ACRYLONITRILE BUTADIENE STYRENE (ABS)/MICA COMPOSITES: PREPARATION AND CHARACTERIZATION

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Abstract

Composite materials are made by combining two or more materials. Composite materials achieve new and unique properties compared to the component materials. Polymeric composite materials consist of a major phase composed of polymer matrix and a minor phase of reinforcing fillers. This study focuses on Acrylonitrile Butadiene Styrene (ABS) as the matrix and mica as the filler. ABS is one of the versatile plastics with high melting point, hardness and strength. Mica is one of the unique plastic fillers in terms of mechanical, thermal, chemical and electrical properties. Five composition with mica contains of 0, 5, 10, 20 and 30 wt (%) where prepared. The mixed materials are shaped into standard specimens through injection molding machine. The prepared composites were tested for structural, mechanical and thermal properties. It's found that, the addition of 30% mica remarkably increases the flexural modulus, tensile modulus and flexural strength by 130%, 55% and 28% respectively, while it decreases the tensile elongation by 77%. On the other hand, the impact strength of the composites is reduced by 75% due to the addition of 30% mica. Based on Fourier transform infrared spectrometry (FTIR), its observed that, as the wt (%) of mica increases the intensity of the peak increasing, while the increasing of wt (%) have a very minor effect on the glass transition temperature (T_g) of the composites.

1. Introduction

Composites can be defined as a combination of two or more heterogeneously different materials separated by physical as well as chemical properties and are connected through a distinct interface. As technology develops, a lot of composite materials were produced and utilized for various applications. Polymer composite is one of them which have enormous advantages like corrosion resistance, resistance to a chemicals, high strength, light weight etc. It is easy to fabricate very complex parts with low tooling cost. As polymer composite materials has advantages, there are some disadvantages, like the polymer matrix materials decomposes at high temperatures[1].

Acrylonitrile Butyl Styrene copolymer (ABS) is one of the low cost engineering plastics that are uncomplicated to machine and manufacture[2]. ABS is a definitive material for structural applications when there is a need of impact resistance, strength, and stiffness. Because of its excellent dimensional stability it is broadly used for making of prototypes as well as it is easy to paint and glue. For food processing applications natural and black ABS are recommended as per FDA regulations. ABS is produced by emulsion or continuous polymerization techniques.

Mica is a standard term applied to a group of complex aluminosilicate minerals having a sheet or plate structure with different chemical composition and physical properties[3]. It possesses some of the most marvelous mixture of chemical, physical, electrical, thermal and mechanical properties which are not found in any other product. Mica is a composite hydrous silicate of aluminum, potassium, magnesium, iron, sodium, fluorine and lithium and also quite a few percentages of other elements. It is stable and completely inert to react with water, acids (except hydro-fluoric and concentrated sulfuric acid), alkalis, conventional solvents, oils and it is almost unaffected by atmosphere.

Mica has the only one of its kind combination of great dielectric strength, uniform dielectric constant and capacity strength. It has low power looseness (high Q factor), high electrical resistance, low temperature coefficient and capacitance. In terms of temperature resistance, it is within 600^{o}C to 900^{o}C depending on the type of mica. It has low heat conductivity, super thermal stability and there is no noticeable effect when exposed to high temperature. It is plastic, elastic and tough material with high tensile strength. Mica can withstand great mechanical pressure perpendicular to it is plane. In some cases, lamination may split into very thin leaves when high pressure is applied.

Mica is utilized as reinforcing filler for many polymer matrices because of its inherent properties [3-5]. Mica-filled composites of poly(butylene terephthlate) (PBT)/polyacrylonitrile-butyl acrylate-styrene (ABAS) were investigated by Tomar and Maiti with respect to tensile properties and Izod impact strength[6]. Chemically modified mica were utilized as filler for polyetheretherketone matrix and their mechanical properties revealed the effect of surface treatment of mica particles[7]. FRP composites used for civil engineering application were modified with treated mica particles and their water absorption rate, water absorption rate, mechanical properties and UV resistance were evaluated recently[8]. Glass fiber and mica were utilized as filler for polyamide 6 in order to study the mechanical and morphological properties up to 10 to 30 wt%[9]. Liang proposed a new predictive model for tensile strength using mica reinforced polymer composites and compared the experimental data with theoretical predictions[10]. The values were matching together due to the good network formation between the filler and matrix.

