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落實奈米教育計畫:以特殊奈米複合材料強度為例

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摘要

為了落實奈米科學教育，本研究以過去所執行計畫之特殊材料強度案例來啟發學生，使用苯乙烯-乙烯/丁烯-苯乙烯嵌段共聚合物(SEBS)/黏土奈米複合材料，並以馬來酸酐接枝聚丙烯(Polypropylene-g-maleic anhydride, PP-g-MA)及馬來酸酐接枝苯乙烯-乙烯/丁烯-共聚合物(Styrene-ethylene-butylene-styrene block copolymer-g-maleic anhydride, SEBS-g-MA)作為相容劑。結果顯示，雖然 PP-g-MA 對粘土的分散性效果較 SEBS-g-MA 為低，但對於抗張強度與撕裂強度增進效果則較 SEBS-g-MA 為佳，此特殊現象代表基材及相容劑性質是決定良好機械性質的關鍵因素。藉由此案例建構之”問題導向教學方式”來激發學生，並鼓勵學生以獨立思考概念來探討他們自己的領域。結果顯示，使用此”問題導向教學方式”，較未使用此教學方式的效果為佳，參與學生均給予此方式極正面的評價。

關鍵詞: 奈米科教; 苯乙烯-乙烯/丁烯-苯乙烯嵌段共聚合物; 奈米黏土;奈米複合材料; 問題導向教學方式

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Implement Nano-education Program: Inspired through Unusual Nanocomposites Strength

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ABSTRACT

Recently, nanotechnology has received much attention.In order to implement the nano-education into the class to have a higher impact on the students' independent thinking capability, an unusual study of earlier work was designed to allow students to understand how strength of nanocomposites was related to the types of compatibilizers used and the deformation behaviors. Styrene-ethylene-butylene -styrene block copolymer (SEBS)/clay nanocomposites were prepared via a melt mixing technique. Two types of maleated compatibilizers, styrene-ethylene-butylene-styrene block copolymer grafted maleic anhydride (SEBS-g-MA) and polypropylene grafted maleic anhydride (PP-g-MA), were incorporated to improve the dispersion of commercial organoclay (denoted as 20A), respectively. PP-g-MA compatibilized system conferred higher tensile strength and tear strength (initiation condition) than SEBS-g-MA compatibilized system, even though higher dispersion of clay was found in SEBS-g-MA compatibilized system. The nanoclay conventionally claimed to enhance the mechanical properties of nanocomposites became insignificant when the deformation was confined in the nano-deformation region. These unusual results suggest that the matrix properties and compatibilize r types were crucial factors in attaining the best mechanical property performance at a specific clay content. Based on those obtained unusual results, students will be encouraged to pursue their own work in a different aspect through this problem-based learning process. The evaluation responses from students were quite positive as they were inspired to present their own work with more elaborative way by this designing approach.

Keywords: Nano-education; Styrene-ethylene-butylene-styrene block copolymer; Nanoclay;

Nanocomposite; Problem-based learning

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1. Introduction

According to US National Nanotechnology Initiative Program, "Nanotechnology is a multidisciplinary field of discovery. Scientists working in physics, chemistry, biology, engineering, information technology, metrology, and other fields are contributing to today's research breakthroughs. The worldwide workforce necessary to support the field of nanotechno logy is estimated at 2 million by 2015." The National Center for Learning and Teaching in Nanoscale Science and Engineering, NCLT, established in 2004, focused on reinforcing the learning capability through science, technology, engineering and mathematics to equip learners with the advanced knowledge of Nanoscale Science and Engineering Education in US [www.nclt.us]. It is our attempt to involve and implement nano-education in the class to promote students' understanding on the cutting edge of new technology.

