeLa cells

(Singhsa, Narain and Manuspiya, 2017) revealed that examination of the cationic-modified BCNC at concentrations of 0.1, 1 and 10 mg/mL resulted in over 90% cell viability in HeLa cells. Cell viability decreased at higher concentrations. K9-S cell viability presented better results at all concentrations. The higher cytotoxicity of cationic-modified BCNC results from the binding ability of negative charges with positive charges of the cell membranes, resulting in increased cell apoptosis.

Cationic-modified BCNC was also examined to assess efficacy in cancer drug delivery. In this study, siRNA was selected as the nucleic acid model due to its applications in gene therapy cancer treatment. Because of its cationic properties, cationic-modified BCNC is able to bind to the negatively charged nucleic acids and form a delivery system that is able to protect the nucleic acid from immune system responses. Examination of the binding ability of cationic-modified BCNC-siRNA complexation by agarose gel electrophoresis retardation assay found that both cationic-modified BCNCs could satisfactorily bind siRNA at a w/w ratio of 100 to 1. Thus, no free siRNA bands were visible on the agarose gel, which is comparable to the results of polyethylenimine (PEI). PEI is a cationic polymer that is widely used for the production of nucleic acid delivery systems.

Conclusions

Bacterial cellulose nanocrystals (BCNC) can be easily produced by BC using sulfuric acid hydrolysis and can be further developed to achieve positive charges through physical reactions with polymers, forming cationic BCNC. The cationic BCNC was effective in binding with the negative charge of siRNA and had low cytotoxicity. From these results, the developed product displayed potential for cancer drug delivery. Further studies are required on cellular uptake and transfection efficacy to confirm the effectiveness of this delivery system.

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Lessons Learnt: from Research to Development at National Scale

Dr. Suphot Wattanaphansak, DVM, MS, PhD

Dr. Suphot Wattanaphansak, DVM, MS, PhD, one of Thailand's leading veterinarian researchers, recently shared some lessons and insights learned from his long experience in research into farm animals in scaling a research project for large-scale industrial use on a national scale.

Rationale for the autogenous vaccine research project

"...the duration of protective immunity acquired from the autogenous vaccine lasted in their immune systems. This protection efficacy of vaccination differs from that of using antibiotics in term of disease control, in which resulted in reinfection may occur after the end of a course of antibiotics..."

The idea of autogenous vaccine research project to prevent diseases caused by bacteria or viruses in pig farms stemmed from a series of farm visits in several parts of Thailand led by Dr. Suphot Wattanaphansak, DVM, MS, PhD, Dr. Pornchalit Assavacheep, DVM, MSc, PhD and Rachod Tantilertcharoen, DVM, MS. The three researchers visited several pig farms where their veterinary students were working as interns.

Talking with farmers, the researchers observed a pattern that pig diseases frequently reoccurred in some pig farms despite implementation of an available commercial license vaccination program. One of the underlying factors was the specificity of available vaccines, which were less effective against field pathogens due to difference in strain or serotype of the antigens. Moreover, licenced vaccines are not available for all diseases, adding to the challenges of epidemic control. At the global level, antibiotic resistance among common pathogenic bacteria is causing increasing concern, leading to campaigns in many countries to reduce the use of antibiotics in pig farming and other livestock production. This movement triggered the start of autogenous vaccine research as an alternative approach to battle antimicrobial resistance, prevent animal disease outbreaks and, at the same time, reduce the use of antibiotics.

In its initial stages, the research revealed that the duration of protective immunity acquired via the autogenous vaccine was longer-lasting in the animal immune system. This disease protection stood in contrast the pattern often seen with antibiotics, in which reinfections frequently occur following the end of treatment.

Optimal disease control in pig farming relies heavily on early vaccination prior to being exposed to the disease. Therefore, an appropriate vaccination schedule, good farm management and vaccination practice are all essential.

