計畫名稱：聚氯乙烯/木纖維複合材料製成微泡膠其機械性質之研究
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ABSTRACT

A series of wood fiber reinforced PVC composites were prepared. Three different types of mixture were formed under the same conditions: (1) PVC alone, (2) 30 phr of untreated wood fiber/PVC composites, and (3) 30 phr of silane treated wood fiber /PVC composites. Sorption experiments were carried out on these composites through the dissolution of CO_2 in the composites. Then, the gas-saturated composites were microcellular foamed. The effects of the wood fiber and coupling agent (silane) on the mechanical properties of the microcellular foamed composites were investigated.

INTRODUCTION

A microcellular plastic is a polymeric foam characterized by cell sizes in the range of 0.1 to 10 μm and cell density in the range of 10^9 to 10^{15} cells/cm^3. The development of these materials is based on the idea that the creation of a very large number of microbubbles, smaller than the pre-existing natural flaws in a polymer, can reduce the material cost and consumption in mass produced plastic parts without compromising mechanical properties.

It has been shown that microcellular foamed plastics possess higher impact strength, increased toughness, prolonged fatigue life, and an increased thermal stability as compared to unfoamed polymers. Moreover, the specific density reduction can reach 75% or higher. Due to these unique properties, microcellular plastics can be used in a large number of innovative industrial applications. These include lightweight and high-strength parts for automotive and aerospace industries. Applications are also available for furniture, sporting goods, and packaging as well as thermal and electrical insulators. In addition, this process is environmentally attractive, since the non-reactive gases (e.g. CO_2 or N_2) used in this process do not contribute to the depletion of the ozone layer.

However, microcellular foams of reinforced plastic composites have not been studied extensively. In this paper, microcellular foaming of wood fiber reinforced PVC is investigated. Presently, the fiber-reinforced plastic composites markets, which represent one-third of all performance plastics, are dominated by glass fiber (93% of reinforcement materials) and some of other inorganic fillers such as talc, mica, clay, and calcium carbonate. These high-density conventional fillers offer wide property changes in the composites, but on a volumetric basis, their use is not cost-effective.

Because wood fibers are strong,

lightweight, abundant, renewable, recyclable, nonhazardous, biodegradable, and cost-effective, they can serve as excellent additions for many types of plastic and can supply a number of desirable properties to the composite that could not be obtained if the product was made from either material alone. In this paper, wood fibers were used as reinforced fibers.

Despite these advantages, the first issue confronting the design of plastic/wood-fiber composites is the incompatibility of phases due to the mixing of the hydrophillic wood-fiber with hydrophobic polymer matrix [1-4]. The interfacial adhesion plays a great role in controlling the mechanical properties of the composites, particularly, in PVC/wood-fiber composites. In this paper, silane was used as a coupling agent to enhance the compatibility between wood fibers and PVC matrix.

EXPERIMENTAL

Three steps were involved in the production of microcellular foamed PVC/wood-fiber composites. First, the composites were manufactured by compounding PVC with either untreated or treated wood-fiber in a high intensity turbine mixer. Before being treated with silane, wood-fibers were pre-dried in the turbine mixer to reduce the moisture content of fibers. This was followed by adding 0.3 phr (1 phr is equivalent to 1 part of silane per hundred of PVC) of silane to the cooled, pre-dried fibers and then mechanically mixing the treated fibers to insure a good dispersion of silane onto the fibers. The compounded materials were compression-moulded into panels. Three different types of mixture were formed under the same condition: (1) PVC alone, (2) 30 phr of non-treated wood-fiber/PVC composites, and (3) 30 phr of silane-treated wood-fiber/PVC composites Second, sorption experiments were carried out on these composites through the dissolution of CO_2 in the composites. The compression-moulded sheets of 0.25 cm thickness were cut into 10 cm X 14 cm rectangular samples. The weight of these samples were measured using a microbalance. The sample were then placed in a pressure chamber and saturated with CO_2 at various pressures (2.5 to 5.5 MPa) at room temperature for 5 hours. Once the time was reached, the CO_2-saturated samples were removed from the pressure chamber and weighed again on the balance to determine the amount of CO_2 absorbed. Finally, the gas-saturated composites were microcellular foamed. This was achieved by dipping the saturated sample in a glycerol bath which was maintained at 150℃. The foaming time was 30 seconds in all the foam experiments. The foamed samples were characterized by a scanning electron microscope to investigate the effects of wood-fiber and treatment on the cell morphology of the foamed composites. The foamed samples were machined according to ASTM satndard D638, type IV with a gage width of 0.6 cm and a gage length of 2.54 cm. They were pulled on an tensile machine at a rate of 2 cm/min at room temperature.

