10th Eco-Energy and Materials Science and Engineering Symposium


On December 5-8, 2012
Sunee grand hotel,
Ubon-ratchathani

Organized by

Co-organized by
PREFACE:
Message from the President of
Rajamangala University of Technology Thanyaburi

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This international conference is not only giving an opportunity for Thai and foreign researchers to present and discuss their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Our program consists of six research tasks: (1) Energy Technology, (2) Environmental and Social Impact, (3) Nanotechnology and Materials Science, (4) Energy Economics and Management, (5) New Energy Technology and (6) Nuclear Technology.

I would like to take this opportunity to express our sincere gratitude to our two distinguished Plenary Speakers for kindly accepting our invitation. I deeply appreciate the very strong support given by Kyoto University. Thanks to the tireless works of the Organizing Committee, the Technical Program Committee, the invited speakers and paper and poster contributors, and excellent program been assembled to cover a broad spectrum of interesting topic.

We warmly welcome you to the 10th EMSES on December 5-8, 2012, Ubon Ratchathani, Thailand.

Numyoot SONGTHANAPITAK, Ph.D.
President of Rajamangala University of Technology Thanyaburi
and Conference Chairman of 10th EMSES 2012
PREFACE:
Message from the Director of
Institute of Advanced Energy, Kyoto University

It is my great pleasure to have the 10th Eco-Energy and Materials Science and Engineering Symposium (EMSES) with Rajamangala University of Technology Thanyaburi (RMUTT) under the long-term collaboration between RMUTT and Kyoto University. The 1st EMSES was held in 2001 in Thailand and the symposium has been expanded in its scientific contents as well as the academic network. I believe that the 10th EMSES gives a good opportunity to all participants to exchange their knowledge and idea to realize eco-friendly energy system in society. I would like to express my welcome to all participants and sincere thanks to the 10th EMSES organizing committee and all supporting organizations to make us having this symposium.
I hope that the symposium will be successful and lead to further progress in energy science and technology and also in friendships of participants.

Professor Yukio Ogata, Ph.D.
Director of Institute of Advanced Energy, Kyoto University
PREFACE:
Message from the Former Dean of Graduate School of Energy Science, Kyoto University Program Leader,
Global COE “Energy Science in the Age of Global Warming”

I want to express my hearty welcome to all participants of Eco-Energy and Materials Science and Engineering Symposium (10th EMSES). This symposium is aiming the realization of importance of energy and materials technology through the academic, science and technology network among the world communities. The symposium gives an opportunity for researchers to discuss their research works and also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the further cooperation work will be developed.

I would like also extend my sincere thanks to all who made the meeting possible, including the 10th EMSES organizers, the SEE forum committee members, and the Japanese Government, JSPS, for their kind support. I am looking forward to seeing you in Ubon Ratchathani, Thailand.

[Signature]

Professor Takeshi YAO, Ph.D.
Former Dean of Graduate School of Energy Science, Kyoto University
and Program Leader, Global COE “Energy Science in the Age of Global Warming”
Message from the Chairperson of 10th EMSES Organizing Committee

Rajamangala University of Technology Thanyaburi (RMUTT), in conjunction with Kyoto University, is pleased to host the 10th Eco-Energy and Materials Science and Engineering Symposium (10thEMSES).

RMUTT has a major mission on encouraging and supporting all areas of research. One of the key reasons is to assist in developing capability in science and technology in order to cope with recent rapid change in this field. We have jointly set up an academic symposium on the 10thEMSES with the perception on the significance of exchanging knowledge and research experiences between researcher in the field of energy, materials technology and environmental science. This symposium is not only giving an opportunity for Thai and foreign researcher to present and discussion their research works and update their expertise but also to initially stimulate the development of research works on eco-energy and materials science and engineering. Once the cooperation among researchers has been created, the closer future cooperation incorporate with joint-research works will be developed. Thus, to support the aforesaid role, the symposium working committee would like to invite you to participate in this academic symposium.

I would like to express our sincere thanks to the organizing committee, participants and contributors for your kind corporation to this symposium. I wish this symposium proceeding will be a useful reference for future scientific research development.

