A Review of Thailand’s Contributions to Particle Technology Research and Development

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Abstract

This paper focuses on the review of research works contributed by Thai researchers over the last two decades. It surveys research works available in domestically issued journals, which are therefore inaccessible to any international database. Based on our survey, the spectrum of researches involving Particle Technology in Thailand covers three major categories which are 1) Fundamental research in particle synthesis and production, 2) Research and development in particle processing and handling, and 3) Research and development in particle application and utilization.

It could clearly be seen that fundamental research works have continuously been conducted while there are increasingly strong policies from governmental and funding agencies to encourage Thai researchers to pay more attention to applied research and development because there have been few successful cases of commercialized research outcomes. This is attributable to imperfect linkages among universities, industries and governmental agencies, which still lack a systemic supporting mechanism from the government, thereby resulting in research projects not amenable to commercialization.

Keywords: Thailand, Particle, Synthesis, Processing, Handling

1. Introduction

Not only around the world but also in Thailand, a sizable number of researchers and engineers who never consciously think of Particle Technology (P.T.) have contributed significantly to PT, while accumulating a wealth of technical experiences collected from industrial workplaces and laboratories. Meantime, a growing number of Thai scholars and researchers have begun to recognize PT as one of the advanced technologies to facilitate academic advancement and further enhance industrial competitiveness of Thailand. Though the number of publications contributed by Thai research teams to the international database on P.T. is growing, there are still many more published only in major national and institutional journals. It is noteworthy that, due to the rapid development and diversification of P.T., it is not possible or meaningful to review all obscure publications in all domestic journals issued so far. Therefore, the authors have decided to summarize only selected P.T. research contributions over the last two decades. Major P.T.-related journals and conference proceedings will be reviewed and analyzed to give an overall picture on the current situation of P.T. R&D in Thailand.

2. Domestic contributions to P.T.

In Thailand, all major academic institutions have
actively encouraged their academic personnel to focus more on research and development. Issuance of university/faculty bulletins and journals is one of the key strategies to disseminate and enhance the application potential of research outcomes. Meanwhile, it should be noted that some journals, such as Songklanakarin Journal of Science and Technology ([69,12]) and Science Asia ([99-121]), are gaining regional and international recognition. They attract contributions not only from Thai but also foreign researchers([5,12,115-137]). All journals dealing with conventional P.T. have recently extended their scope to cover new disciplines such as nanotechnology.

Our literature surveys cover a total of 13 journals issued by 11 major universities (Chiang Mai, King Mongkut’s Institutes of Technology (Ladkrabang, and North Bangkok), King Mongkut’s University of Technology (Thonburi), Mahidol, Prince of Songkla, Rachmangkala Institute of Technology, Srinakarinwrirote, Suranaree University of Technology and Thammasat) and 2 academic / professional organizations (Engineering Institute of Thailand, and National Science and Technology Development Agency). The numbers of investigated domestic papers in each category are summarized in Table 1. However, only some “major” papers published over the last two decades and listed in the Bibliography will be analyzed and summarized in this paper. It is noteworthy that the only journal listed in international citation database is Songklanakarin Journal of Science and Technology, which has had P.T. contributions of 7.5 per cent while KMUTT Research and Development Journal has the highest contributions of 11.1 per cent.

Among the surveyed journals, our summary shown in Table 2 reveals that publications in Material Science and Technology have the highest contribution. This is attributable to the fact that many Thai researchers are still paying attentions to employing P.T. for the fundamentals of material synthesis and application. The second aspect, which is Civil Engineering application, corresponds to the requirement of the national infrastructure development. As expected, Industrial Applications comes third due to the encouraging strategies and policies of the funding agencies in Thailand. Particularly, research works related to rice husk and fly ash applications are comprehensively investigated. Meanwhile, dust collection and air pollution control has gained many attentions.