Another interesting work of non-isothermal crystallization kinetics of PET reinforced with mica and TiO_2 modified mica showed that the fillers act as heterogeneous nucleating agents[11]. Pultrusion technique was used to prepare vinyl ester based composites of glass fiber and modified nano mica particles in order to study the processing parameters and mechanical properties[12]. The composites showed that 2 phrnano-mica and 75.6 vol% of glass fiber yielded best results. Composites with mica and potassium based geopolymer was recently prepared[13]. The flexural strength and thermal conductivity showed improvement with 25 wt% of mica particles. Rigid polyvinyl chloride foam composites with mica were reported recently[14]. The flexural and tensile properties improved for 10wt% of mica loading. The dynamic mechanical properties and thermal properties also showed improvement at 10wt% and these were compared with similar fillers such as glass fiber and fly-ash.

ABS/PC 65/35 blends were reinforced with mica in a Haake Torque Rhemoter System 9000 with Rheomix 600 mixer[15]. Mica surface was treated with silane in order to improve the matrix/filler interactions. Among the composites, 30 phr mica incorporated ones showed the optimum properties and showed the maximum improvement in the case of flame retardancy. Twin screw extrusion was employed to prepare polyester thermoplastic elastomer (Hytrel) mica composites by varying the weight percentage from 5 to 40 [16]. Mechanical properties were directly proportional to the mica concentration except for tensile strength. Flexural modulus and strength showed significant improvement. The increase in properties is attributed to the good dispersion of filler in the matrix which was confirmed by the morphological analysis. Moreover, electrical and thermal properties of the composites also showed improvement according to the mica concentration.

Untreated and treated mica were incorporated into PC /ABS blends and studied the effect of the treatment on mechanical, thermal and structural properties [17]. Twin screw extrusion followed by injection molding was employed to prepare the samples. The untreated mica decreased the mechanical properties and impact strength; however, they were improved upon surface treatment of the mica filler. The present study focused on developing ABS with locally obtained mica composites by varying content of mica content up to 30 wt% by melt mixing technique and characterizing the obtained composites by various techniques.

2. Materials Preparation and Testing

2.1 Materials

The type of ABS used is MAGNUM 3404 and the mica was collected from local sources in Saudi Arabia. The properties of ABS and mica are given in Table 1.

Property	ABS	Mica
Density (ASTM D792)	1.05 (g/cm^3)	2.05 (g/cm^3)
Average Particle size	-	35 µm
Hardness (Moh scale)	-	2.8-3.2
Refractive index (ASTM D351-57T)	1.54	1.58
Melt mass flow rate (MFR) 22^{o}C/10.0 kg (ASTM D1238)	6.6g/10min	-
Tensile modulus (ASTM D638)	2102 MPa	172 GPa
Tensile strength (ASTM D638)	46 MPa	225 MPa
Tensile elongation (ASTM D638)	4.1 %	-

2.2 Methods

2.2.1 Batch mixing

A non-intermeshing counter rotating Haake Rheomix OS R 6000 was used for the compounding of mica with ABS. The rotor used for the mixing was roller one and a maximum torque of 160 N.m could be achieved for them. The best mixing performance for these kinds of machines is normally 75% so that no over loading or under loading is expected. Mica filler was dried at around 80^{o}C for about 8 hours before mixing to avoid any content of moisture present. The temperature of the compounding was 230^{o}C, total mixing time was set as 10 min and the rotor speed was 60 r.p.m. The rotors were first heated up to the set temperature and once it is stabilized the ABS material were inserted through a software controlled program. After softening the material for 2 minutes the filler was added slowly within the next 2 minutes time in order to have efficient mixing. Thereafter the mixing continued for the remaining 6 minutes.