Sommai PIVSA-ART, Ph.D.
Dean of Faculty of Engineering, RMUTT
Director of CoE on Sustainable Energy System (Thai-Japan)
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# Conference Program of 10th Eco-Energy and Materials Science and Engineering

**5th December 2012**

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<tr>
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<tr>
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<td>Registration</td>
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<td>05:00-06:00 pm</td>
<td>EMSES committee meeting</td>
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*Time: 6th December 2012*

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<tr>
<td>07:00-09:00 am</td>
<td>Registration</td>
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<tr>
<td>09:00-09:40 am</td>
<td>Opening Ceremony at Taptim Siam 4 Hall</td>
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<td></td>
<td>Assoc. Prof. Dr. Numyoot Songthanapitak, President of RMUTT, Thailand and Chairperson of 10th EMSES conference</td>
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<td></td>
<td>Prof. Dr. Kiyoshi Yoshikawa, Vice President of Kyoto University, Japan Co-Chairperson of 10th EMSES conference</td>
</tr>
<tr>
<td>09:45-10:45 am</td>
<td>Keynote Speaker I: Japan Power Generation Mix and Energy Security after Fukushima Nuclear Accident, presented by Professor Dr. Keiichi N. Ishihara, Graduate School of Energy Science, Kyoto University, Japan</td>
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<td>10:45-11:00 am</td>
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<td>11:00-12:00 am</td>
<td>Keynote Speaker II: Vertical Motions in Greater Bangkok Area after the 2004 Sumatra-Andaman Earthquake from GPS Observations and Its Prediction based on the Geophysical Modelling, presented by Professor Dr. Chaiermonch Satirapod, Chulalongkorn University, Thailand</td>
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<td>12:00-01:30 am</td>
<td>Lunch at Taptim Siam 5 Hall</td>
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<td>Chair</td>
<td>Prof. Dr. Padungsa Ramthanachow</td>
<td>Assoc. Prof. Dr. Wisanu Pecharapa</td>
<td>Assoc. Prof. Dr. Seiichi Kawahara</td>
<td>Prof. Dr. Daee Hee Park</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Wirachai Roynarin</td>
<td>Dr. Sorapong Pavaupree</td>
<td>Asst. Prof. Dr. Warunee Arayawartihan</td>
<td>Asst. Prof. Dr. Jakhee Srinonchart</td>
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<td>Prof. Dr. Narongrit Sombatsompop</td>
<td>Prof. Dr. Hideaki Ohkaki</td>
<td>Prof. Dr. Susumu Yoshikawa</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Boonyang Plongklang</td>
<td>Dr. Supakij Suttiruengwong</td>
<td>Dr. Nithiwatthn Choosakul</td>
<td>Dr. Surawut Chuangchote</td>
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<td>05:00-06:30 pm</td>
<td>Poster Session</td>
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<tr>
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<td>Co-Chair</td>
<td>Dr. Sorapong Pavaupree and Dr. Sumonman Niamlang</td>
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# Conference Program of 10th Eco-Energy and Materials Science and Engineering

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<td>Dr. Seichi Aiba</td>
<td>Prof. Dr. Takeshi Yao</td>
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<td>Assoc. Prof. Dr. Thawatch Kerdcuen</td>
<td>Dr. Leong Yew Wei</td>
<td>Dr. Supaporn Tomson</td>
<td>Dr. Nathabhat Phankong</td>
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<td>Prof. Dr. Jun Li</td>
<td>Prof. Dr. Hiroyuki Hamada</td>
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<td>Assoc. Prof. Dr. Kawee Srikulkit</td>
<td>Dr. Sarocha Charoenvai</td>
<td>Dr. Narongchai O-Charoen</td>
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<tr>
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<td>Asst.Prof.Dr. Boonrit Prasartkeaw</td>
<td>Assoc. Prof. Dr. Yuji Aso</td>
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<td>12:15-13:00 pm</td>
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<td>Energy Economic &amp; Management 1</td>
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<td>EM02,EM03,EM04,EM07,EM08</td>
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<td>Prof. Dr. Yuichi Anada</td>
<td>Prof. Dr. Keiichi N. Ishihara</td>
<td>Assoc. Prof. Dr. Nata Kuptashtien</td>
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<tr>
<td>Co-Chair</td>
<td>Dr. Winai Chanpeng</td>
<td>Assist. Prof. Dr. Kazushi Yamada</td>
<td>Asst. Prof. Dr. Sommai Pivsa-art</td>
<td>Dr. Boonyang Plangothien</td>
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<td>03:00-03:15 pm</td>
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<td>Coffee break</td>
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<td>03:15-04:00 pm</td>
<td>Closing Ceremony at Taptim Siam 4 Hall</td>
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<td>Time</td>
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<tr>
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Prof. Dr. Takeshi Yao, Leader of GCOE Program/Professor, Graduate School of Energy Science, Kyoto University
Mechanical Property of Surface Modified Natural Fiber Reinforced Poly(lactic acid) Composites