<table>
<thead>
<tr>
<th>Journal title</th>
<th>Numbers of papers involving with P.T.</th>
<th>Percentages of papers involving with P.T.</th>
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</thead>
<tbody>
<tr>
<td>1. Songklanakarin Journal of Science and Technology</td>
<td>45</td>
<td>7.5</td>
</tr>
<tr>
<td>2. Science Asia</td>
<td>14</td>
<td>3.5</td>
</tr>
<tr>
<td>3. KMUTT Research and Development Journal</td>
<td>31</td>
<td>11.1</td>
</tr>
<tr>
<td>4. Research and Development Journal of the Engineering Institute of Thailand</td>
<td>2</td>
<td>6.7</td>
</tr>
<tr>
<td>5. Engineering Journal Chiang Mai University</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td>6. Suranaree Journal of Science and Technology</td>
<td>6</td>
<td>2.0</td>
</tr>
<tr>
<td>7. Mahidol University Journal of Pharmaceutical Science</td>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>8. The Journal of King Mongkut’s Institute of Technology North Bangkok</td>
<td>4</td>
<td>1.3</td>
</tr>
<tr>
<td>9. Engineering Journal of King Mongkut’s Institute of Technology Ladkrabang</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>10. Thammasat International Journal of Science and Technology</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>11. Civil Engineering Journal, EIT</td>
<td>1</td>
<td>3.3</td>
</tr>
<tr>
<td>12. Engineering Journal Kasetsart University</td>
<td>15</td>
<td>3.8</td>
</tr>
<tr>
<td>14. The 20th Symposium on Thai Pharmaceutical Researches</td>
<td>8</td>
<td>8.0</td>
</tr>
<tr>
<td>Total</td>
<td>146</td>
<td></td>
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</tbody>
</table>

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in research and development works. It could indicate that requirement of higher life quality has become a key issue in Thailand.

Besides those journals, there are several national conferences, congresses and symposia which are organized on a regular basis by various organizations such as the Engineering Institution of Thailand (EIT), the Science Society of Thailand, the National Science and Technology Development Agency (NSTDA) and its affiliated national centers as well as National Research Council of Thailand (NRCT) and Thailand Research Fund (TRF). Occasionally, PT. is a key session in these conferences and symposia. In Chulalongkorn University, the Thai Powder Technology Center (TPTC), the Center of Excellence in Particle Technology (CEPT) and its partners have proactively organized many conferences and symposia. In Chulalongkorn University, the Thai Powder Technology Center (TPTC), the Center of Excellence in Particle Technology (CEPT) and its partners have proactively organized many conferences and symposia with collaborations from many domestic and foreign organizations, such as TRF and Kasetsart University in Thailand, as well as the Association of Powder Process Industry and Engineering (APPIE), Society of Powder Technology Japan (SPTJ) and Japan Association of Aerosol Science and Technology (JAASST) in Japan. Two of the historic events are the first Asian Particle Technology (APT) in 2000 and the Asian Conference on Three-phase Fluidized Bed Reactor (ASCON) in 2002, which attracted researchers not only within Asia but also from America, Europe and the Oceania. The 3rd APT will be organized in China in the year 2007. Since it is quite difficult to get access to these proceedings, some selected works by Thai contributors will also be introduced in the present review.

3. Categories of Major P.T. Research Works in Thailand

To the best of our knowledge, there has not been any thorough review of PT.-related research works in Thailand. For the sake of simplicity, we adopt the following 3 main categories of research works: 1) Fundamental research in particle synthesis and production, 2) R&D in particle processing and handling, and 3) R&D in particle application and utilization.

