

## THERMAL PROPERTIES & HARDNESS OF PA6/HDPE/ SEBS-g-MA/CLAY NANOCOMPOSITES

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### Abstract

*Thermal properties & hardness of PA6 / high density polyethylene (HDPE)/ SEBS-g-MA / Modified clay nanocomposites were studied. Mixing was performed using melt processing in an Extruder Co rotating Twin Screw. The hardness & thermal properties included melting temperature, melting enthalpy and heat deflection temperature were studied.*

*The thermal properties and hardness of these nanocomposites are discussed in terms of the nanoclay and SEBS-g-MA contents. Adding of nanoclay increased hardness but reduced the thermal properties of produced nanocomposites slightly but presence of SEBS-g-MA as a compatibilizer enhanced and improved thermal properties as well as hardness property.*

### 1 Introduction

Nanocomposites based on thermoplastic polymers and clay, especially with organically modified montmorillonite, are a group of materials that have been investigated with growing intensity since the beginning of the 1990s [1] because of their improved properties at very low clay loading compared with conventional filler composition [2].

PA6 is one of the most widely used engineering polymers, but it has some disadvantages such as brittleness, high moisture absorption and poor dimensional Stability. To overcome these disadvantages PA6 is frequently blended with polyethylene, although they are incompatible. When incompatible polymers are blended, they usually form multiphase morphologies. This characteristic is also shown in Polyethylene and PA6 blends [19-23].

This study investigated the hardness and Thermal properties through mixing different composition ratios for nanocomposite system PA6/ HDPE/ SEBS-g-MA/ Clay and the best composition ratios has been selected based on the observed properties results.

## **2 Materials and testing methods**

### *2.1 Materials:*

PA6 was used with a density of 1130 kg/m<sup>3</sup> which was the product of Royal DSM Company (Netherlands); Polyethylene used was high density polyethylene, grade HCH5110 with a density of 995 kg/m<sup>3</sup> and MW 247 g/mol which was the product of Aryasol polymer Company (Iran); the modified organo-montmorillonite used was Cloisite 30B produced by Suther Clay Company (USA) which had 18.5 Å interlayer spacing with Ion modifier (methyl, tallow, bis-2-hydroxyethyl, quaternary ammonium) and a cation exchange (CEC) of 90 meq/100g clay; Styrene Ethylene Butylene Styrene rubber (SEBS-g-MA) with brand name Kraton FG1901X is a S-EB-S type block polymer which has been grafted with 2%w maleic anhydride.

### *2.2 Testing methods & apparatuses*

2.2.1 Extruder co-rotating twin screw, model plasticorder, Brabender, Germany; for sample preparation

2.2.2 Differential scanning calorimeter, model STARe DSC 822e, METTLER TOLEDO; for determination of temperature & enthalpy of melting according to ISO11357

2.2.3 HDT/Vicat Analyser, model HDT 3 Vicat, Ceast, Italy; for determination of heat deflection temperature according to ISO 75.

2.2.4 Hardness durometer, model BH04.3131.000, Zwick, Germany; for determination of hardness shore D according to ISO 868

2.2.5 Scanning electron microscope (SEM), model VEGA//, TESCAN Company, Czech.

SEM was used to evaluate and determine the morphology and the compatibility between PA6 and HDPE polymers. The prepared nanocomposites put in liquid Nitrogen and after completed quenching process, these samples have been broken and in order to extract SEBS-g-MA from the broken surfaces. They have been kept in THF solvent for 24 hours at room temperature. Finally, to create a proper electrical conductivity for electron capture, the surface of samples were coated by gold before SEM test.

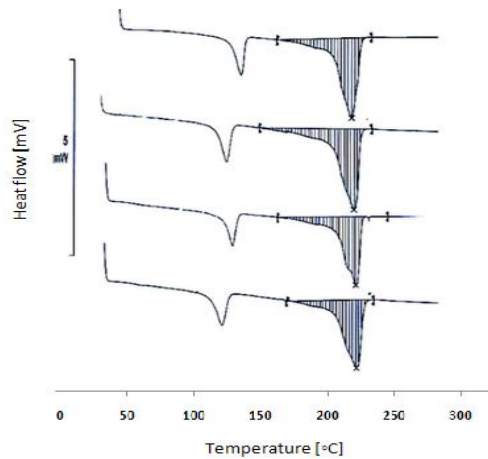
## **3 Description of the analysis**

### *3.1 Sample preparation*

The nanocomposites have been prepared through melt processing using an extruder co-rotating twin screw with 60 rpm speed according to the temperature program (feed 230°C; melting zones 235, 236, 237, 238 & 240°C; die 245°C). The samples with composition of 72% polyamide and 8% high density polyethylene and different weight percents of clay nanoparticle and elastomer SEBS-g-MA were prepared.

