Analysis of temperature dependent viscous behavior of PMMA through Dynamic Mechanical Analyzer

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Abstract: The present paper deals with the analysis of viscous behavior of poly methyl methacrylate (PMMA) polymeric sample from room temperature to elevated temperature. Dynamic mechanical analyzer technique is used to evaluate viscosity of the prepared samples. The viscosity is being determined by measuring storage and loss modulus values at different temperature range. The study reveals that the viscosity decreases on increasing temperature.

Keywords: Activation Energy, Thermal Conductivity, Phase transition temperature, Viscosity.

I. INTRODUCTION

Poly methyl methacrylate (PMMA) is a well-known polymeric material in view of industrial and researches both. The recent advancement in the applications of PMMA belongs from biomedical, optical, solar, sensors; battery electrolytes, etc. were publicized [1]. During the applications, most of the materials have to undergo through heat transfer mechanism like problems of heat removal in processes involving electronics chips, laser applications, similar high energy devices and the power generation industries. So, it becomes crucial to have knowledge regarding the thermal behavior of the material. Among thermal behavior knowledge viscosity stands as a primary objective of one. There are several types of viscometers reported for the direct measurement of viscosity of the samples but they have their own limitations. Some of researchers have also reported alternative technique like Dynamic Mechanical Analysis (DMA) for the determination of viscosity [2, 3]. Dynamic mechanical analyzer is a sensitive technique that monitors property change with respect to the temperature and frequency of applied sinusoidal stress. DMA provides data of storage modulus (E') and loss modulus (E'') with respect to the temperature [4].

Both of these moduli are related to the viscosity (η) of the blend by the relation:

$$\eta = \sqrt{E'^2 + E''^2/2\pi f} \qquad (1)$$

(Where "f" is the frequency used)

In this way, in the present study, an effort has been made to investigate the viscous behavior of PMMA from room temperature to elevated temperature range.

II. EXPERIMENTAL

Material preparation

The PMMA is dissolved in 20 ml THF solution at room temperature (about 30°C). The PMMA solutions is being continuous stirred through magnetic stirrer for about 6 hrs, then solution is poured into flat-bottomed glass petri dish. The solvent is allowed to evaporate slowly over a period of 24 hours in dry atmosphere. The film so obtained is peeled off and dried in vacuum at 50°C, well below the boiling point of solvent for 24 hours in order to avoid bubbling, and to ensure the removal of the solvent [5].

Dynamic Mechanical Analyzer (DMA) measurements

Dynamic Mechanical Analyzer (TRITEC-2000 DMA) is a sensitive technique that characterizes the mechanical response of materials by monitoring property change with respect to the temperature and frequency of applied sinusoidal stress. DMA film samples were cut to be between 4-6mm in width and 10mm in length. The average thickness of each sample is of 100-micrometer order. After adjusting DMA device in tension mode, the furnace was sealed off, sample scanned over a temperature range from room temperature to 140 °C. The sample was held at that temperature for five minutes. The heating/ ramp rate was 2 °C/min for all temperature scan tests. Frequency of oscillations was fixed at 1Hz and strain amplitude 0.01mm within the linear visco-elastic region [6, 7].

III. RESULTS AND DISCUSSION

Viscosity and phase transition temperature:

The variation of viscosity with temperature for PMMA sample is shown in Figure 1. It is observed that viscosity decreases on increasing temperature. This behavior can be explained on the basis of the influence of temperature on the crosslink density [8]. At room temperature, there is a bonding between crosslinks and chains and therefore the molecules of the polymeric material are tightly bound to each other. Hence in this state, the motion of molecules or molecular chains is very small with applied load or stress to which the sample is subjected [9, 10], as a result they offer a high value of viscosity. As the temperature further increases (up to near about T_g), crosslinks between chains are opening up, thereby resulting in an increment in the motion of molecular chains. The motion of these chains provides more strain in the samples with applied load; hence the viscosity of the samples decreases as temperature the temperature.

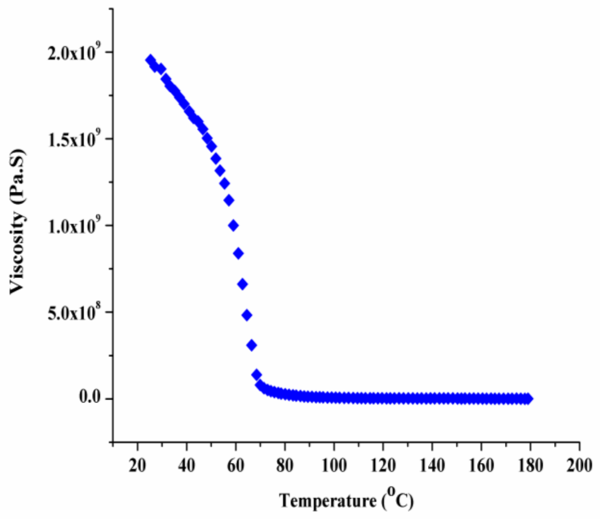

Figure: Variation of viscosity with temperature

IV. CONCLUSIONS

From this study, following conclusions can be drawn:

(i) Dynamic Mechanical analyzer is also a good approach for the viscosity measurements of polymeric samples.

(ii) For PMMA sample viscosity decreases with temperature.

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