Wassamon Sujaritjun1, Putimun Uawongsuwan2, Weraporn Pivsa-Art1 and Hiroyuki Hamada2

1Department of Chemical and Materials Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Klong 6, Thanyaburi, Pathumthani 12110
E-mail: w11s_1990@hotmail.com

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E-mail: putimunu@kmitl.ac.th

Abstract—Environmental friendly composites of poly(lactic acid) reinforced with natural fibers were fabricated using a twin-screw extruder. Natural fibers studied included bamboo fibers, vetiver grass fibers and coconut fibers. Treatment of surface of natural fibers was carried out using flexible epoxy resin. Tensile modulus of composites increased with increasing amount of reinforced fibers. Bamboo fiber was most effective reinforcement for PLA composites. With 40wt% bamboo fiber reinforced PLA, the tensile modulus of composite increased up to 150%. However, tensile modulus of treated natural fiber/PLA composites decreased than untreated fibers and neat PLA composites. Morphological study using SEM confirmed interaction of surface of natural fibers and biodegradable polymer.

Keywords—Bamboo fiber, Biocomposites, Coconut fiber, Flexible epoxy, Poly(lactic acid), Vetiver grass fiber.

1. INTRODUCTION

As a result of the increasing environmental awareness, the concern for environmental sustainability and the growing global waste problem is increased year by year. Research in the field of polymers and composites from biological sources strives to replace traditional, synthetic ones with more environmentally friendly and sustainable alternatives. Fossil fuel-derived plastics are often harmful to the environment: their production can be very polluting and a great deal of waste is generated from them. Biopolymers currently have few applications compared with synthetic polymers, in part because they are a relatively new research area. Composites made from biopolymers by adding a reinforcing material can be designed with specific properties. The purpose of this study was to examine the potential reinforcing effects of short, randomly oriented natural fibers on poly(lactic acid) (PLA). Natural fiber and PLA were chosen for composite fabrication because of their availability, mechanical properties, and biodegradability.

Poly(lactic acid) (PLA) is a rigid thermoplastic polymer that can be semi crystalline or totally amorphous, depending on the stereo purity of the polymer backbone. Poly(lactic acid) (PLA) has a special interest as a matrix in natural fiber composites for many reasons. First, PLA is a versatile thermoplastic produced from lactic acid monomer coming mainly from the fermentation of corn, potato, sugar beet, and sugar cane. Second, the commercially attractive features of PLA includes its degradability in a short period of time (0.5–2 years) in contrast to conventional plastics like PS, PE, etc, which need 500–1000 years [1].

Natural fiber as a replacement to synthetic fiber in polymer matrix is the focus of many scientists and engineers. The reason for focus on natural fiber reinforced polymer matrix is because of its low cost, low effect on environment and also it shows good mechanical properties compared to polymer resins. Natural fiber reinforced composites are advantageous over the metals when excellent corrosion resistance is required. Apart from mechanical properties, thermal properties are also required for specific applications[2]. Tests on mechanical properties of natural fiber reinforced composites were extensively done by many investigators. The tensile properties of bamboo fiber, vetiver grass fiber and coconut fiber reinforced composites have been studied, and reported that among all the composites, bamboo fiber reinforced composite exhibited the highest mechanical properties whereas the coconut fiber showed the lowest.

The objective of this study is to develop a new type of biocomposite material. Bamboo fiber, vetiver grass fiber and coconut fiber was chosen as the reinforcement because it is an abundant natural resource in Thailand. The effect of flexible epoxy treated on the mechanical property of biocomposites are investigated.

2. EXPERIMENTAL

2.1 Materials

Poly(lactic acid) (grade: TE-2000C) with a density of 1.25g/cm³, melting point of 170°C was obtained by Ulnikita plastics division, Japan. All natural fiber was obtained from Thailand. Flexible epoxy (grade PB 3600, Daicel chemical Co. Ltd., Japan.) is used as surface treatment for bamboo fiber, vetiver grass fiber and coconut fiber.