Problem-based learning was first proposed by H. Barrows regarding the medical education in 1960 period [Yang, et al. 2005] [Torp, et al. 2002]. The concept was then prevailed in many scientific fields for the higher education purpose [Yang, et al. 2005] [Boud, et al. 1997]. Since 1992, many medical schools in Taiwan also adopted this important education concept for the better teaching efficiency [Yang, et al. 2005] [Kwan, et al. 2009]. To implement the nano-education, the similar process was employed to improve the learning efficiency.

Recently, nanotechnology has received much attention. In order to implement the nano-education into the class to have a higher impact on the students' independent thinking capability, an unusual study of earlier work [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008] was designed to allow students to understand how strength of nanocomposites was related to the types of compatibilizers used and the deformation behaviors. Styenene-ethylene-b utylene-sytrene block copolymer (SEBS) used for this education class is one of the most widely used thermoplastic elastomer, which exhibits balanced elasticity and processibility, good thermal stability, etc. Thus, it is applied in adhesives, the automotive and sports industries. To improve its properties, the intercalated clay was incorporated into SEBS. Most importantly, Szazdi et al. pointed out that a high exfoliation extent may not guarantee high strength for layered silicate nanocomposites demonstrated by PP/clay nanocomposites using PP-g-MA as a compatibilizer [Szazdi, et al. 2006]. This work attempts to summarize this important finding further and focuses on mechanical properties in detail, including tensile strength, and tear strength by varying inter-phase properties using two different compatibilizer s for SEBS/clay nanocomposites [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008]. Based on those obtained unusual results, students will be encouraged to pursue their own work in a different aspect through this problem-based learning process via an independent thinking approach. The evaluation responses from students were quite positive as they were inspired to present their own work with more elaborative way by this designing approach.

2. Approach

Materials description and characterization: SEBS was Kraton G1652 with 29 wt % styrene (Shell Chemical). The commercial O-MMT clay (Cloisite 20A) obtained from Southern Clay Products, Inc. SEBS-g-maleic anhydride (Shell, Kraton FG-1901) with 29 wt % of styrene and the grafting level of maleic anhydride is 1.7 wt %. PP-g-maleic anhydride was Du Pont commercial grade Fusabond 613(MD 613-5). The grafting level of maleic anhydride is 0.55 wt %. The clay content was kept at 5 wt% and the compatibilizer was loaded at 20 phr. The preparation procedure was described in our published literature [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008].

For the characterization, transmission electron microscopy (TEM) was employed to evaluate the dispersion of O-MMT in the composites. The TEM observation was performed on ultrathin sections of cryo-microtomed composite films with a JEOL JEM-2000EX II system. Tensile measurements were conducted based on ASTM-D638 at a crosshead speed of 20 cm/min using a Universal Tensile Testing Machine model QC-506A1. Tensile strength, elongation and Young's modulus were recorded. Trousers tear test was carried out in a similar condition to determine fracture energy (G_c) for this type of thermoplastic elastomer nanocomposites.

Guiding protocol: Based on problem-based learning process, three basic approaches were implemented to guide students for improving learning efficiency, including (i) Coaching, (ii) Case study, (iii) Experiencing. Two separated time periods in one semester was conducted for the instructing lecture to the same group of college students who participates the class. The first half period was instructed via conventional lecturing process by simple presentation in the class. The second half period was instructed via problem-based leaning process by coaching students to develop independent thinking methodology via reasoning, providing the case study of unusual nanocomposites strength, guiding tour on the center of nanotechnology and the lab, inspiring to present their work with demonstration experience.

Evaluation: Evaluation questionnaires were conducted on the first, middle, final period of whole semester.

3. Results and Discussion

3-1. Class Briefing and Coaching

The class is entitled as "Introduction to nanomaterials" for junior college students in National I-Lan University, Taiwan. Total enrollment of the class contains 93 students. The major outline of this class including, nanomaterials introduction, characteristics, types of nanomaterials, manufacture methods, characterization laboratory, applications,organic-inorganic hybrids, special topic discussion on representative nano hybrids, nanoworkshop, and new aspects on nanomaterials. The detail syllabus could be found in the school website and was omitted here for brevity.