2.2.2 Injection molding

Five compositions with mica content of 0, 5, 10, 20 and 30 wt (%) were prepared. The obtained lumps were cut into small pieces and injection molded using a minijet II (Thermo) at 270^{0}C. The molds were kept at 100^{o}C and air pressure was 10 bar. The samples were designated as 100 ABS, 5%, 10%,….and so on where the number stands for the amount of filler incorporated into the matrix.

2.2.3 Mechanical testing

The mechanical properties of ABS and ABS/mica composites were studied in tensile mode and flexural modes. Tensile testing was performed using an Instron 3365 universal testing machine of 10 kN load cell with a speed of 10mm/min at ambient conditions according to ISO 527-2. Flexural testing was done according to ASTM D 790. The flexural properties were measured at room temperature and around 50% relative humidity. Five samples were tested for each composition and average values were reported.

2.2.3.1 Izod Impact Test

ASTM D 256A standard was used to do impact test using a CEAST Izod impact tester, pendulum type mode at room temperature and 50% relative humidity. 2.5 mm notch depth was done to the test specimens obtained from the injection moulding machine before testing. The impact strength results were reported in J/m. Ten specimen test values were recorded for each composition and an average is reported.

Fourier transform infrared spectrometry (FTIR)

FTIR measurements were done on Thermo iS5 FTIR with diamond ATR accessory in the range of 400-4000 cm^{-1}. The resolution was 4 cm^{-1} and the number of measurements for each specimen were 32 and the average spectrum is reported.

Differential Scanning Calorimetry (DSC)

The glass transition temperature of the samples was studied on Shimadzu DSC 60 machine under nitrogen atmosphere. 5 mg of the samples were kept in aluminum pans and the heating rate was 10^{0}C. The temperature is raised to 180 ̊C at a rate of 10 ̊C/min which is quite fast then it is cooled to 30 ̊C at a rate of -10 ̊C/min.

Thermograimetric analysis (TGA)

Thermogravimetric analysis of the composites was done using Hitachi STA7200 simultaneous thermal analyzer system. The heating rate was 10^{0}C/min and the samples were purged with nitrogen to provide inert atmosphere. The samples were heated from room temperature to 700^{0}C. The TGA curves, DTG curves and maximum degradation temperature are reported.

3. Results and Discussion

3.1 Mechanical Tests

Physical testing procedures can incorporate dimensional investigation, assurance of a material's thickness or particular gravity, or measuring a materials quality under a tensile load, for instance. These properties of polymers are critical to determining the right composition and to check the optimum composition for any specific application.

The capacity to resist breaking under tensile stress is extremely important amongst the most generally measured properties of materials utilized as a part of structural applications. A high tensile modulus implies that the material is stiff and more stress is required to create a given amount of strain. In polymers, the tensile modulus and compressive modulus can be close or may differ widely. Tensile strength, tensile modulus and tensile elongation are given in Table 2. Tensile strength showed improvement with respect to filler loading. The maximum was shown by 30 wt%. This increase in tensile strength is believed due to the reinforcement of mica filler provided to the polymer matrix. The modulus of the composites is showing an upward trend which is obvious. The rigid and strong filler inclusion is helping the matrix to transfer the stress effectively. The modulus improved homogeneously with respect to the filler loading. The tensile elongation showed a decrease with respect to the filler loading which means that the composites became more rigid.

Table 2: Tensile and flexural properties of ABS composites

Sample	Tensile strength (MPa)	Tensile Modulus (MPa)	Tensile elongation (%)	Flexural modulus (MPa)	Flexural strength (MPa)
100% ABS	39.50±1.3	1917±15	23.17±0.9	1742±26	87±8
5% MICA	40.43±1.8	2057±19	12.72±0.6	2418±28	91±8
10% MICA	41.50±1.4	2315±24	8.97±0.5	3052±32	96±93
20% MICA	42.21±2.4	2654±28	6.61±0.4	3698±40	102±7
30% MICA	43.20±2.2	2985±32	5.13±0.4	4022±44	112±10

The flexural properties also revealed some sort of interaction between the filler and matrix. The flexural modulus showed significant improvement for 30 wt% of filler loading which is close to 130 % compared to the virgin polymer. The improvement in the modulus can be coined with high modulus of the mica and effective stress transfer between the filler and matrix. The flexural strength also showed similar trends and it increased according to weight percentage of mica.

