

Thermo-Mechanical Properties of Wood Sawdust-ABS Composites with Various Co-Monomer Content in ABS

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Abstract

Acrylonitrile-Butadiene-Styrene copolymers (ABS) reinforced with wood sawdust were investigated for thermal and dynamic mechanical properties. Three grades of commercial ABS resin with different co-monomer contents were used in this work. Sawdust from Para rubber tree treated with N-2(aminoethyl)-3-(aminopropyl) trimethoxy silane was blended with ABS by melt blending process using twin-screw extruder. Sawdust content used in this work was at 10 phr and 50 phr. For thermal properties, in 10 phr wood sawdust composites of both SI-ABS and MI-ABS composites showed the same range of decomposition temperature with neat ABS. While the HF-ABS composites were influenced by polysiloxane and resulted in thermal stability improvement when compared with HF-ABS neat polymer. For dynamic mechanical properties, the storage modulus of MI-ABS neat polymer and MI-ABS composites with the most butadiene content were higher value than HF-ABS and SI-ABS respectively.

Introduction

Wood-plastic composites (WPCs) are materials produced by adding wood sawdust as reinforcement in plastic for the main purpose of disposing of waste materials from wood related manufacturings. WPCs have many advantages over natural counterparts such as better dimensional stability, moisture and insect resistance, as well as longer service life with minimal maintenance required. Moreover, WPCs are usually perceived as the green materials.

It had been widely interested to study the composites produced by using

plastics matrix which has several prominent properties namely Acrylonitrile-butadiene-styrene terpolymer (ABS). ABS combines strength, rigidity, and toughness. In addition, it offers endurance, resistance to chemical substances and can be used in a wide range of temperatures. Each co-monomer in ABS provides different properties for the tailor-made ABS. Acrylonitrile affects on heat and chemical resistance, butadiene monomer offers the impact properties whereas styrene monomer provides on surface finishes and processability. As a result, ABS plastics have various properties by changing the proportion of these monomers.

The purpose of this work is the investigation of composites originated from wood and different grades of ABS plastics based on various ratio of co-monomer content, on their thermal and mechanical properties of wood sawdust/ABS composites.

Experimental

Materials

Three grades of ABS are supplied by IRPC PLC. There are high flow (HF-ABS), medium impact (MI-ABS) and super high impact (SI-ABS) grades. Their co-monomer content and the average molecular weight are shown in Table 1. Wood sawdust particles are supplied by V.P. Wood Co., Ltd. and the average size was in the range of 100–300 microns. The contents of wood sawdust particles added into ABS were 10 and 50 parts per hundred (phr). N-2(aminoethyl)-3-aminopropyl trimethoxy silane from Sigma-Aldrich Inc. (Germany) was used as coupling agent for enhancing interfacial strength between sawdust and ABS.

Table 1 Specification of ABS plastics

ABS	% Acrylonitrile	%Butadiene	%Styrene	\bar{M}_v
HF-ABS	18.9	9.5	71.5	310,000
MI-ABS	20.7	8.6	70.7	540,000
SI-ABS	21.4	12.5	66.2	340,000

Compounding and molding

Sawdust surface was treated by silane coupling agent with 0.5%wt of sawdust. Treatment procedure was detailed as in previous work [1]. Treated sawdust and ABS were dried in oven for 24 hours before blending process. And then, they were dry-blended by high speed mixer for 2 min. After that, ABS and sawdust were compounded by twin screw extruder. The blending temperature profiles on the extruder were 170-190 °C from hopper to die zone. The screw speed was 80 rpm. The extrudates were then passed a pelletizer and then held in an oven for 24 hours at 80 °C. Dried composite pellet were molded to form specimens by compression molding machine at temperature of 190 °C.

Thermo gravimetric analysis (TGA)

Thermal degradation of composites was characterized by thermo gravimetric analyzer (Perkin-Elmer; TGA7). The samples mass ranging from 5 to 8 mg were heated from 50 to 600 °C at rate of 10 °C/min in nitrogen atmosphere.

