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Mechanical Properties of Composite Films of PMMA with Fe_2O_3

KEYWORDS: Young's modulus, stress, strain, electron irradiation, weight loss.

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ABSTRACT *Polymer films of Polymethylmethacrylate at 0.5, 1 and 2N concentrations and its composite with Fe_2O_3 at different weight percent have been used for measurement of Mechanical properties such as stress, strain, and Young's modulus at an ambient temperature. The value of stress is decreased as concentration of the film of Polymethylmethacrylate increased. In case of its composite the value of stress is increased as the weight percentage of Fe_2O_3 increased. The young's modulus decreased and the strain at break increased as concentration of PMMA film increased. In case of its composites the young's modulus as well as the strain at break both are decreased as weight percentage of Fe_2O_3 increased. Further, the films of polymer and its composites are irradiated by an electron beam at a dose rate of 100 kGy. The weight loss and melting temperatures for these samples before and after electron irradiation are measured using TGA and DSC. The weight loss of PMMA after electron irradiation is higher than that of its pristine, whereas in case of composite film the weight loss after electron irradiation is lower compared to that of its pristine values. In DSC measurements it is observed that melting temperature is occurred at 394.64^{0}C for polymer of PMMA and at 392.85^{0}C for its composite. This leads that addition of Fe_2O_3 reduced melting temperature of the PMMA by 1.79 ^{0}C. The melting temperature after an electron irradiation is occurred at 388.16^{0}C for PMMA and at 384.74 ^{0}C for its composite. Hence these observations are indicated in lowering of their melting temperatures as compared to that of their pristine measured values.*

INTRODUCTION

Polymer composites have shown improved thermal, mechanical, and dielectric properties as compared to conventional polymers due to the stronger interactions between polymer and filler phases [1]. The important use of composite materials is in reinforcing of polymer matrices. Recent research has shown that small additions of certain materials modify the physical properties such as mechanical, thermal and optical properties. Although the precise mechanism responsible for this enhancement is not entirely understood, hence interactions at molecular level clearly hold the key for the modifications in mechanical properties [2]. These properties are different from those in the bulk state [3]. Hence in the present work the study carries the measurement of mechanical and thermal properties of the films of PMMA and its composite films with Fe_2O_3.

EXPERIMENTAL

Polymer substance of PMMA and Fe_2O_3 are obtained from S. d. Fine Chem. Ltd, Mumbai, India. The different weight percent of Fe_2O_3 substance have been used with PMMA for preparing the composite films. The composite polymer films of PMMA with Fe_2O_3 are prepared by solution casting method [4] at different weight percentages such as 10, 20, 30 and 60. The mechanical properties are studied by using Universal testing Machine (UTM). These samples are irradiated by electron beam at a dose rate of 100 kGy using Microtron facility at Mangalore University, Mangalore. The Thermal properties for these samples before and after electron irradiation have been measured using TGA (SDT Q600 V20.9 Build 20) and DSC by taking samples of weighing at 6.0 mg were scanned in the temperature range of 0-600 ^{0}C under nitrogen atmosphere at a heating rate of 20 ^{0}C/min.

RESULTS AND DISCUSSION

THERMO GRVIMETRIC ANALYSIS

The weight loss for PMMA and its composite film with Fe_2O_3 at 10 weight percentage have been measured before and after irradiation by electron beam at a dose rate of 100 kGy and are given in Fig 1. Here it is observed that PMMA lost its weight 97.79% (5.962 mg) at 359.32 ^{0}C before irradiation and after irradiation it lost its weight 96.90% (7.355 mg) at 358.03 ^{0}C. In case of the composite film it lost its weight 73.13% (3.900 mg) at temperature of 357.61^{0}C before irradiation and after irradiation it lost its weight 83.38% (5.057 mg) at 357.34 ^{0}C. This reveals that after electron beam irradiation the weight loss of the PMMA and is increased. The weight loss of PMMA after electron irradiation is higher than that of its pristine, whereas in case of composite film the weight loss after electron irradiation is lower compared to that of its pristine values.