Table 1. Composition and characteristic of selected natural fibers [3,5]

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Mean fiber angle (deg)</th>
<th>cellulose (%)</th>
<th>lignin (%)</th>
<th>Fiber aspect ratio (average)</th>
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<tr>
<td>Bamboo</td>
<td>2.10</td>
<td>60.8</td>
<td>32.2</td>
<td>2.34-8.9 (3.5)</td>
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<tr>
<td>Vetiver grass</td>
<td>N/A</td>
<td>72.64</td>
<td>17.03</td>
<td>2.2-6.9 (3.8)</td>
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<tr>
<td>Coconut</td>
<td>30.49</td>
<td>43</td>
<td>45</td>
<td>8.6-49.8 (26.0)</td>
</tr>
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</table>
Table 2. Physical and mechanical properties of natural fibers [3,5]

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Density (g/cm³)</th>
<th>Tensile modulus (GPa)</th>
<th>Tensile strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bamboo</td>
<td>0.80</td>
<td>35.9</td>
<td>441</td>
</tr>
<tr>
<td>Vetiver grass</td>
<td>1.50</td>
<td>12.49-8</td>
<td>247-723</td>
</tr>
<tr>
<td>Coconut</td>
<td>1.1-1.5</td>
<td>4.6</td>
<td>131-175</td>
</tr>
</tbody>
</table>

2.2 Specimen preparation

The flexible epoxy resin was dissolved in acetone (1 g resin : 200 ml acetone) for reducing the viscosity prior to treat with natural fiber. The ratio between natural fibers, PLA matrix and flexible epoxy resin was shown in Table 3. The treated natural fibers were first dried at room temperature for 24 hours and were dried in vacuum oven 80°C for overnight. The purpose of chemical treatment is to improve thermal properties and also interfacial bonding between fiber and matrix. The untreated and treated natural fibers were compounded with PLA matrix by twin screw extrusion at 200°C. The testing specimens of untreated and treated natural fibers were fabricated by injection molding at 200°C to the dumbbell shape specimens.

Table 3. Composite compositions and specimen code

<table>
<thead>
<tr>
<th>PLA Content (wt.%)</th>
<th>Natural fiber Content ( wt.%)</th>
<th>Flexible epoxy (1 wt. % of fiber-content)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Untreated</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>30</td>
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<tr>
<td></td>
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<td>40</td>
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<tr>
<td>Treated</td>
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<td>30</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

2.2 Testing

For tensile tests, dumbbell-shaped specimens were used the gauge length of 115 mm, and strain was measured using extension measurement. Tensile test was conducted on an Instron universal testing machine (Type 4026) with a load cell of 5 kN. Under a nominal test speed of 1mm/min. Five specimens were repeated.

3. RESULTS AND DISCUSSIONS

3.1 Effect of natural fiber on tensile property

![Fig. 1. Tensile modulus natural fiber/PLA composites](image)

The tensile modulus of composite at different natural fiber content was show in Fig. 1. Tensile modulus of biocomposite increased with increasing reinforcement content. It can be seen tensile modulus of untreated bamboo fiber composite was higher more than vetiver grass fiber, coconut fiber and neat PLA. This effect was due to the physical and mechanical properties of bamboo fiber higher than vetiver grass fiber and coconut fiber can be seen at table 2. Moreover, it was found that coconut fiber is lowest may be caused by cellulose of bamboo fiber and vetiver grass fiber was higher than coconut fiber.

![Fig. 2. Tensile strength of natural fiber/PLA composites](image)

Fig. 2 shows the tensile strength of the natural fiber/PLA composites. The tensile strength of untreated vetiver grass fiber/PLA and coconut fiber/PLA composites were lower than neat PLA and decreased with increasing fiber content. On the other hand, tensile strength of bamboo fiber/PLA composite slightly decreased at 40 wt. % bamboo fibers. This was due to the difference of fiber strength as listed in Table 1 that bamboo fiber has higher fiber strength than vetiver grass fiber and coconut fiber. Moreover, the interfacial bonding between natural fiber and PLA matrix were different. As observed from SEM micrograph as shown in Fig. 3, bamboo fiber has better interfacial bonding with PLA matrix than that of vetiver grass fiber and coconut fiber.

![Fig. 3. The SEM micrograph of fracture surface; (a) bamboo fiber/PLA, (b) vetiver grass fiber/PLA and (c) coconut fiber/PLA.](image)

3.2 Effect of flexible epoxy resin treatment

3.2.1 Bamboo fiber

Tensile modulus of flexible epoxy treated bamboo fiber reinforced PLA composite was lower than an untreated composite as shown in Fig. 4. It is found that the flexible epoxy resin treated reduced the stiffness of the fiber. Moreover, may be due to acetone washes lignin of the fiber resulting in high flexibility of the fiber. However, it was found that tensile strength of flexible epoxy treated bamboo fiber composites were higher than untreated of bamboo fiber composites as shown in Fig. 5. Usually the mechanical properties of fiber-reinforced composite depends considerably on the fiber-matrix interface because a well-formed interface allows better stress transfer from matrix to fiber. Therefore, good interfacial
adhesion between PLA matrix and flexible epoxy treated bamboo fiber in Fig. 6 is found to improve the tensile strength of the PLA biocomposites.