3.1 Fundamental research in particle synthesis and production

Here development of new catalysts as well as new types of functional (nano) particles has attracted great attention of Thai researchers. Catalysis covers the research topics for several research groups in both the academic institutions and petrochemical manufacturers. Synthesis of novel activated carbons from industrial wastes such as waste tires, broken anthracite, palm-oil shell or coffee beans remains one of the most popular research topics. For example, Tanthapanichakoon et al. and Boonamnuayvittaya et al. have selected different approaches in developing highly mesoporous activated carbons. The former team revealed that acid treatment enhances mesoporosity in activated carbons prepared from waste tires, which are useful for adsorbing large-molecule gaseous pollutants. The latter team paid more attention to the utilization of agricultural wastes such as coffee bean residues to produce activated carbons. In addition, a pilot-scale and a full-scale system for producing mesoporous activated carbons from waste tires have been investigated and designed, though not yet implemented due to shortage of investment.

Synthesis of zeolites from fly ash generated in coal-fired power plants employing indigenous lignite as main fuel has been attempted by several research teams. Research teams in Kasetsart University have made several contributions to the effective means to convert lignite fly ash to ZSM-5 and related zeolites. In addition to fundamental examination, catalytic functionalization of the synthesized zeolites was investigated and reported. Interestingly Suvachittanont et al. of KU have developed and patented a method to synthesize adsorptive microcellulose particles from agricultural wastes. Fig. 1 shows that

<table>
<thead>
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<th>Technical Aspects</th>
<th>Numbers of papers involved</th>
<th>Percentages of papers involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Science and Technology</td>
<td>36</td>
<td>26.2</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>33</td>
<td>21.4</td>
</tr>
<tr>
<td>Industrial Applications</td>
<td>30</td>
<td>19.3</td>
</tr>
<tr>
<td>Dust Collection</td>
<td>20</td>
<td>14.5</td>
</tr>
<tr>
<td>Pharmaceutical Applications</td>
<td>14</td>
<td>10.3</td>
</tr>
<tr>
<td>Synthesis and Application of Catalysts</td>
<td>12</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 2 Summary of technical aspects in particle technology papers published in domestic journals

Fig. 1
the synthesized microcellulose particles exhibit a narrow size distribution which is supposed to provide uniform adsorption capability. As shown in Fig. 1, the microcrystalline cellulose particles synthesized via hydrolysis of bagasses could provide adsorption capability on par with that of commercial products.

Recently nanomaterials, including nanoparticles, have increasingly attracted the interest for Thai researchers. Research teams in Chiang Mai (CMU) and Chulalongkorn Universities (CU) have been exploring several techniques, such as pyrolysis, arc discharges in gas or liquid, and Chemical Vapor Deposition (CVD), for the synthesis of carbon and metal nanoparticles. Meantime, other well-known wet processes (sol-gel, microemulsion etc.) and dry processes (sputtering and flame spray pyrolysis) have also been investigated for the synthesis of nanoparticles of various metallic and semiconductive compounds. For example, Charinpanitkul et al. reported that the use of naphthalene as main carbon source with an additional small amount of ferrocene could yield a remarkable amount of well aligned multi-walled carbon nanotubes (MW-CNT). Meanwhile, Singjai et al. of CMU reported their success in growing CNT with the CVD technique.

3.2 Research and development in particle processing and handling

It is noteworthy that large-scaled industrial enterprises in Thailand often adopt turn-key technologies whereas small- and medium-scaled enterprises often resort to the use of modified processes they have adopted or procured from other companies. As a consequence, process retrofitting is inevitably a key issue for all industries.

Among the relevant issues, dust collection and air pollution control are among the most frequently raised research topics. Tanthapanichakoon et al. are among Thai chemical engineers who have contributed significantly to air filtration or industrial dust collection. Before the financial crisis in Thailand in 1997-1999, the rapid growth in national infrastructure development and construction boom has resulted in great demand for construction materials, which in turn led to fugitive dust dispersion problem and product losses. Having investigated their collection efficiencies theoretically and experimentally, several simple but effective methods, such as water droplet curtains generated by a series of nozzles, wet screen dust collectors, and improved wet scrubbers, have been designed, installed and utilized both in lab-scale and pilot-scale processes before actual applications are implemented in some industrial factories, such as rock crushing plants, windsurf manufacturer and grinding wheel producer. Moreover, high-temperature dust collection using candle filters has also been investigated.