Dynamic mechanical analysis (DMA)

Dynamic-mechanical property of composites was performed on Dynamic mechanical analyzer (GABO, EPLEXOR QC 25). The specimen’s dimensions is 10x60x2 mm cut from composites sheet, were tested by tension mode with frequency 10 Hz. The studies were done in the range of temperature of 50-150 °C and heat rate of 2 °C/min.

Results and discussion

Thermo gravimetric analysis (TGA)

The thermal decomposition behavior of HF-samples (both neat and composite) was shown in Figure 1 and their decomposition temperatures were listed in Table 2. TGA curves of HF-ABS shows one step for the degradation of ABS main chain whereas the composites show two steps of weight loss processes. The first degradation process representing sawdust decomposition was illustrated in the temperature range 250-350 °C. The second step between 350 and 470 °C was assigned to the degradation of ABS plastics. These phenomena were also found in those samples of MI-ABS and SI-ABS composites.

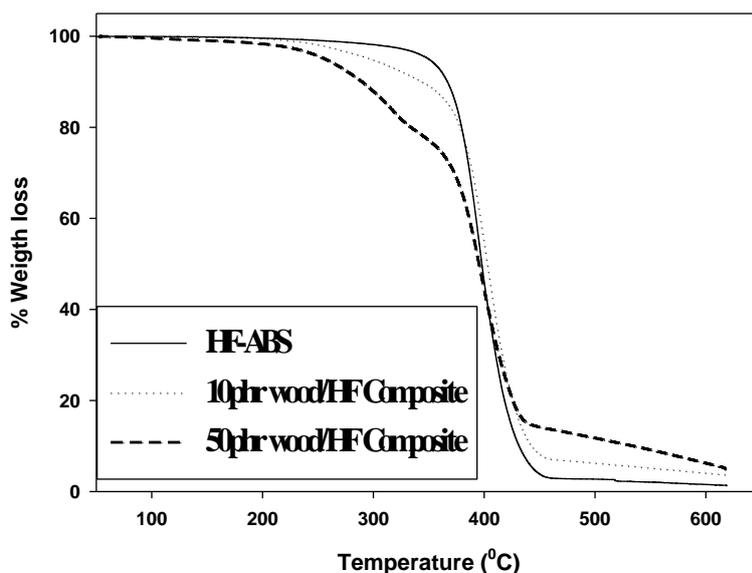


Figure 1 TGA curves of neat HF-ABS and wood sawdust/HF-ABS composites.

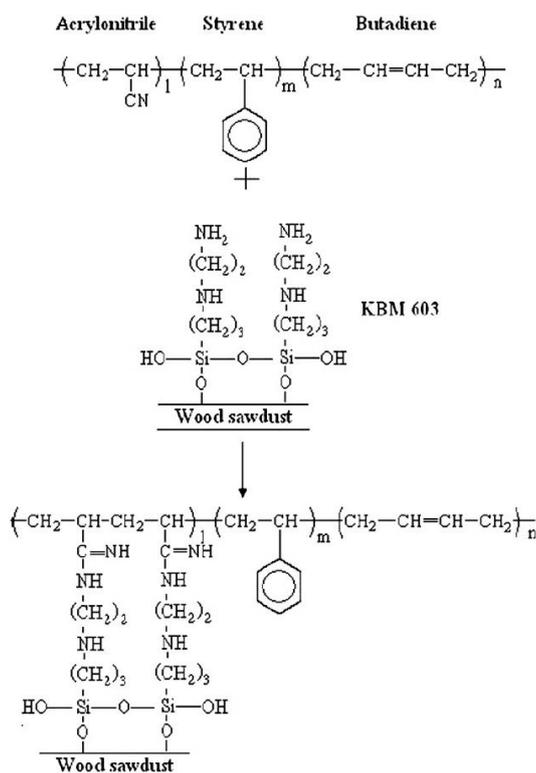


Figure 2 Adhesion mechanism of N-2(aminoethyl)-3-aminopropyl trimethoxy silane in wood sawdust/ABS composites[2]