Research collaboration between the government sector and the industry for improvement of pig industry

"...Data were systematically collected during the study period and incorporated into a progress report and sent back to DLD ... focusing on the efficiency of vaccine in reducing mortality rate and improving farm productivity..."

Research and development into autogenous vaccines indicated that the vaccine was able to control and prevent diseases, supporting the policy of the Department of Livestock Development (DLD) requiring farmers to reduce antibiotic use on the farm. These early finding resulted in a Memorandum of Understanding (MOU) between Chulalongkorn University and the Department of Livestock Development in April 2015 to collaborate on further research and development of autogenous vaccines, together with an assessment of its use in the pig industry.

Reaching out to farmers with such problems required support from the industry sector. Industry representatives from the industrial sector introduced researchers and farmers, raised awareness among farmers through presentations of the concept to interested farmers, and encouraged them to participate. Establishing these connections was fundamental to the emerging university and industry collaboration.

The MOU between Chulalongkorn University and the Department of Livestock Development focused on collaboration on small-scale production and testing of the autogenous vaccine. Only a limited number of participating farms were eligible to access the vaccine. Moreover, the research focused only on diseases caused by bacteria and viruses found only on specific farms. Therefore, each autogenous vaccine development project was highly specific, targeting only the specific pathogen found at each farm. The time scale of each project varied from 3 months, 3–6 months or one year. The farm owners were responsible for the cost of the autogenous vaccines tailored to their farm pathogen profile. The data were systematically collected during the study period and incorporated into a progress report to DLD. The report focused on the efficiency of the vaccine in reducing infection and mortality rate, and in boosting farm productivity.

The Importance of further research for industrial application

"...the genetic differences between antigens in commercial vaccines and the pathogens found in Thailand, together with the government's policy to reduce on-farm antibiotic use, has stimulated interest in autogenous vaccines as a promising alternative approach..."

Using autogenous vaccines for industrial farming has becoming more popular, particularly in light of government pressure to reduce the use of antibiotics in livestock farming, and the rapid emergence of antibiotic resistance at global levels. Farmers urgently need an alternatives and autogenous vaccines offer an answer. Although many countries are collaborating to address this serious global health issue, reinfections remain frequent. The key question is whether substitution of antibiotics with the autogenous vaccine can help reduce disease outbreaks on participating farms. The challenge for farmers and researchers is that despite rigorous commercial vaccination regimes, mutations still occur that confer antibiotic resistance within pathogen populations, which can stay one step ahead of available vaccines. Moreover, imported commercial vaccines suffer from another limitation, in some cases, the vaccine antigens are not a genetic match for specific pathogen strains found in Thailand. Moreover, the antigens in the commercial vaccines is not feasible to produce cover for every serotype or subtype of outbreak antigens. For example, *Streptococcus suis*, a gram-positive bacterium, a has 35 distinct serotypes; however, the vaccine is available for only 2-3 serotypes. In such a situation, livestock infected by *S. suis* serotype of 20 will not be protected by vaccination. Vaccination programmes must therefore take into account these limitations in the effectiveness of commercial vaccines and the dynamics of local pathogen populations.

Though Thailand's pig production industry has expanded considerably in recent years, animals face increasing threats of disease outbreaks caused by intensive production and stress in pigs still occur. Farmers face increasing challenges in protect their livestock from disease outbreaks by increasing the use of antibiotics and vaccines.

However when the effectiveness of antimicrobials is decreased in the face of antimicrobial resistance, and government requirements to reduce antibiotic use, and limitations of commercial vaccines. These factors have led to emerging interest in autogenous vaccines as an alternative disease control tool for livestock, veterinary scientists and veterinarians. There is broad recognition among veterinarians and researchers that autogenous vaccines offer a possible solution, warranting further research in this area.

Problems and obstacles to the scaling of research for national development

"...Thailand has yet to enforce legislation to allow or control the production and use of farm-specific autogenous vaccines. This limits research-industry collaboration and limits the readiness of industry to invest in expanding production capacity. The lack of enabling legislation is a serious obstacle to scaling up of the use of autogenous vaccine at farm level..."