RESULTS AND DISCUSSION

Figure 1 compares the percentage of gas-uptake between pure PVC, untreated, and treated wood-fiber/PVC composites at various of saturation pressures. It was found that the percentage of gas-uptake increased with increasing saturation pressure in all three types of sample. It was also found that pure PVC has the highest percentage of gas-uptake among the others. This indicates that the introduce of wood-fibers into the PVC matrix decreased the solubility of CO_2 in the composites. The decrease in the solubility of CO_2 implies that only the amorphous region in the composite (i. e., PVC) absorbs the gas. Wood-fibers would reject CO_2 and act like crystallites. The use of wood-fibers in the composites tends to decrease the volume of amorphous material available for diffusion; wood-fiber regions in the composites obstruct the movement of CO_2 molecules and, therefore, increase the average length of the paths they have to travel. As a result, the diffusivity would decrease as the polymer mass fraction decreases in the composites. For the composite with untreated wood-fibers, the percentage of gas-uptake, in general, was greater than those treated wood-fiber composites. This might be attributed to the poor surface adhesion between PVC and wood-fiber in the composites. The lack of intimate adhesion between composites leads to the composite containing many voids and pockets. These voids and pockets served as a sink for the gas-uptake.

Figure 2 compares the tensile strength between untreated and treated wood-fiber foamed composites at various of saturation pressures. It was found that the tensile strength decreased with increasing saturation pressure in both types of sample. The tensile strength of silane treated wood-fiber composite was slightly greater than those untreated wood-fiber/PVC composites at each saturation pressure. This implies that silane did serve as a coupling agent between wood-fibers and PVC matrix, thus increasing the interfacial adhesion between wood-fibers and PVC matrix. Figure 3 compares the percent elongation at break between untreated and treated wood-fiber foamed composites at various of saturation pressures. In general, the percent elongation at break increased with increasing saturation pressure in both types of sample. This is because the large bubbles produced at higher saturation pressure would impede the crack propagation thus increasing the percent elongation at break.

Figures 4 (a) and (b) are micrographs of untreated and treated wood-fiber foamed composite, respectively. The insufficient adhesion untreated wood-fibers and PVC matrix causes a fiber pull-out when the samples were fractured. However, for the treated wood-fiber foamed composite, the improved adhesion between wood-fibers and matrix causes fiber breakage when the sample were fracturecfor SEM pictures.

CONCLUSIONS

1. The inclusion of wood fibers in the composite decreased the amount of gas up-take for both untreated and treated wood-fiber/PVC composites.

2. The silane treated wood-fiber foamed composites showed slightly better tensile strength than untreated one, which implies silane acted as a coupling agent in the composite.
3. The morphology between untreated and treated wood-fiber/PVC composites was different.