Table 2. The decomposition temperature of neat ABS and their composites

ABS	Decomposition temperature T_d , °C		
	Neat ABS	Low-sawdust composites (10 phr)	High-sawdust composites (50 phr)
HF	395.0	399.6	393.7
MI	393.3	392.0	393.8
SI	397.3	396.9	393.5

From Table 2, the decomposition temperature of polymer phase in MI-ABS and SI-ABS composites in case of low wood sawdust content show slight difference from those of neat ABS. Whereas thermal stability of plastic in HF-ABS composites is somewhat improved compared with the neat HF-ABS. HF-ABS is composed of the lowest amount of acrylonitrile content thus giving the least probability to have the chemical reaction of $-CN$ groups in acrylonitrile and $-NH_2$ groups in the amino-silane coupling agent. The adhesion mechanism was previously discussed by L.Chotirat et al. [2] as seen in Figure 2. The excess silane coupling agent at the interfacial wood sawdust layer would then form silane cross-linking i.e., condensation reaction of silane that resulted in coupling silane molecules together and forming polysiloxane network which can improve thermal stability of materials [3, 4]. Meanwhile, degradation temperatures of high-sawdust composites show no difference among themselves due to the dilution effect as shown in Table 2.

Dynamic-mechanical analysis (DMA)

Dynamic mechanical properties were analyzed for neat ABS and their composites. Their results were illustrated in Figure 3-5 showing the storage modulus (E'), loss modulus (E'') and $\tan \delta$ as a function of temperature.

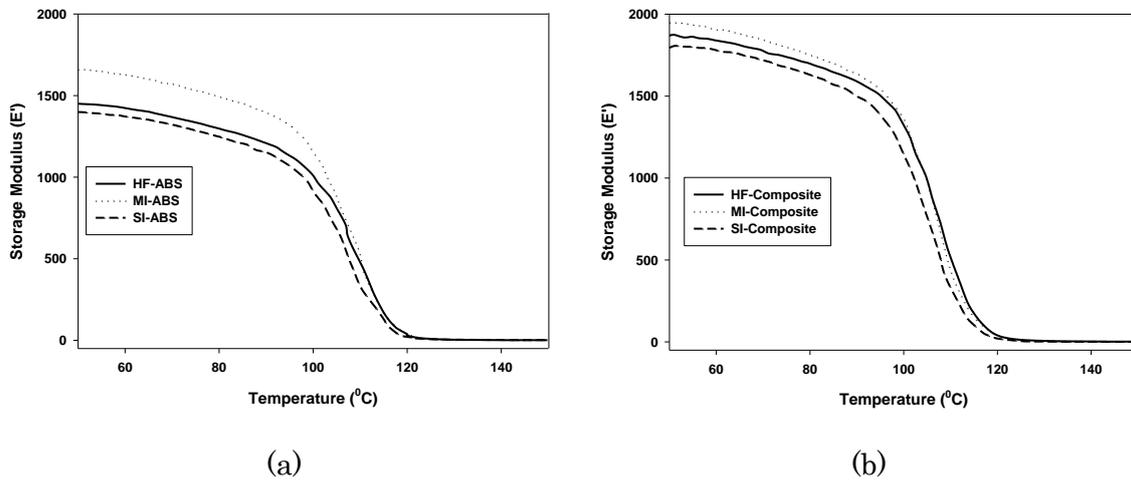


Figure 3 Storage modulus of (a) neat ABS and (b) their composites with 10 phr wood sawdust content

Storage modulus (E') related to elastic response of polymer which could store the energy like a spring. Loss modulus (E'') was proportional to viscous response of polymer which dissipated the energy in the deformation process. The presence of rubber phase in materials improved the toughness with the sacrifice of the modulus of materials. The storage modulus of neat ABS (Figure 3a) was higher than ABS composites (Figure 3b) because of presence of higher modulus of wood sawdust. The storage modulus of neat MI-ABS and MI-ABS composites with the highest butadiene content were higher than HF-ABS and SI-ABS respectively.