Research has shown that autogenous vaccines can be used on farms of different sizes or even in pig farming groups. However, their use at a larger, industrial scale, requires support and coordination from various sectors, especially from the government. Thailand has yet to enforce legislation to allow or control production and use of farm-specific autogenous vaccines. This effectively prevents their wide-scale adoption. Moreover, Thailand faces a shortage of veterinary vaccine manufacturers that can produce autogenous vaccine. The country's only veterinary vaccine manufacturer is operated by the DLD and manufactures swine vaccines only for foot and mouth disease (FMD) and hog cholera.

Autogenous vaccines represent a new area of study even among veterinarians in Thailand, and there is limited specialist expertise in this domain. A public debate is needed among stakeholders to raise awareness and understanding of the benefits and limitations of autogenous vaccines. In particular of course, we need to connect with pig farmers nationwide through industry networks and veterinarians who work closely with farming communities. Once the farmers are engaged and supportive, the use of autogenous vaccines will grow, providing further justification and opportunity for researchers to continue their research.

To elaborate on the challenges to accomplishing this, Thailand lacks specialized vaccine production capacity. To produce autogenous vaccines, samples of the pathogen are taken from the farm, to be cultured, attenuated and killed off before bringing back to use on the farm. Autogenous vaccines are farm-specific, tailored to the pathogen population of each individual farm. Increasing the production capacity will enable scaling of this intensive process to cover hundreds of farms throughout the country.

The discussion of the potential and boundaries of developing autogenous vaccines at industry scale is ongoing. Nevertheless, their development should not suggest that currently available commercial vaccines are obsolete. Certain diseases respond well to currently available commercial vaccines and are still widely and successfully used. In such cases, autogenous vaccines are unnecessary. However, both types of vaccines should be encouraged since they offer alternative strategies to benefit Thailand's pig industry.

Recommendations for the future

"...To drive the industry's future development, government support will be essential in order to establish an enabling regulatory environment, together with effective enforcement. Universities should broaden existing opportunities for study and research related to autogenous vaccines..."

Thailand spends more than Baht 4-5 billion annually on imported vaccines. This is because DLD is currently able to manufacture only two swine vaccines (foot and mouth disease (FMD) and hog cholera) at production volumes that cannot meet domestic demand. If Thailand can encourage expansion of vaccine manufacturing, this will reduce import bills and contribute to vaccine security should supply be impacted by unforeseen circumstances with overseas manufacturers. Capacity to produce autogenous vaccines is an important part of a national strategy, for which government support is needed to drive long-term development of the industry through enabling legislation, regulations and compliance regimes.

Universities need to broaden opportunities for study and research related to autogenous vaccines for veterinarians, who need a deep understanding of the conceptual basis, production and development processes, and on-farm application. Research in autogenous vaccines should therefore be encouraged and supported including the establishment of research facilities for production of autogenous vaccines, animal testing and opportunities for research-industry collaboration.

The current study of the development of autogenous vaccines offers a good demonstration for DLD, veterinarians and farmers that autogenous vaccines can be produced and used in practice to treat, prevent and control outbreaks within a short period. There are several opportunities to further this research to scale for industry application; these include production technology, bacterial culture and prolongation of the specific immune response to vaccine antigens which may occur in the next generations of the vaccines.

In Europe and USA, scientists have been researching on autogenous vaccines for over 20 years, although in Thailand this journey has only just begun with this project. Autogenous vaccines may offer an effective response in the case of outbreaks where control by commercial vaccines has failed. Moreover, by helping to reduce the use of antibiotics, the approach slows down the emergence of antibiotic resistance within pathogen populations and prolongs the useful life of currently available antibiotics.

