Effect of Gypsum Content on the Properties of PVC/Gypsum Polymer Blend Material: Physico-Mechanical Properties, Thermal Properties and Morphology Development

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SUMMARY: Polyvinyl chloride (PVC)/gypsum polymer blend materials were prepared by melt blending of PVC with gypsum and additives. Effect of gypsum content on the properties of PVC/gypsum polymer blend material was studied by investigating physico-mechanical properties, thermal properties and morphology development. It was found that the replacement of gypsum for methylene-butadiene-styrene (MBS) component in PVC/gypsum polymer blend material enhanced the tensile strength, but gradually decreased its impact strength. Besides, with the increase of gypsum content, the elongation at break of material gradually decreased. The presence of the different gypsum contents made a shift of glass transition temperature and increased the thermal stability as well as the processing temperature range of polymer blend materials. The observation of morphology, the results of the physico-mechanical properties and thermal properties proved simultaneously that PVC/gypsum polymer blend material with the gypsum content of 22.56 wt.% reached the optimum results among five kinds of PVC/gypsum polymer blend materials investigated.

KEYWORDS: Gypsum, PVC, blend.

INTRODUCTION

Polyvinyl chloride (PVC), as an important commercial polymer, has been studied and used widely in industrial fields for many years. However, due to its inherent disadvantages, such as low thermal stability and brittleness, PVC and its blend are subjected to some limitations in certain applications [1]. The wet phosphoric acid has obtained by dissolving phosphate ore into sulfuric acid in a artificial way, Namhae Chemical Company has been obtained the wet phosphoric acid according to this way to produce phosphatic fertilizers. A lot of obsolete gypsum produced in this process have been buried. Gypsum consists of a dihydrate sulphate calcite ($CaSO_4.2H_2O$), anhydrate sulphate calcite ($CaSO_4.H_2O$), calcite oxide (CaO), phosphate, and with particle size less than 200 nm. Though a lot of researches on recycling the abandoned gypsum in advanced countries, for example Germany and Japan etc. are being conducted, actually, a small amount of gypsum are used for plaster boards but most are buried in the sea wasting tremendous amount of expenses [1]. Especially, there is no example so far that has researched the mechanical and physical properties of a product by using the gypsum onto PVC resins.

Hence, in polyvinyl chloride (PVC)/gypsum polymer blend research, the primary goal is to enhance the strength end toughness of polymer component using nanoscale reinforcement gypsum. Therefore, in this paper, we mainly investigated the effect of gypsum content with and without the presence of MBS content on the physico-mechanical properties, thermal properties of the PVC/gypsum polymer blend material. Five kinds of rigid PVC/gypsum polymer blend with different gypsum contents were prepared by melt blending method. The morphology development of the PVC/gypsum polymer blend samples is also discussed in this paper.

EXPERIMENTAL

Materials

Suspension polymerization PVC (PVC LS-100, DP = 1000) was provided by Lucky Co. LTD, Korea. Gypsum was produced with particle size less than 200 nm by Namhae Chemical Co, Korea; the composition of gypsum was shown in Table 1. The component ratios of PVC/gypsum and additives used to observe the change of dynamic properties base on the difference of gypsum content was shown on Table 2.

Preparation of PVC/gypsum Polymer Blend Materials

PVC/gypsum polymer blend samples were prepared by melt mixing PVC, gypsum, and processing additives in the roll-mill (Nishimura, KR-250, Japan) at 175^{o}C for 5 minutes. After that, the polymer blend samples were quickly molded into sheets of 3mm in thickness by hot pressing machine (Wabash, G302-BCLX, USA) at 175^{o}C and 20 MPa for 5 minutes, followed by cooling to room temperature at 5 MPa. The sheets were prepared for the structure characterization and the property measurements.

Table 1 Chemical composition of Gypsum (wt.%)

	COM	AVG	STD	MIN	MAX
D-Gypsum	TP-	1.30	0.79	0.32	3.89
	WSP-	0.93	0.68	0.19	3.01
	CaO	33.7	10.37	29.00	36.30
	F-H_2O	23.00	5.76	10.90	36.70
	C- H_2O	17.60	2.65	9.60	20.40

Where:
D : Dry; TP- : Total Phosphate; WSP- : Water Soluble Phosphate; F-H_2O: Free - H_2O;
C- H_2O : Combined - H_2O; COM : Composition; AVG : Average; STD: Standard;
MIN: minimum; MAX : Maximum

Table 2. Sample code and composition of polymer blend material

	PVC (g)	Lubricant (g)	Stabilizer (g)	MBS (g)	Gypsum (g/wt.%)
PVC0	100	0.5	3.0	-	-
PVC1	100	0.5	3.0	7.0	20.0/15.38
PVC2	100	0.5	3.0	-	20.0/16.26
PVC3	100	0.5	3.0	-	30.0/22.56
PVC4	100	0.5	3.0	-	40.0/27.97
PVC5	100	0.5	3.0	-	50.0/32.67