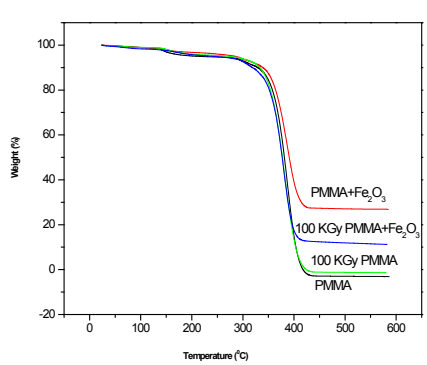

Figure.1 The plots of TGA after irradiation and pristine for PMMA and its composite with Fe_2O_3

DIFFERENTIAL SCANNING CALORIMETRY

The DSC is also measured for these samples at 6.0 mg were

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scanned in the temperature range of 0-600 ^{0}C under nitrogen atmosphere at a heating rate of 20 ^{0}C/min. The thermo plots of DSC for the PMMA and its composite film film with Fe_2O_3 at 10 weight percentage are is given in Fig 2. It is observed from Fig 2 that the melting is occurred at temperature 394.64^{0}C for PMMA before electron irradiation and it is occurred at 392.85^{0}C after electron irradiation at a dose rate of 100 kGy. This leads that addition of Fe_2O_3 reduced melting temperature of the PMMA by 1.79 ^{0}C. In case of its composite with Fe_2O_3 at 10 weight percentage, the melting temperature occurred at temperature 388.16^{0}C before electron irradiation and it is occurred at temperature 384.74 ^{0}C after electron irradiation at a dose rate of 100 kGy. This leads that electron irradiation reduced the melting temperature of the composite film by 3.42 ^{0}C. From these results it has been observed that the melting temperature of the PMMA and its composite film with Fe_2O_3 are decreased after electrons irradiation. Hence it is observed that the electron irradiation is indicated in lowering of their melting temperatures as compared to that of their pristine measured values.

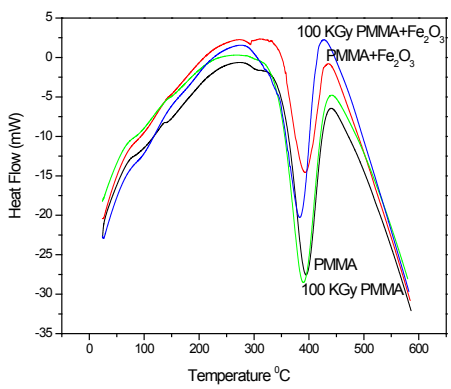

Figure .2 The plots of DSC after irradiation and pristine for PMMA and its composite with Fe_2O_3

MECHANICAL PROPERTIES

The mechanical property of stress as a function of strain for the PMMA at different concentration and its composite films with Fe_2O_3 at different weight percentage have been measured using the Universal Testing Machine at an ambient temperature. The plots for stress versus strain of polymer films of PMMA for different concentrations such as 0.5, 1, 2 and 3N are given in Fig 3. It is noticed from Fig 3, that the linearity in stress with strain is observed i.e. the stretching value of stress for 0.5N concentrated PMMA film is 1.8780 MPa and afterwards it has shown discontinuity in the linearity indicates the value of rupture [5]. Similarly for 1N PMMA film stretching value of stress is 1.1488 MPa, for 2N PMMA film is 1.1240 MPa and for 3N PMMA film is 0.2634 MPa and after these values it has shown discontinuity and hence the films are going to be ruptured. Hence it is observed that as concentration of the PMMA film increased the region of stretching in stress is decreased. In case of 3N concentration the discontinuity is observed at 0.2634 MPa and afterwards the variation of stress remains constant and independent of strain and rupture at 0.1502 MPa. Further, the plots of stress versus strain of the composite films of PMMA with Fe_2O_3 for different weight percentages such as 10, 20, 30 and 60 are given in Figure 4. Here it observed that for 10, 20, 30 and 60 weight percent the behaviour of stress as function of strain shows linear response. It is noticed from Fig 4, that the linearity in stress with strain is observed i.e. the stretching value of stress for 10 wt % of Fe_2O_3 with PMMA film is 19.5747 MPa and afterwards it has shown discontinuity in the linearity indicates the value of rupture. Similarly for 20 wt % of Fe_2O_3 with PMMA film stretching value of stress is 22.0032 MPa, for 30 wt % of Fe_2O_3 with PMMA film is 20.5866 MPa and for 60 wt % of Fe_2O_3 with PMMA film is 20.8901 MPa and after these values it has shown discontinuity and hence the films are going to be ruptured. Hence it is observed that the weight percent of Fe_2O_3 increased the strain at rupture values decreased. The observations reveal that as weight percentage of Fe_2O_3 increases the linear response of the composite film of PMMA also decreases due to hardness of the composite film. The rupture strain for 10 wt% is 0.026, for 20 wt% is 0.020, for 30 wt% is 0.014. But in case of 60 wt% the rupture strain is 0.011 and 0.019. It is clearly observed that as weight percent of Fe_2O_3 increases the values of rupture strain decreases Hence it is observed that the mechanical properties of the composite film of PMMA have been modified by adding different weight percentage of Fe_2O_3 [6].