The impact strength shows a significant reduction with the addition of mica as shown in Table 3. The impact strength decreased sharply for the sample with mica, which indicates good stress transfer between the matrix and filler so that effective transmission of sudden force is happening.

Table 3: Impact strength of ABS composites

Sample	Impact strength (J/m)
100% ABS	200
5% MICA	76
10% MICA	55
20% MICA	52
30% MICA	49

As mica is very rigid filler and has a layered structure, the polymer chains might have incorporated between the layers of the filler. This has to be established from morphological analyses. If the mica is treated with a surfactant more significant results could be obtained with respect to impact properties.

Fourier transform infrared spectrometry (FTIR)

FTIR studies will help to understand the interaction between the components in polymer composites or blend. The spectra for mica, pure ABS and composites are given in figure 1. Mica being an inorganic material, it shows bands in the finger print region. ABS show its characteristic peaks corresponding to the styrene group, peaks at 1136, 1550, 2312 and 2910 cm^{-1} which account for the different vibrations in the molecule. As the weight percentage of mica increases the intensity of the peak corresponding to mica is increasing as evidenced from the figure (1).

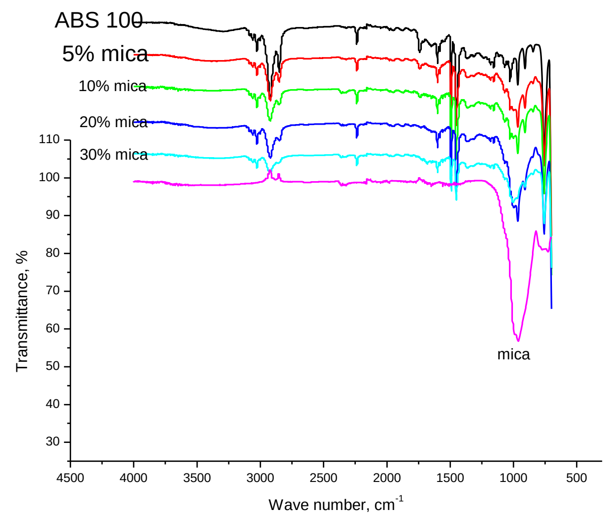

Figure 1 : FTIR spectra of ABS, mica and ABS/mica composites

Thermo gravimetric analysis

Thermogravimetric analysis provides information about the thermal stability of the materials involved. Figure 2 shows the thermograms of ABS the mica filled composites under nitrogen atmosphere. All the thermograms show similar behavior and there are two step degradations for the materials. The first one is major step which belongs to degradation of the polymer backbone and it can be considered for the thermal stability of the system. There is small degradation step after the first one which is related to the mica particles degradation of the lose contents. It is also noticeable that the residue increase with respect to the filler content.