The first half period was instructed via conventional lecturing process by simple presentation in the class to cover the most part of major outline as mentioned previously. The second half period was instructed via problem-based leaning process to have a better contrast on the same group of students.

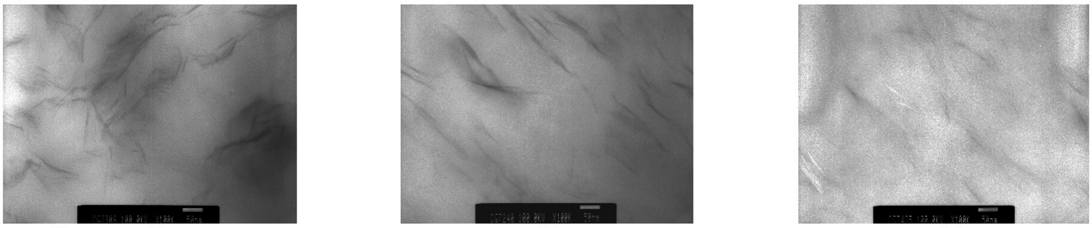
To implement the problem-based learning process, students were separated into 21 groups in total. Each group was encouraged to investigate their selected interested topics of nanomaterials. During which, each group was coached independently via 5W1H (What, Who, Where, When, Why, and How) to ask themselves on the motivation to this selected topic, contrast to conventional materials, targeted application and industry, etc. before their formal investigation and presentation. In order to set a good model example as the guidance, one case study on our previously published work regarding the special topic of the representative nano hybrids was demonstrated in the class. The following briefly described our earlier finding and reasoning to coaching students with independent thinking ability.

3-2. Case Study

The case study listed below was directly adopted from our previous work [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008] for the coaching process in order to bring in the newest concept for the class.

Dispersion Assessment

To elucidate the clay dispersion in the nanocomposites in detail, Figure 1 illustrates the TEM micrographs of SEBS/clay nanocomposites containing various amounts of PP-g-MA or SEBS-g-MA as a compatibilizer. In Figures 1(a), a well-dispersed clay image was obtained, except for some observed stacked silicate platelets. Figures 1 (b) to 1 (c) show the clay dispersion status with the further incorporation of two different compatibilizers. A relatively thinner layered structure was observed for both compatibilizers. The effect of compatibilizer types on the clay dispersion was quite limited. However, the SEBS-g-MA compatibilized case appeared to be more effective in assisting clay dispersion, especially at 20 phr.



__50nm (a) (b) (c)

Figure 1 TEM micrographs of (a) SEBS/clay, (b) SEBS/PP-g-MA(20 phr)/clay, (c) SEBS/SEBS-g-MA(20 phr)/clay

<u>Unusual Nanocomposites Strength</u>

As discussed in the TEM analysis, the expansion degree of clay was slightly larger in SEBS-g-MA compatibilized system. Surprisingly, PP-g-MA compatibilized system conferred higher tensile strength than SEBS-g-MA compatibilized system (Figure 2), even though a higher dosage of SEBS-g-MA was of benefit to expand the interlayer spacing of the clay based on previous results [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008]. The results suggested matrix properties and interfacial phase were crucial factors to attain best performance of nanocomposites in terms of tensile properties [Chen, et al. 2008] [Lai, et al. 2007] [Lai, et al. 2008].

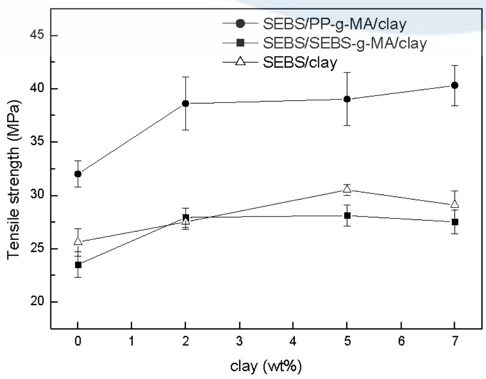


Figure 2 Tensile strength of SEBS/clay nanocomposites with 20 phr compatibilizer at various amounts of clay.