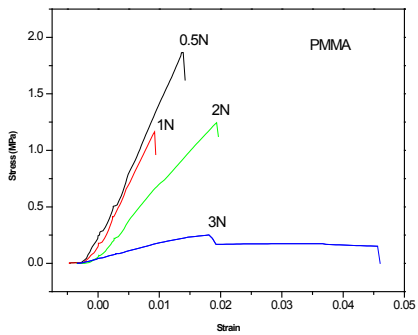

Figure. 3 The plots of stress versus strain for PMMA at different concentrations.

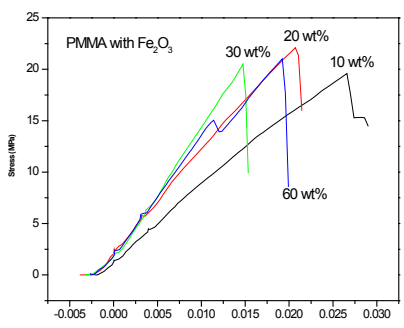

Figure. 4 The plots of stress versus strain for composite films of PMMA with Fe_2O_3at different weight percentages

The tensile strength, Young's modulus and stress at break for PMMA at different concentrations such as 0.5, 1, 2 and 3N and for its composites with Fe_2O_3 at 10, 20, 30 and 60 weight percentages are measured and are given in Table-1. Here it is observed that the tensile strength, Young's modulus and stress at break of PMMA goes on decreased as concentration of films of PMMA increased except at concentration 1N the Young's modulus has maximum. In case of its composites, as weight percentage of Fe_2O_3 increased the tensile strength goes on decreased but the Young's modulus and stress at break goes on increased. Hence it shows that mechanical properties of the polymer have been modified by making its composites with Fe_2O_3.

Table 1
The mechanical properties of PMMA and its composites with Fe_2O_3.

Sample	Concentration	Tensile Strength (MPa)	Young's Modulus (MPa)	Stress at Break (MPa)
PMMA	0.5N	18.70	1644.66	18.70
	1N	11.73	2073.46	11.73
	2N	12.53	1014.85	12.53
	3N	2.52	202.02	1.519

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PMMA with Fe_2O_3	10 wt%	22.36	940.87	8.30
	20 wt%	21.21	1278.87	11.72
	30wt%	19.61	1653.95	20.54
	60 wt%	13.69	1733.55	21.21

CONCLUSION

The weight loss of PMMA after electron irradiation is higher than that of its pristine, whereas in case of composite film the weight loss after electron irradiation is lower compared to that of its pristine value. In DSC measurements it leads that addition of Fe_2O_3 reduced melting temperature of the PMMA by 1.79 ^{0}C. and after electron irradiation reduces the melting temperature of the composite film by 3.42 ^{0}C. From these results it has been observed that the melting temperature of the PMMA and its composite film with Fe_2O_3 are decreased after electrons irradiation. Hence it is observed that the electron irradiation is indicated in lowering of their melting temperatures as compared to that of their pristine measured values. In case of mechanical properties it is observed that as concentration of the PMMA film increased the region of stretching in stress is decreased. It is also observed that the weight percent of Fe_2O_3 increased the strain at rupture values decreased. Hence it is observed that the mechanical properties of the composite film of PMMA have been modified by adding different weight percentage of Fe_2O_3.

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