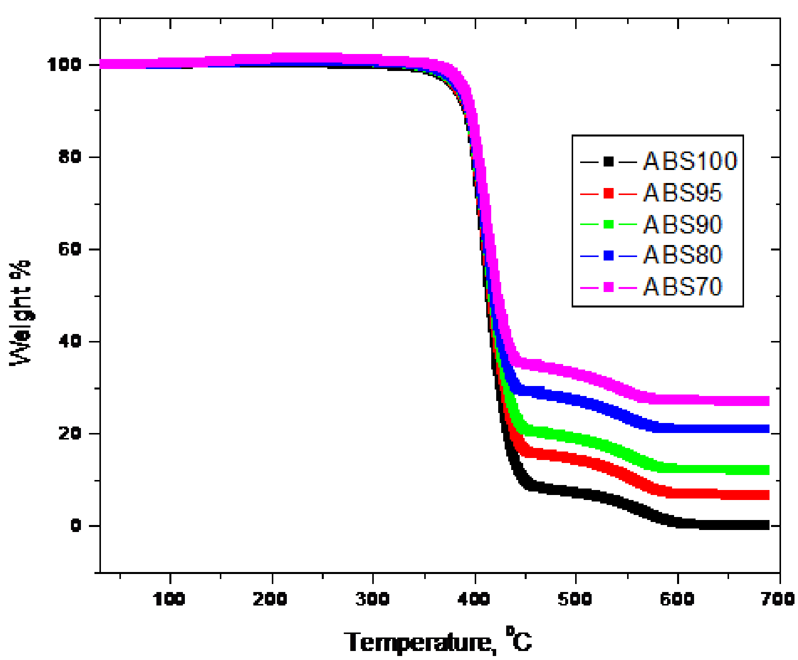

Figure 2 : Thermograms of ABS and ABS/mica composites

Table 4: Degradation temperatures for different composition

Sample	Max. Degradation Peak Temp.(˚C)
100% ABS	415.3
5% MICA	421.5
10% MICA	422
20% MICA	418.8
30% MICA	417.1

The maximum degradation temperatures of the samples are given in Table 4. The sample with 10% mica has the best degradation temperature which differs from pure ABS by nearly 7 °C.

Differential Scanning Calorimetry (DSC)

Differential Scanning Calorimetry (DSC) measure the phase changes in the system as a function of time and temperature in a controlled climate. These estimations give quantitative and subjective data about physical and chemical changes that include endothermic or exothermic procedures, or changes in heat capacity. The glass transition is the reversible change of the amorphous areas of a polymer from fragile state to a thick state. Since ABS is considered as an amorphous solid, glass transition temperature of ABS and composites are measured and are reported in Table 5.

Table 5 : Glass transition temperature for ABS and ABS composites

Sample	Onset T_g (° C)	End set T_g (° C)	T_g (° C)
100% ABS	111.4	117.9	113.7
5% MICA	117.0	124.7	121
10% MICA	118.8	125.1	122
20% MICA	117.6	124.7	121.5
30% MICA	116.4	121.8	120.1

The results of DSC test show that T_g value is increasing for ABS with more quantity of filler which means that the composites show more rigidity due to the incorporation of mica particles. As the more rigid filler is incorporated it will impart its inherent properties to the system which affect the thermal relaxations too. Also, its clear that, the improvement on (T_g) temperature is independent on the wt (%) of mica.

4. Conclusions

1. The mica addition improves the flexural modulus and tensile modulus up to 130 % and 55 % respectively, while it has a minor effect on tensile strength of the composites.
2. The composite of 30 wt (%) has a lower ductility and impact strength by about 75 % compared to ABS.
3. AS the wt (%) of mica increase, the intensity of the peak increases, based on FTIR spectra.
4. The addition of mica to ABS slightly increases the maximum degradation temperature and also, the glass transition temperature of the composites.

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تجهيز وتوصيف خليط مكون من الاكريلونيتريل بيوتادين ستيرن والميكا

د/ محمد الغامدي
قسم تكنولوجيا الهندسة الميكانيكية – كلية ينبع الصناعية – الهيئة الملكية بينبع – مدينة ينبع الصناعية – المملكة العربية السعودية

الملخص:
تصنع المواد المركبة من خليط من مادتين أو أكثر وذلك للحصول على خواص أفضل مقارنة بمواد التركيب. اهتمت هذه الدراسة بخلط مادة (ABS) مع الميكا كمادة مالئه. (ABS) نوع من البلاستيك له درجة انصهار وصلادة ومقاومة عالية. والميكا نوع من مواد البلاستيك لها خواص ميكانيكية وحرارية وكيميائية وكهربائية متميزة، وتم تجهيز العينات بنسب ٠ ، ٥ ، ١٠، ٢٠و ٣٠ بالمائة، وزن بواسطة ماكينة حقن النموذج. تم اختبار التركيب والخواص الميكانيكية والحرارية للمركب، وتم التوصل إلى العديد من النتائج الهامة منها: تحسين خواص معامل الانحناء والشد ومقاومة الانحناء بنسب تصل إلى ١٣٠%، ٥٥%، ٢٨% على الترتيب وذلك بإاقة ٣٠% من الميكا.