### *3.2 DSC Analyze*

The melting & fusion enthalpies of prepared nanocomposites were studied by differential Scanning Calorimetry. The samples sealed in Aluminum pan were heated from 50 to 300 °C at 10°C/min, held at 250°C for 5 min, cooled back to 50°C at 10°C/min, held at 50°C for 5 min and then the second heating and cooling similar to the first were performed in order to remove the thermal history. The melting temperature (T<sub>m</sub>) and fusion enthalpy were measured through DSC thermograms. In all samples two strong melting peaks were observed in 120-125 °C for HDPE and 217- 220°C for PA6 (figure 1).



**Figure 1.** DSC thermograms of prepared nanocomposites

The measured results are listed in the below table 1.

SEBS-g-MA [wt%]	Clay [wt%]	Tm of PA6 [°C]	Enthalpy [J/Kg]
17	3	219.6	49130
15	5	220.5	47190
13	7	219.3	46620
10	10	217.3	95470

**Table 1.** DSC results of prepared samples

The melting temperature of PA6 was significantly increased which address more uniform distribution and dispersion of HDPE through using optimized nanocaly and compatibilizer ratios in the PA6 matrix also when nanocompsites was compatibilized with SEBS-g-MA

The addition of SEBS-g-MA into PA6/HDPE/nanoclay led to the phase transformation from  $\gamma$  to  $\alpha$  form crystals of PA6 phase.

Sample containing 5 wt% clay nanoparticles with high melting point can address more interactions of clay layers with polymer and proper dispersion of the particles which led increasing of melting temperature as well.

### 3.3 HDT analyze & Hardness

The heat deflection temperature was measured by HDT apparatus, oil bath, programmed with heat rate 50°C /hr with 0.45 MPa force. The hardness shore D measured with mentioned apparatus and 50N force. The measured results are listed in the below table 2:

Clay (wt%)	HDT[°C]	Hardness[ShoreD]
3	58.8	64.1
5	59.7	65.2
7	59.4	64.8
10	59.1	64.4

**Table 2.** HDT & Hardness results of prepared samples

The results again addressed that by adding 15% of SEBS-g-MA elastomer, more uniform distribution and dispersion of HDPE can be created in the PA6 matrix and due to less distance and more uniformity between nanoparticles better morphology and higher hardness have been obtained.

### 3.4 SEM results

SEM images (Fig 2) also confirmed that by adding 15% of SEBS-g-MA elastomer, more uniform distribution and dispersion of HDPE was observed in the PA6 matrix and due to less distance and more uniformity between nanoparticles better morphology and higher hardness and melting point have been obtained.

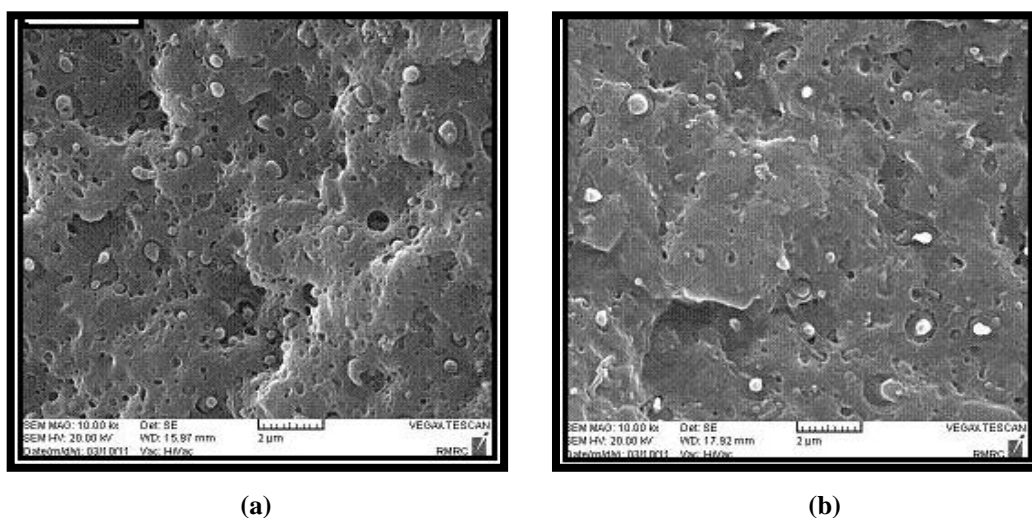


Figure 2. SEM images of nanocomposite samples (a) with 15% elastomer (b) with 13% elastomer

## 4 Conclusions

Adding of Cloisite 30B increased hardness but reduced the thermal properties of produced nanocomposites slightly but presence of SEBS-g-MA as a compatibilizer enhanced and balance thermal properties as well as hardness property. In other words, the addition of elastomer compound to this nanocomposite system has created a balance between hardness versus thermal properties.

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