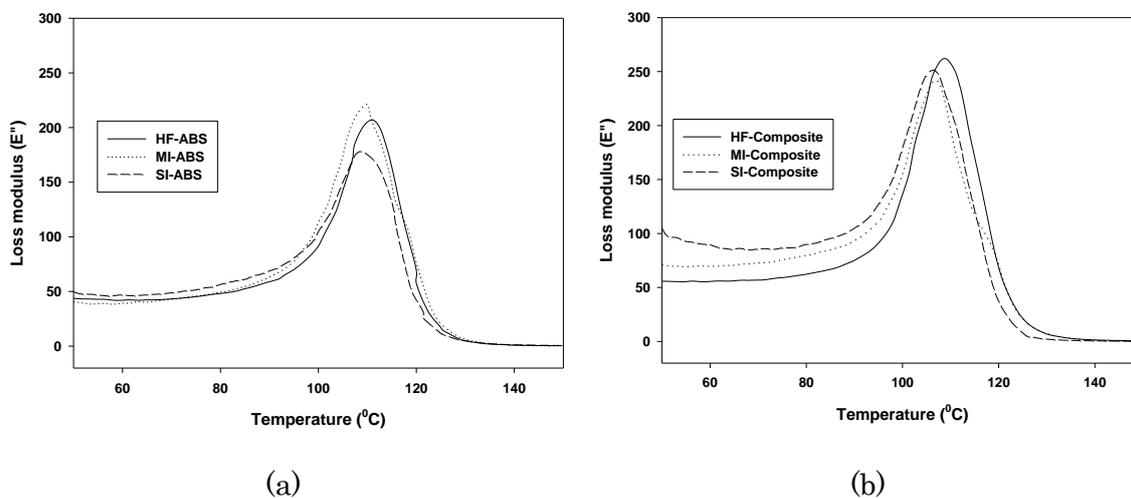


Figure 4 Loss modulus of (a) neat ABS and (b) their composites with 10 phr wood

sawdust content

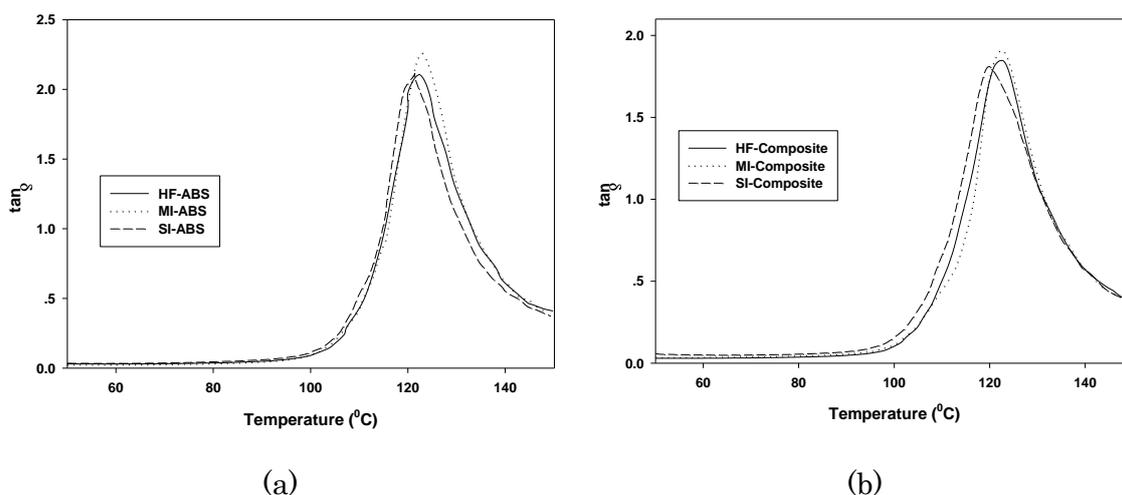


Figure 5 Tan δ of (a) neat ABS and (b) their composites with 10 phr sawdust content