RESULTS AND DISCUSSION

Physico-Mechanical Properties:

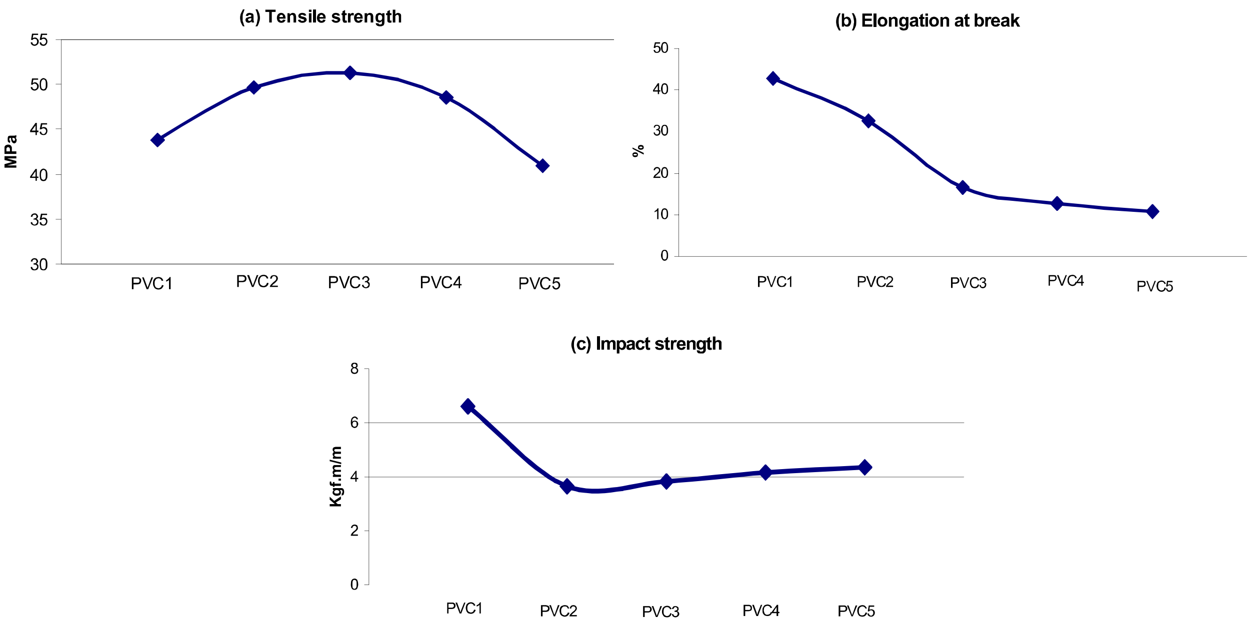

Fig.1 Physico-mechanical properties of PVC complexes containing various amounts of gypsum. (a: Tensile strength, b: Elongation at break, c: Impact strength)

Upon adding of gypsum to the PVC compound replacing the MBS on PVC2 sample with the content of gypsum of 16.26 wt%., the tensile strength of PVC compound was increased from 43.8 MPa up to 49.6 Mpa (Fig. 1a). The highest tensile strength among five samples was measured on PVC3 sample with the gypsum content of 22.56 wt%, reached a value of 51.3 MPa, then which gradually decreases to 48.5 MPa and 40.9 MPa as the amount of gypsum phase increases at PVC4 and PVC5 samples, respectively. On observation of the elongation at break of PVC compound samples, when MBS, as a reinforcement agent, was rejected from PVC compound, the elongation at break drop drastically from 42.9 % (PVC1, 15.38 wt% gypsum) to 32.7 % (PVC2, 16.26 wt% gypsum) , then 16.5 % (PVC3, 22.56 wt% gypsum), and then gradually decrease to 12.7 % (PVC4, 27.97 wt% gypsum), to 10.85 % (PVC5, 32.67 wt% gypsum). It was revealed that the gypsum phase plays a role as an inorganic distributed phase, which causes a decrease of the flexibility of PVC matrix phase because of the small particle side of gypsum (around 200 nm), which easily intercalated into the vacancy of the bulk polymer [2]. From the impact strength observed, Fig. 1c, comparing between the samples with and without of the presence of the MBS phase the impact strength of PVC compound sample dramatically decreases from 6.61 Kgf.m/m to 3.65 kgf.m/m. It revealed that the gypsum phase not only plays a role as good filler, but also is a good interactive inorganic material with PVC matrix phase, which was well dispersed in the polymer system, and hence good impact strength..