Dr. Suphot Wattanaphansak, DVM, MS, PhD

received his Doctor of Veterinary Medicine from the Faculty of Veterinary Science, Chulalongkorn University and his Master's and Doctoral degrees from the University of Minnesota, USA. He is currently Deputy Director of Chulalongkorn Animal Hospital's Student Training Centre, Faculty of Veterinary Science, Chulalongkorn University. Dr. Suphot Wattanaphansak is also a lecturer at the Department of Veterinary Medicine, Faculty of Veterinary Science, Chulalongkorn University.

Science and Technology in Developing Countries

"Around Us"

Assoc. Prof. Thavivongse Sriburi, Ph.D.

Science and technology (S&T) has been a priority for Thailand, long before the establishment of the Ministry of Science and Technology in 1979. Government-led research into cutting-edge pure science and technology was supported by the Ministry's establishment of the National Science and Technology Development Agency, as well as an integrated high-level national plan to integrate and align science and technology to support national social and economic goals. The National Economic and Social Development Plan is now in its 12th 4-year cycle (2017 - 2021).

Thailand's government has recently given a further boost to S&T through its latest policy platform, the Thailand 4.0 initiative. Thailand 4.0 aims to boost R&D to drive the country's future stability, prosperity and sustainability.

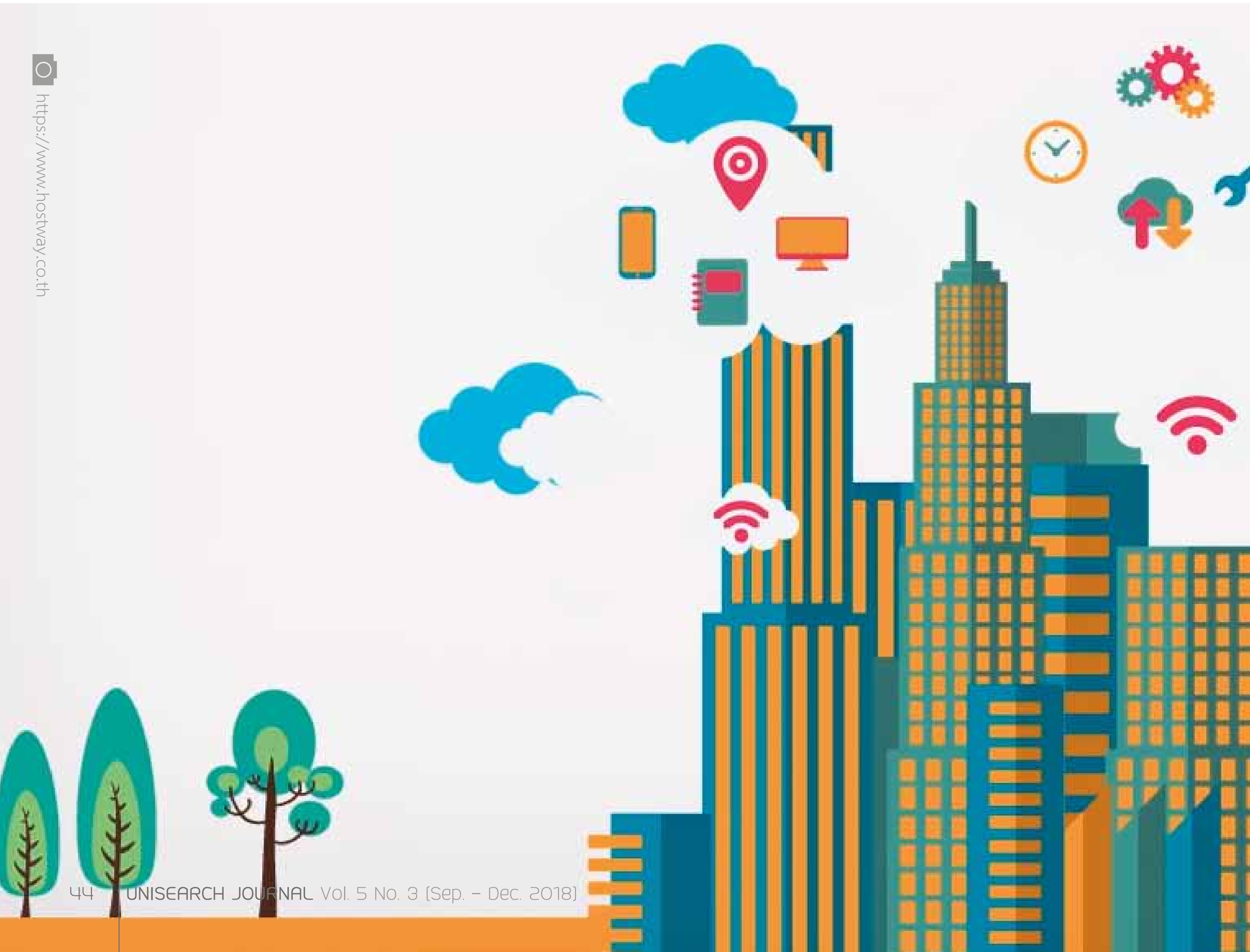
The initiative aims to address enduring challenges faced by many developing countries including Thailand, despite its elevation to the status of a Newly Industrialized Country (NIC). Three key constraints, or traps, are identified: the *Imbalance trap*, the *Inequality trap* and the *Middle income trap*. To overcome these fundamental obstacles to development, three specific policies have been implemented. The imbalance trap is addressed through the *Circular Economy policy;* the inequality trap is addressed by the *Distributive Economy* policy, whilst the middle income trap is addressed via the *Innovation-Driven Economy* initiative. These polices are coordinated under an overall umbrella or economic structure, dubbed as the *Value-Based Ecosystem.* S&T is thus a crucial enabler of Thailand 4.0 and its supporting policies and initiatives. However, as we embrace inevitable global trends, it will be essential that all Thai citizens are ready to adapt to change and even disruption in terms of the way we access and apply knowledge, the way we work and the way we play.