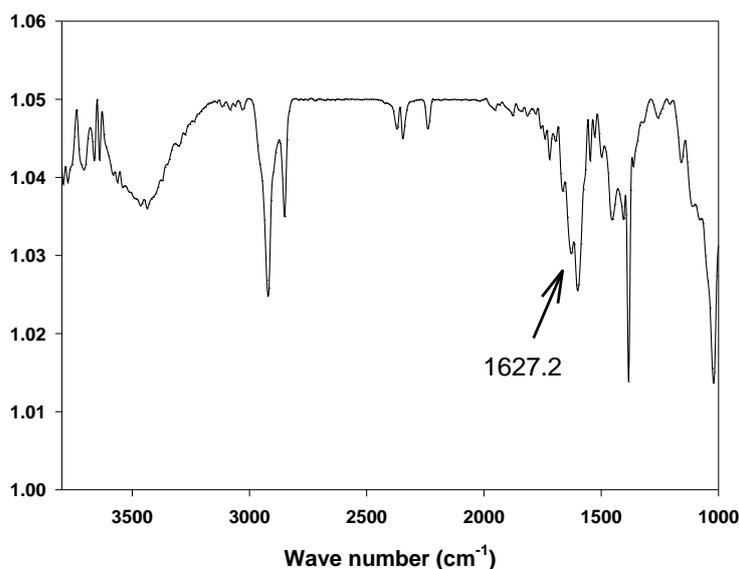


Figure 6 FTIR spectra wood sawdust/MI-ABS composites

Tan δ or damping factor is represented by the ratio of loss modulus to storage modulus (E''/E'). The materials with high tan δ value means that they would exhibit more viscous-like behavior. From Figure 5, the temperature at which tan δ show the maximum value, materials have changed from elastic-like to viscous-like behavior. And that temperature refers to the glass-transition temperature (T_g) of materials. In general, T_g value was expected to increase by the covalent bond ($-\text{C}=\text{N}$) at the acrylonitrile monomer during the wood-silane-ABS interaction as depicted in Figure 2. Nevertheless, neither neat ABS nor composites show any different of T_g value at 122 $^{\circ}\text{C}$ that is the transition temperature of ABS

phase regardless of the FTIR confirmation data seen in Figure 6. It illustrated the interaction between wood-silane-ABS. Previous work by Chotirat et al.[2] also found that the peak which refer to the bonding between phase as well as all samples in this study. Beside, the limitation of added silane amount, the coupling reaction was likely low and insufficient to cause any change for the transition temperature (T_g) of ABS. Henry et al [5] found that filler has no effect on T_g of elastomeric systems and Ruy et al. [6] investigated that composites and their neat polyurethane materials had no significant change in transition temperature as well.

Conclusions

For thermal properties, in 10 phr wood sawdust composites of both SI-ABS and MI-ABS composites showed the same range of decomposition temperature as compared with neat ABS. While the HF-ABS composites were influenced by polysiloxane and resulted in improved thermal stability when compared with HF-ABS neat plastics. On the other hand, the higher sawdust at 50 phr composites showed no difference in thermal stability because of the dilution effect.

For mechanical properties, the storage modulus of neat ABS was higher than ABS composites because of presence of higher modulus of wood sawdust. The storage modulus of neat MI-ABS and MI-ABS composites with the highest butadiene content were higher than HF-ABS and SI-ABS respectively. This could also due to the effect of rubbery butadiene content.

Acknowledgements

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