Fly ash from some coal-fired power plants has also been investigated for concrete preparation. Fly ash has many characteristics, such as mechanical strength, porosity and setting time, which are important for civil engineering researches. Works focusing on municipal waste ash have also been carried out to simultaneously tackle the environmental problem and develop an alternative resource. Some research teams in KMUTT, for instance, a team consisting of Jaturapitkul et al. have investigated the classification of fly ash generated from the largest lignite-fired power plant in Thailand and the mixing of the ash with Portland cement. They reported that, in addition to changes in its chemical composition, the particle size distribution of the classified fly ash could significantly affect the compressive strength of the composite concrete.

Fluidization and its applications are also widely investigated in Thailand. For examples, at least 1 group in KMUTT and 2 groups in CU have contributed to fluidized bed drying, combustion and granulation as well as coating. Soponronnarit et al. have made many contributions to the drying technology for agricultural products and waste utilization, which at present have become commercially available. Damronglerd et al. in CU have conducted many investigations of solid waste combustion in fluidized beds. Similarly, Tia et al. attempted to utilize...
a fluidized bed furnace to extract thermal energy from agricultural wastes. In CEPT, Charinpanitkul et al. have developed a batch-scale fluidized-bed granulator/coater by co-opting electrostatic atomization of the binder or coating agent. Fig. 2 reveals the schematic diagram of their coating fluidized bed with some typical examples of uniformly coated particles which could provide controlled-release functionality.

3.3 Research and development in particle application and utilization

Applications and utilizations of particulate materials are one of the most important research topics for Thai researchers. Recycle of waste materials - either in particulate or bulk forms, substitution of some specific materials with indigenously available natural materials, and new products development were conducted and reported by Thai academic staffs. Typical waste materials abundant in Thailand are biomass, such as rice husks, wood shavings and sludges obtained mainly from the agricultural sector. The means to recycle these waste materials are pyrolysis for developing new products, such as zeolites and diamond films, and compositing with polymeric materials (PVC, PE or LDPE). For instance, Rimdusit et al. focused on utilizing benzoxazine as matrix material and wood flour as filler in the preparation of high-quality wood composite, which could be employed as housing materials. The composites exhibit superior physical properties up to a very high filler fraction of 75%.

For other applications in environmental aspects, many research teams, such as Kiatkomol et al. of SUT applied montmorillonite as well as organo-clays for the removal of organic pollutants from simulated aqueous solutions. They reported that the capacity of adsorption strongly relied on the contact time between the adsorbent and adsorbate.

As an inevitable aspect of nanotechnology, the utilization and applications of nano-scale particles have also attracted great interest. Numerous attempts from various institutions employed typical nanoparticles, such as TiO₂ for wastewater treatment. It has been reported that such a system has high potential to tackle wastewater with complicated molecules of dye stuffs or volatile hydrocarbon compounds which could not be handled by conventional systems.

4. Future Direction of P.T. in Thailand

Domestic and international collaborations in R&D in P.T. and its relevant fields have played an important role in their sustainable development in the whole Southeast Asian region including Thailand. Japan
and other developed countries have provided technical and financial supports to Thailand, especially from APPIE Japan to TPTC and CEPT in CU. With high demands from the funding agencies for Thai researchers to conduct R&D that leads to actual applications, the use of nanoparticles in composites and sensors as well as cosmetics and advanced drug delivery would for the time being remain the focal point of P.T. research activities in Thailand.

5. Conclusions

Major contributions in P.T. of Thailand have come from Chemical, Civil and Environmental Engineering fields. Pharmaceutical scientists and technologists have contributed to the development of new methods and new recipes for specific pharmaceutical products composed of niche indigenous materials, such as rice husk and lignite. The present finding reveals that Thailand still requires more fundamental research but demand for applied research is stimulated by the policies of the government and funding agencies.