Fig. 4 The tensile modulus of untreated and flexible epoxy treated bamboo fiber/PLA composites

Fig. 5 The tensile strength of untreated and flexible epoxy treated bamboo fiber/PLA composites

(a) (b)

Fig. 6 SEM micrographs of fracture surface shows the interfacial adhesion between bamboo fiber and PLA matrix; (a) Untreated and (b) Flexible epoxy treated

3.2.2 Vetiver grass fiber

As mentioned above, the modulus of treated vetiver grass fiber/PLA composite were also decreased due to the effect of coated soft material onto the fiber surfaces as shown in Fig. 7. However, in Fig. 8, the tensile strength was slightly increased when compared with untreated vetiver grass/PLA composites. This behavior is probably because the difference surface and shape of vetiver grass which was less effectively improved the interfacial bonding by treated with flexible epoxy resin. From the SEM micrograph of fracture surface in Fig. 9, the interfacial adhesion between untreated and treated vetiver grass fiber and PLA matrix was inconsiderable different.

Fig. 7 The tensile modulus of untreated and flexible epoxy treated vetiver grass fiber/PLA composites

Fig. 8 The tensile strength of untreated and flexible epoxy treated vetiver grass fiber/PLA composites

(a) (b)

Fig. 9. SEM micrographs of fracture surface of vetiver grass fiber/PLA composites; (a) Untreated and (b) Flexible epoxy treated

3.2.3 Coconut fiber

The tensile modulus of untreated and treated coconut fiber of composite was insignificantly different as shown in Fig. 10. This result indicated that the modulus of the soft coconut fiber was unaltered by coating of flexible epoxy resin. However, tensile strength increased significantly at 40 wt.% coconut fiber by the effect of flexible epoxy resin treated as shown in Fig. 11. This indicate that the flexible epoxy can be improved the interfacial (a) ties between coconut fiber and PLA matrix. The SEM photographs of the fracture surface of untreated and treated coconut fiber/PLA composites are shown in Fig.12. It can be found that the gap between coconut fiber and PLA were disappeared in the flexible epoxy treated coconut fiber/PLA composites.
4. CONCLUSION

In this study, mechanical properties of natural fiber and PLA composites were prepared by extrusion and injection molding. The tensile modulus of untreated natural fiber/PLA composites were increased with increasing natural fiber content. The tensile strength of untreated vetiver grass fiber/PLA and coconut fiber/PLA composites were lower than neat PLA and decreased with increasing fiber content. On the other hand, tensile strength of bamboo fiber/PLA composite slightly decreased at 40 wt.% bamboo fibers. The tensile properties of untreated natural fiber were strongly dependence on the properties of natural fiber.

The effect of surface treatment on the tensile property of natural fiber/PLA composites was depended on the type of fiber as shown in Fig. 13 (a)-(b). The plot was obtained from the differential ratio in percentage of mechanical properties of 40 wt.% natural fiber comparing to the properties of PLA matrix. The modulus rigid natural fiber such as bamboo fiber and vetiver grass fiber were strongly affected by flexible epoxy treated. The modulus of the soft coconut fiber was unaltered by coating of flexible epoxy resin. The interfacial bonding between bamboo fiber and coconut fiber was improved by flexible epoxy treated. However in case of vetiver grass fiber, the tensile strength was slightly increased when compared with untreated vetiver grass/PLA composites. This behavior is probably because the difference surface and shape of vetiver grass which was less effectively improved the interfacial bonding by treated with flexible epoxy resin.

Fig. 10 The tensile modulus of untreated and flexible epoxy treated coconut fiber/PLA composites

Fig. 11 The tensile strength of untreated and flexible epoxy treated coconut fiber/PLA composites

Fig. 12. SEM micrographs of fracture surface of coconut fiber/PLA composites; (a) Untreated and (b) Flexible epoxy treated

Fig. 13 Performance comparison between untreated and flexible epoxy treated natural fiber/PLA composites; (a) tensile modulus improvement and (b) tensile strength reduction

REFERENCES