In a developing country context, it is important to consider the impact of new S&T, in the form of disruptive innovation, on individuals, communities

and society as a whole. S&T can bring profound benefits, but also unforeseen adverse impacts, e.g. on employment, on the economy, and on the quality of life of citizens and communities. Innovation based on S&T has already revolutionized Thai life- for example the mobile phone. No longer is this merely a single-function telephone; today's multi-media smartphones are GIS-enabled, providing new solutions to a wide range of issues in daily life, including transportation, media sharing, finance and banking, cashless transactions, shopping, group communications, political activity, games and much more.

This enormous array of innovative services enabled through mobile phone architecture is driven by technology convergence. This in turn created new secondary business needs, such as mobile security and app development to exploit the infinite possibilities unlocked by S&T.

The explosion in mobile phone ownership in Thailand is driven by these new, discretionary functions, not by the basic utility of the mobile telephone to make voice calls. Inevitable too has been the marketing of smart phones as fashion accessories and status symbols, whose functionality is way beyond that needed for practical use by the average consumer. Negative impacts include the ease with which online fraud can be committed, exploiting a lack of general understanding and an overestimated sense of trust by many users. The growing incidence and sophistication of hi-tech fraud continues to cause tremendous social problems as well as economic hardship to individuals.



In the field of education, the advent of the internet has had a profound effect on how young people learn and access knowledge. The ability to search for information has largely usurped the use of physical libraries as repositories of knowledge. However, the on-tap availability of vast amounts of instant information creates a problem with filtering. What information can be trusted, and what is false or even deliberately aimed at causing social harm or chaos? Adults as well as children have yet to develop our ability to filter or screen the authenticity of the vast amount of user-created content on any given topic. There is however a large gap in digital literacy between rural and urban children, and in their ability to navigate this new and unsignposted digital world.

Today more than ever, as S&T affects all our lives more directly and personally, and in so many new and fast-changing ways, it is important that the government focuses on education for digital literacy among both adults and children. By focusing on the sustainable development philosophy of His Late Majesty King Bhumibol Adulyadej, the UN declared a global strategy for all countries to adopt in order to improve quality of life, education, industry, business, religious and cultural live as well as conserve our natural resources and the environment.