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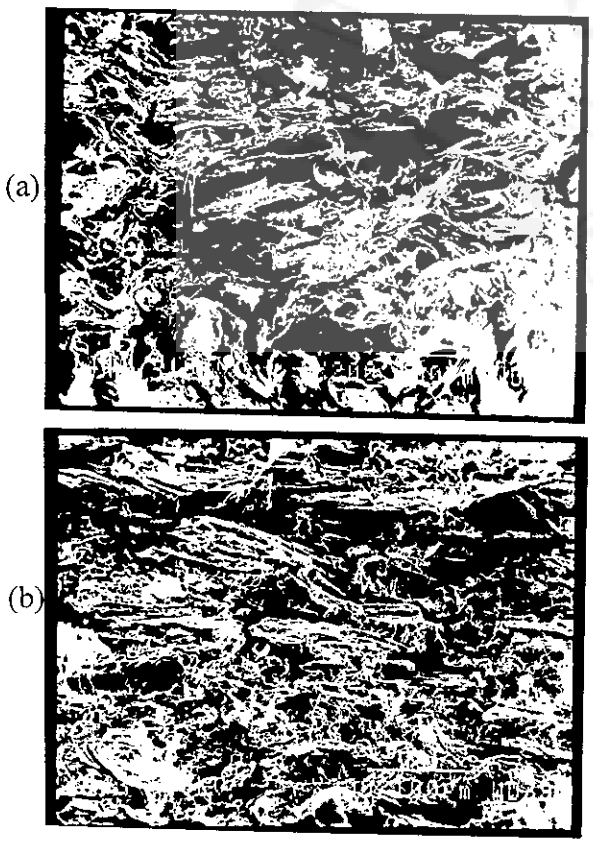

Figure 4. Comparison of morphology between (a) untreated and (b) treated wood-fiber foamed composites.

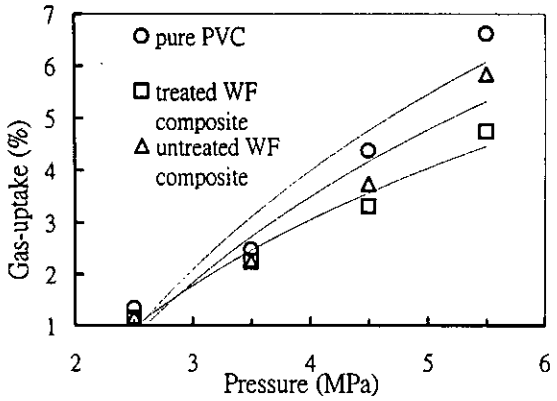

Figure 1. Comparison of gas-uptake between pure PVC, untreated, and treated wood-fiber composites.

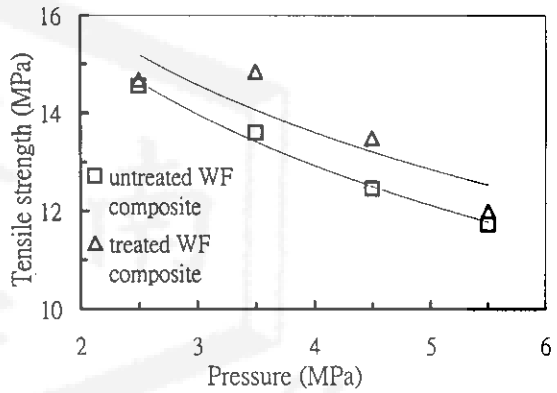

Figure 2. Comparison of tensile strength between untreated and treated wood-fiber foamed composites.

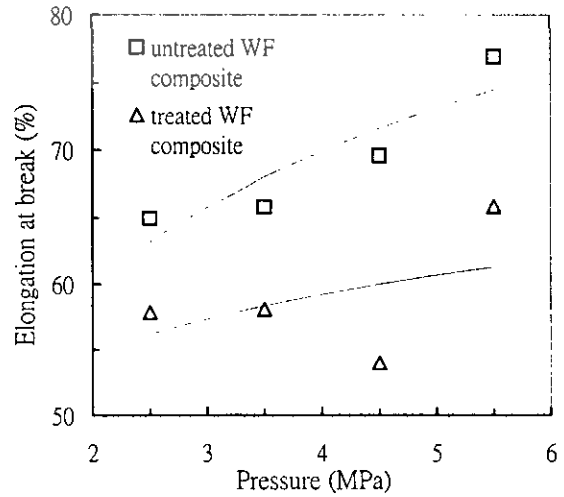

Figure 3. Comparison of elongation at break between untreated and treated wood-fiber foamed composites.