Thermal Properties:

On the observation of glass transition temperature of five samples (Fig. 2), it was obvious that had existentially a limitation of the distribution of the gypsum phase over PVC matrix phase at which made a highest shift of the glass transition temperature. It should be noted that highly electronegative chloride atoms of PVC chains endow PVC with strong polarity. At the same time, large quantities of polar hydroxyl group of gypsum (as showed in Table 1) and calcium (Ca^{+}) layers existing on the surface of gypsum particles make the layer surface polar too. In this case, the dipole-dipole interaction between PVC matrix phase and gypsum dispersed phase may act as driving force for gypsum phase to intercalate into PVC phase. Fig 3 shows the TGA curves of the PVC/gypsum blend samples. It was interesting that for the case of without the presence of gypsum, the decomposed temperature of polymer was about 278 ^{o}C, however, for the other later cases, the decomposed temperature of polymer blend was about 285 ^{o}C. This might be expected that calcium oxide (CaO) presented in gypsum composition which played a role as a fire resistance, effectively scavenge HCl gas liberated from burning halogenated polymer (PVC), thereby reducing the corrosiveness of the generated smoke, and improving the thermal stability of PVC/gypsum polymer blend samples [3].

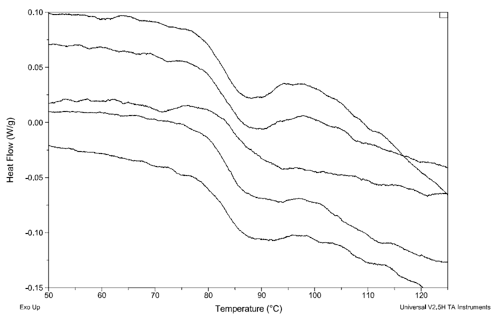

Fig. 2 DSC diagram of PVC complexes containing various amounts of gypsum.

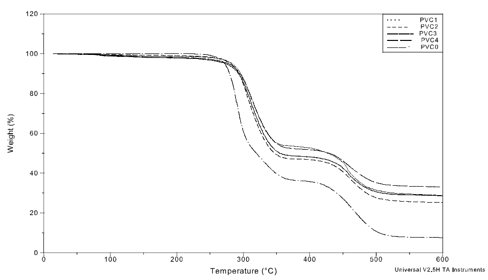

Fig. 3 TGA diagram of PVC complexes containing various amounts of gypsum

Morphology of PVC/Gypsum Blend Material

On observation of the distribution of gypsum phase (Fig. 4), it obviously had the change of the morphology of each other. It is clearly realized that for the case PVC3 sample, gypsum phase was best dispersed among the investigation of four given samples, gypsum particles finely intercalated into PVC matrix phase and made significantly a change on morphology of sample. This suggested that the physico-mechanical properties vary in accordance with the morphology changes of the polymer blends. Thus if the gypsum content exceeds 22.56 wt.%, it event will influence no good on the physico-mechanical properties because of the appearance of the coalescence effect.

CONCLUSIONS

The PVC/gypsum blend material was obtained via a melt blending process. The physico-mechanical properties was investigated base on the different gypsum content of the blend samples to establish the mechanical strength of this material. The highest tensile strength of this material was measured at PVC 3 with the content of gypsum component of 22.56 wt.%.

Finally, as a result of adding the gypsum buried in the sea to PVC resin, we cannot only get the polymer blend material that has such superior physico-mechanical properties and thermal stability, but also solves the enviromental problems by using waste matters.

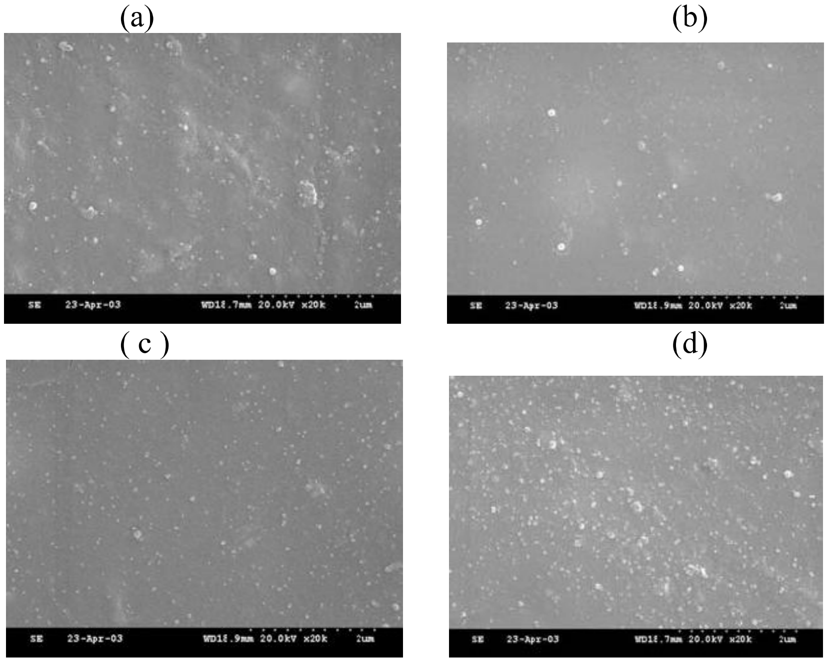

Fig. 4 Micrographs of PVC complexes containing various amounts of gypsum.
(a: PVC1, b: PVC2, c: PVC3 and d: PVC4)

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