The positive benefits of S&T for developing countries are wide-ranging, including communications, manufacturing and services, finance, medicine, education, transport, entertainment, etc. In education, His Late Majesty King Bhumibol Adulyadej was a pioneer in

satellite-based distance learning, providing education to many children in rural schools located in remote and rugged, often mountainous terrain. Remote medicine is also of particular importance in developing countries, where the ratio of doctors to patients in rural areas is far lower than in urban areas, and specialists may be virtually inaccessible. Also, online shopping is available to anyone, anywhere, anytime, even in remote areas of the country- no need to waste time travelling to the nearest mall in the nearest city.

Alongside these significant benefits, technology can bring many negative impacts too. A borderless world can lead to competition among diverse cultures and values, leading to erosion of traditional values, or moral corruption through access to inappropriate content. Internet communication is generally free from the restraints and etiquette inherent to face-to-face social interaction, so debate can frequently trend towards extreme positions, leading to alienation and a whole set of new social problems such as online bullying, trolling and social sanction. Are we losing our social skills as a result of communicating only with our phones?

Moreover, exacerbated by the tendency towards extreme positions and the ease with which like-minded groups can form and be marshalled, the internet has facilitated the violation of personal rights and privacy. The courts today frequently encounter Internet-based cases of defamation, financial scams and identity theft.

Whilst appropriate deployment of new technologies in a strategic way is certainly essential to drive long-term national development, any policy to promote S&T must consider both benefits and potential adverse impacts. However, achieving an appropriate balance that minimizes negative social and economic impact represents a major challenge due to the rapid pace of technology advancement.

Despite the diversity of potential applications of S&T, in practice, individual agencies with a narrow mandate tend to maintain a narrow focus to address a specific problem identified. This runs the risk of unintended negative consequences leading from a lack of coordination and policy coherence. Therefore, in order to develop and deploy S&T-based innovations, the Thailand 4.0 policy provides a roadmap that will maximize the benefits of new technologies within the Thai social, economic and cultural context.

Overall, the use of and benefits derived from S&T are contingent on absorptive capacity. In developed countries with high levels of literacy, infrastructure and purchasing power, it is relatively easy for people to embrace change. However, for less developed countries, the pace of such change is likely to be much slower, and chances of success correspondingly reduced without adequate preparation of target users. Technology can frequently exacerbate inequity in developing countries, increasing information asymmetry, marginalizing those who cannot participate, disadvantaging them from participating in new technology-enabled economic opportunity, and leaving them vulnerable to exploitation from technologically adept actors. A deep understanding of these dynamics will be essential to the future success of Thailand 4.0 and its long-term policy goals of stability, prosperity and sustainability.

Fretting Corrosion Testing of the Unipolar Modular Hip Prosthesis at the Joint Interface According to the ASTM F1875 International Standard

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Orthopedic implants such as hip or knee prostheses and spine stabilization are expensive and the devices must currently be imported at a cost of several billion baht per year. The price of an imported unipolar prosthesis ranges from 12,000-15,000 baht; a bipolar prosthesis may cost from 35,000-45,000 baht, while a total hip prosthesis may cost from 70,000-120,000 baht. Each year, orthopedic surgeons in Thailand use approximately 10,000 hemi-hip prosthesis 10,000 joints and about 5,000 total hip prosthesis joints. In all, each year, up to 100,000 patients in Thailand require hip joint surgery. The annual cost to government health services amounts to several hundred million baht. The high cost has been a burden to both patients and government for more than 20-30 years, and in fact only about 10,000-15,000 patients have the financial means to access hip joint surgery. Domestic production of hip prostheses in Thailand will greatly reduce production costs and ensure more universal access. This will greatly enhance mobility and quality of life for both patients and their families.