In short, Particle Technology (P.T.) is now recognized as a key technology that plays a tremendously important role in the development of Thailand’s industries. In addition to the conventional aspects ranging from handling and processing to synthesis and applications of particulate materials, R&D in P.T. in Thailand has expanded to nanoparticle technology and its applications. It is believed that more researchers and engineers should study and make use of the diversity and multi-disciplinary features P.T. in their own fields to expand production capacity and develop new manufacturing practices in their factories.

Acknowledgement

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**Author’s short biography**

**Dr. Tawatchai CHARINPANITKUL**

Dr. Tawatchai CHARINPANITKUL is director of Center of Excellence in Particle Technology (CEPT), CHULALONGKORN University (CU). He received his B. Eng. in Chemical Engineering from CU. in 1986. After completing his M. Eng and D. Eng. in the same field from University of TOKYO, JAPAN in 1989 and 1992, respectively, he worked with Prof. W. TANTHAPANICHAKOON to establish a research team focusing on Particle Technology in Thailand. His research contributions are mainly concentrated on fluidization, aerosol collection and biomass utilization processes. His current research involvement is also extended to synthesis and application of nano particulate systems, in particular, Carbon Nanoparticles, Metallic Nanoparticles (i.e. Au, TiO₂, ZnO and ZnS). At the moment, he has leaded a research group which consists of about 30 young researchers with both domestic and international collaborations in JAPAN, KOREA, FRANCE and USA. etc.

**Chalida Klaysom**

Miss Chalida Klaysom was born on August 2, 1980 in Suratthani province, Thailand. She received the Bachelor Degree (Chemical Technology) and Master Degree in Chemical Engineering from Chulalongkorn University. Her master thesis was entitled as “Preparation, Characterization and Continuous Process Design of Activated Carbon from Waste Tires”, in which she not only prepared and characterized the carbonaceous porous materials from industrial residue like waste tires, but also designed the process to develop the products industrially. At present, with support of Thai government, she is conducting her Ph.D. in the University of Queensland, Australia, and will be working as a lecturer in Chulalongkorn University when graduation.

**Siriporn MONCHAYAPISUT**

Siriporn MONCHAYAPISUT obtained her B. Eng. in Petrochemical and Polymeric Materials from Silpakorn University. Since 2002 to present she has joined Center of Excellence in Particle Technology (CEPT), Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University as a research assistant. Her research interest covers polymer science and technology as well as nanotechnology.
Author’s short biography

Sira Srinives
Sira SRINIVES was awarded his MS. Degree in Chemical Engineering on March, 2006, from Chulalongkorn University (CU), Thailand, and has worked as a full-time research assistant in the Center of Excellence in Particle Technology, CU, since then. He experienced some background in the field of dust collection technology, as shown in his thesis work, “Development of rice mill dust collection system using rice husk bed”. At present, he is looking forward to a commercialization of this patented system in Thai rice mill industries. In August 2006, he was granted a scholarship from Thai government to pursue his Ph.D. in USA, in the field of Nanotechnology, and will become a lecturer in the Department of Chemical Engineering, Mahidol University, upon his return.

Wiwut TANTHAPANICHAKOON
Wiwut TANTHAPANICHAKOON obtained his PhD (U of Texas at Austin) and B. Eng. (Kyoto U) in chemical engineering. At present he is the founding Director of the National Nanotechnology Center (NANOTEC) under the umbrella of National Science and Technology Development Agency, Ministry of Science and Technology. Concurrently, he is Professor Emeritus of Chulalongkorn University (CU) and Chair Professor in particle Technology, Faculty of Engineering, CU. Since NANOTEC serves as Secretariat of the National Nanotechnology Policy Committee chaired by the Prime Minister of the Royal Thai Government, Dr. Wiwut is directly involved with the policy formulation and promotion of nanotechnology in Thailand. His life-long research interests covers particle technology, aerosol engineering (dust collection technology, air pollution control), process analysis and simulation, drying technology, energy technology, and nanotechnology.