A further comparison for tear strength at various clay dosages under a fixed content of each compatibilizer is illustrated in Figure 3. Tear strength was found to effectively increase with increasing clay dosages. An important reinforcing effect of nanoclay normally found for conventional filler reinforced composites was still effective. The crystalline nature resulting in a higher energy dissipation of PP-g-MA was a dominant factor in these compatibilized nanocomposites, as demonstrated by the higher tear strength for SEBS/PP-g-MA blends in comparison with SEBS/SEBS-g-MA blends without incorporated clay. Moreover, tear strength for SEBS-g-MA compatibilized case was slightly higher than SEBS/clay without compatibilizer.

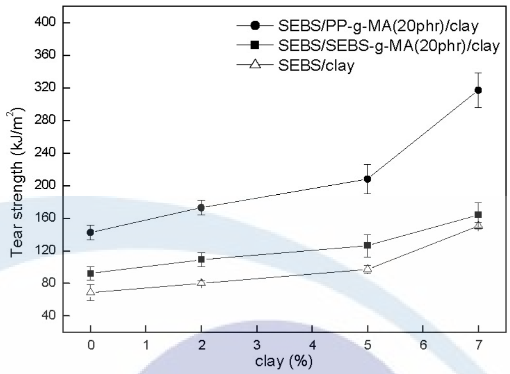


Figure 3 Tear strength at maximum forces of compatibilized SEBS/clay nanocomposites with 20 phr compatibilizer at various amounts of clay.

Does High Dispersion of Nanoparticles Guarantee High Strength of Nanocomposites?

Nanoclay conventionally claimed for the enhancement of mechanical properties for general nanocomposites was found to be an insignificant role played in the confined deformation of materials on behalf of cutting design. Higher dispersion of clay may not guarantee the high strength of nanocomposites.

3-3. Experiencing to Explore

Besides the case study presented for better understanding the myth of unusual nanocomposites materials. Students were encouraged to attend a tour to the center of nanotechnology and the lab for more involvement. More inquiries were proposed during the tour to motivate their learning curiosity.

The teaching assistant also was guided to provide her model demonstration of the nanomaterials in self-healing application for the class to get some idea on the preparation of their topics. The following, Figure 4, is the typical sample for a basis to cover a good understanding for the main topics of nanomaterials class, including a video, samples, supporting references, motivation, etc.

Figure 4 self-healing demonstration sample.

To get a handed-on experience, students are also encouraged to demonstrate their designed or prepared samples or video accessories to effectively deliver their presentation on their investigation. Twenty one topics were presented.

3-4. Evaluation Responses

The questionnaire for the first set regarding the basic understanding of the nanomaterials characteristics,types of nanomaterials, manufacturing methods,characterization techniques, application, etc.(see listed queries below) The rating of each question scales from 1 to 5, where 5 is the highest rating. As most students have not attended the related courses before, therefore, "disagree" percentage (scale 2) was the highest among the class. The results are shown in Figure 5.

1. Fundamental definition and significance of nanoscale
2. Classification of nanomaterials
3. Types of nanoscale measurement technique, for example, transmission electron microscope, TEM, et al.
4. Types of characteristic of nanomaterials, for example, quantum, small scale, and surface area effects.
5. Physical methods to prepare nanomaterials, for example, sputtering, et al.
6. Chemical methods to prepare nanomaterials, for example, sol-gel process, et al.
7. Preparation of organic and inorganic nanocomposites
8. Nanomaterials modification methods
9. The application of nanomaterials technology, for example, optoelectronic technology, medical science, and consumer products, et al.
10. Understanding the risk or myth of nanomaterials products
11. More comprehensive understanding on nanomaterials through the course of self-designed