However, the hip prosthesis is classified as high risk medical device (Class III), necessitating a high level of performance testing, safety and quality certification, including certification of product quality, safety, performance as well as the production process, by an internationally-accredited agency. Under a special project established by the Thailand Center of Excellence for Life Sciences (Public Organization) the TCELS Center for Advanced Medical Robotics provided funding for a rigorous corrosion testing study in accordance with the recognized International Standard **ASTM F1875: Standard Practice for Fretting Corrosion Testing of Modular Implant Interfaces: Hip Femoral Head-Bore and Cone Taper Interface (Method I)**. Sample prostheses were produced to test performance and secure certification for design, development, production, and distribution under international safety standards. The samples could then be used as prototypes for clinical evaluation of performance and risk before the devices could be approved for local manufacture in Thailand.

During testing, cyclic corrosion testing of modular implant interfaces between hip femoral head-bore and cone taper interface tests was performed as specified under ASTM F1875. Two alternative testing methods are specified as follows.

1) Method I is intended as a long-term test to determine the amount of damage caused by measuring particles emitted as a result of corrosion between the head-bore and cone taper interface. The test specifies a cyclic load using the ASTM F1440 - 92(2002) Standard Practice for Cyclic Fatigue Testing of Metallic Stemmed Hip Arthroplasty Femoral Components Without Torsion standards. After 10 million cycles, surfaces are analyzed, and measurements are made of loss in mass and ion concentration.

2) Method II is intended as a short-term test, using electrochemical evaluation of the corrosion. No particles are released from corrosion between head-bore and cone taper interface. This test is faster than Method I, since it analyzes changes in electrical current passing through the joint interface to calculate the level of corrosion using Faraday's Law. However, it is considered only as a preliminary assessment.

In the ASTM F1875 test, two important standard preparatory steps are required:

1) Produce five sample units of the Unipolar Modular Hip Prosthesis, comprising hip stem, femoral head and sleeve, for ASTM F1875 corrosion testing between head-bore and cone taper interface by the pilot plant at the Department of Mechanical Engineering, Chulalongkorn University. The facility as the required CNC machine, tools and equipments for manufacturing, cleanroom, sterilization and packaging of hip prostheses in order to control standards of production and product quality.

2) Conduct ASTM F1875 performance test (corrosion testing) in an overseas laboratory accredited under ISO Standard 17025 (General Requirements for the Competence of Testing and Calibration Laboratories). This allows the laboratory test results to be used to support application for certification, e.g. by ISO 13485, CE Mark or the US Food and Drug Administration.

This research and development on the CU Unipolar Hip Prosthesis device represents a significant milestone in the country's progress in research on medical devices; this is because at present Thailand has no production capacity within government or in the private sector to manufacture high-risk Class III medical devices such as hip prostheses in compliance with international certification such as the CE Mark or USFDA. International certification of the CU Unipolar Hip Prosthesis device will pave the way for the laboratory to manufacture a wider range of orthopedic implants e.g. bipolar, total hip prostheses, knee implants, etc., reducing the need to import these devices and lowering costs. Moreover, project researchers will be able to share their expertise and transfer technology for uptake by private sector industrial manufacturers in Thailand.

Certificate of EN ISO13485:2016 for CU Unipolar Hip Prosthesis

Chulalongkorn is Thailand's first university to obtain complete accreditation under the EN ISO13485:2016 Quality Management System certification. The accreditation was awarded to Prof. Bundhit Eua-arporn, Ph.D., President of Chulalongkorn University by the leading global inspection company TÜV SÜD (Germany) and includes design, development, production, and distribution of the CU Unipolar Hip Prosthesis device. The award ceremony on 9 May 2018 was also attended by Supichai Tangjaitrong, Ph.D., Deputy Managing Director of Chula Unisearch.

Research and development into orthopedic implants, which are medical devices with the highest level of patient risk (Class III) has received substantial research funding from the Ratchadaphiseksomphot Endowment Fund under the University's Research Cluster Project, which promotes in-depth research in high potential fields.

This collaboration between the Health Cluster and Advance Materials Clusters is implemented with **Chula Unisearch** serving as a central project management unit, led by Assoc. Prof. Pairat Tangpornprasert, Ph.D., (Lecturer, Department of Mechanical Engineering) as Project Leader.

Conference participants discussed of the project "Live A Life Rama IV"

On 1 June 2018, Assoc. Prof. Thavivongse Sriburi, Ph.D. (Managing Director, Chula Unisearch), accompanied by Assist. Prof. Saowanee Wijitkosum, Ph.D. and Supichai Tangjaitrong, Ph.D. (Deputy Managing Directors), together with Assoc. Prof. Pinraj Khanjanusthiti, Ph.D., (Dean, Faculty of Architecture, Chulalongkorn University) and Assoc. Prof. Nopanant Tapananon, Ph.D. (Professor of Architecture) and administrative staff, recently joined conference participants to discuss development of the project *"Live A Life Rama IV"* including operational guidelines for collaboration among the parties involved. The project aims to develop academic and research projects in the Rama IV area, by establishing multi-stakeholder cooperation, e.g. among educational institutions, government agencies, state enterprises, the private sector and civil society groups.

Grand opening "Live A Life Rama IV"

To mark the occasion of the 150th Anniversary of the passing of King Mongkut (Rama IV), on 1 October 2018, **Chula Unisearch**, together with the Urban Renewal and Development Research Unit, Faculty of Architecture and partners launched the project *"Live A Life Rama IV"*. The ceremony, which took place at the Chulalongkorn University Centenary Park, was presided over by Assoc. Prof. Thavivongse Sriburi, Ph.D., Managing Director of Chula Unisearch.

Executives of partners collaborating in this initiative also participated, including the Bangkok Metropolitan Administration, Mass Rapid Transit Authority of Thailand, Pathumwan District Office, The Krungthep Thanakom Co., Ltd., Metropolitan Electricity Authority, TICON Industrial Connection plc, Frasers Property Holdings (Thailand) Co., Ltd., Central Pattana plc and Total Access Communication plc. The event was also attended by numerous academics specializing in urban development, as well as representatives from the Embassy of Japan in Thailand, Nippon Koei Co., Ltd., German International Cooperation (GIZ), the Thailand Board of Investment and BTS Group Holdings plc.

Representatives from MFU Visit Chula Unisearch

Assoc. Prof. Thavivongse Sriburi, Ph.D., Managing Director of Chula Unisearch, recently welcomed a delegation from Mae Fah Luang University, led by Tophan Thandorn, Ph.D., Director of MFU's Center for Academic Service. The delegation met with senior Chula Unisearch executives for discussions on guidelines for future academic collaboration between the two institutions.

Training on *"Practices related to Government Procurement and Supplies Management Act B.E. 2560"*

On Friday 18 May 2018, **Chula Unisearch** conducted a training programme on *"Practices related to the Government Procurement and Supplies Management Act B.E. 2560"* for 78 staff and representatives from various government agencies. The objective of the training, held at the Chulalongkorn Research Building, was to raise understanding of the legislation and its implementation, and particularly including precautions required in order to ensure compliance with the Government Procurement and Supplies Management under Government Procurement and Supplies Management Act B.E. 2560 as well as regulations pursuant under the Act. Weerapon Thepanon, Fiscal Analyst (Professional Level), Comptroller General's Department (CGD) served as a high-level speaker and resource person, facilitating knowledge transfer to trainees through a number of real-life case studies.

Chula Unisearch sports unity

On Thursday 26 July 2018, the *"Unisearch Games 2018"* took place at the University's Indoor Stadium II. The competitive sports event aims to strengthen unity and cohesion among all staff, promote physical activity and health and improve quality of life among **Chula Unisearch** staff. The event included a wide range of activities for all ages and abilities, including competitive sports such as volleyball, badminton, table tennis as well as traditional Thai fun games such as '*Ngu-kin-hang*', '*Kwang-ling*', rope-jumping and football.

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