experiments or presentation discussion via the problem based learning process

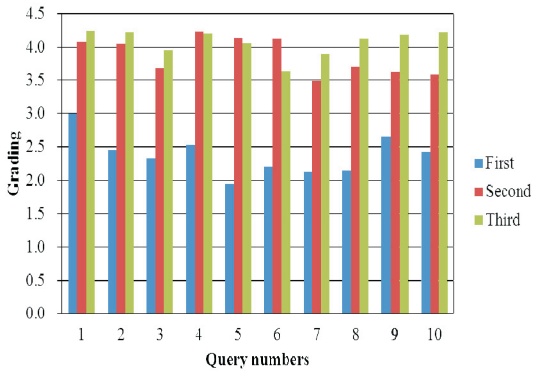


Figure 5 Rating of each query for three evaluation periods.

After the first period of simple lecturing process, the "agree" percentage increased significantly on the basic understanding of courses content in the middle period of second questionnaire. In addition, the "disagree" percentage decreased in most questions, except questions #7 to #10, in which the lecturer didn't have enough time to address the manufacturing methods, hybrids, modification methods, myths and risk of nanomaterials in detail.

For the same class, three basic approaches were implemented in the second half of the semester to guide students for improving learning efficiency, including (i) Coaching, (ii) Case study, (iii) Experiencing. The queries including the additional note regarding "After a successful presentation workshop or designed experiment" for each query in the original set of questionnaire. For instance, "After a successful presentation workshop or designed experiment, do u have further understood fundamental definition and significance of nanoscale?" in the query #1.

The final questionnaire indicated that the percentage of "strongly agree" (scale 5) or "agree"(scale 4) increased significantly, except queries#5 and 6 regarding the understanding of manufacturing physical and chemical methods to prepare nanomaterials after the presentation workshop training. This was attributed to the lack of real practice of this skill during the class due to the limited time available. However, most significantly, as shown in Figure 6, the additional query #11 regarding the overall approval rate for this class based on the problem based learning approach showed up to 95% of approval rate (including "strongly agree" and "agree" percentage) equivalent to scale 4.3, the highest rating of all queries. This was very encouraging to the lecturer. Apparently, the problem based learning approach to guide students in the nanomaterials lecture was apparently a very fantastic way to promote nano-education in college class.

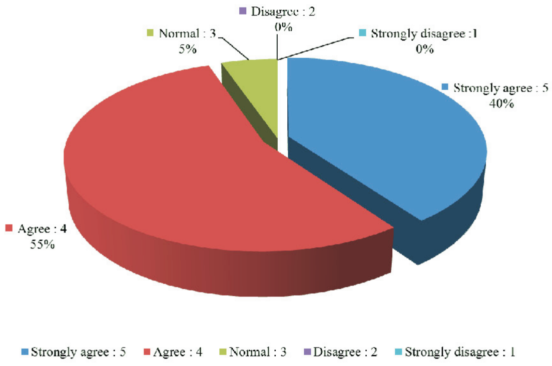


Figure 6 Rating of query #11 for problem-based learning approach for this class.

4. Conclusions

In order to implement the nano-education into the class to have a higher impact on the students' independent thinking capability, an unusual study of earlier work was designed to allow students to understand the myth of strength of nanocomposites. Higher dispersion of clay may not guarantee the high strength of nanocomposites. Based on problem-based learning process, three basic approaches were implemented to guide students for improving learning efficiency, including (i) Coaching, (ii) Case study, (iii) Experiencing. Evaluation questionnaires were conducted on the first, middle, final period of whole semester. Based on those obtained unusual results, students will be encouraged to pursue their own work in a different aspect through this problem-based learning process. The overall approval rate for this class based on the problem based learning approach showed up to 95% of approval rate (including "strongly agree" and "agree" percentage) equivalent to scale 4.3, the highest rating of all queries, indicating a successful way of improving class interests through this approach.

Acknowledgments

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