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Research Article

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Mechanical and Thermal Properties of Polyurethane/Epoxy IPN's

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Abstract The Interpenetrating polymer networks (IPNs) were prepared from polyurethane and epoxy. The polyurethane-toughened epoxy was developed. Epoxy had toughened by weight fraction of 10, 20, 30, and 40% Polyurethane resin. PU–epoxy matrices were characterized for their mechanical behavior and thermal properties. The results show that the mechanical strength and mechanical modulus are lowered through the introduction of PU into the epoxy matrix to form the IPN structure. As the polyurethane content increases, the tensile strength and flexural strength of the IPNs decrease. The specific heat capacity and thermal conductivity have been affected with the PU percentage.

Keywords Epoxy, Polyurethane, Interpenetrating polymer networks, Mechanical properties, Specific heat, Thermal conductivity

Introduction

The high Epoxies are thermosetting polymers that structure 3D arrange structures after exothermic responses with anhydride hardeners [1,2]. Epoxies are intriguing materials due to their chemical stability as well as brilliant mechanical and thermal properties [3–6]. A primary weakness of the saps is their fragility, which permits split engendering upon outside mechanical effect.

Subsequently, numerous investigations have been led to beat this shortcoming by including toughening operators that upgrade sway obstruction. Generally, rubbery pitches, for example, carboxyl-terminated butadiene (CTBN) [7] and amine- terminated butadiene (ATBN) [8] have been utilized as toughening specialists, while thermoplastic polyethersulfone [9] and polyetherimide [10] have additionally been applied.

Elastomeric polyurethanes (PUs) are toughener agents for thermosetting polymers. PUs are made out of a delicate section of polyol and a hard portion of diisocyanate [11], which are not good with one another and lead to stage detachment. Endless supply of PUs to different polymers, the mechanical properties are improved in view of the systems administration of the two polymers. The cooperation among PU and the epoxy grid is normally accomplished by blending PU, which contains –NCO utilitarian gatherings, with epoxy, which contains a hydroxyl bunch [12,13], or responding polyol with diisocyanate within the sight of fillers [14,15]. Then again, the communication between epoxy framework and PU can be accomplished by presenting glycidyl ethers in the polyol spines of PUs as opposed to responding epoxy bunches with terminal NCO gatherings. Once the readied polyols respond with diisocyanate (DIC), the subsequent PUs are outfitted with epoxy useful gatherings. Along these lines, the association between PU with the polyols and epoxy framework can be upgraded by chemical reactions.

Interpenetrating polymer networks (IPN's) are blends of crosslinked polymers containing essentially no covalent bonds between them. In this paper, polyurethane/epoxy resins interpenetrating polymer networks IPN's were prepared, and their tensile, flexural, thermal conductivity and specific heat were investigated.

Experimental

A universal material testing machine was used for mechanical property (tensile and flexural) tests, namely instrument Zwick/Roel (Germany) type (BT1-FR2.5 TN.D14). The tensile strength and modulus were measured following the specification of German calibration services (DKD) to DIN EN ISO/IEC 17025.70. The sample was dumbbell shaped, with dimensions of 165×19×3.0 mm^3 (length×width×thickness) and a crosshead speed of 10 mm/min. The flexural strength and modulus were measured following the specification of DIN EN ISO/IEC 17025.70. The sample dimensions were 127×12.7×3.0 mm^3 (length×width×thickness), the span was 90 mm, and the crosshead speed was 2 mm/min.

The specific heat capacity of the prepared IPN's was determined by using a DSC-60 Shimadzu (Japan) in the range of temperature 50–150 ºC at 10 ºC/min heating rate within nitrogen atmosphere. Thermal conductivity can be calculated using the equation:

$$\frac{dH}{dt} = -KA\frac{dT}{dx} \quad (1)$$

Where: *H*, Heat energy (J), *t*, time (Sec), K, thermal conductivity (W/°K.m), *T*, temperature (°K), *x*, thickness of test specimen (m), and *A*, area of test specimen (m^2). Before the measurement, all the samples were maintained in the same condition in order to avoid surface roughness, thickness, and geometry of the samples to cause the heat loss.

Results and Discussion

Effect of PU content Figures 1, 2, 3 and 4 illustrate the tensile strength, tensile modulus, flexural strength and flexural modulus versus PU content of PU/epoxy IPNs.

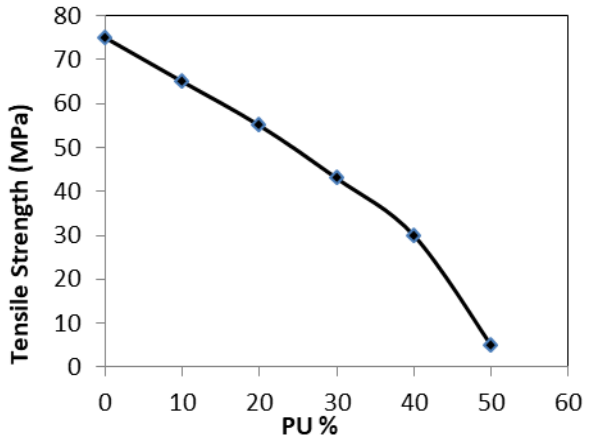

Figure 1: Tensile strength versus PU content of PU/epoxy IPNs.

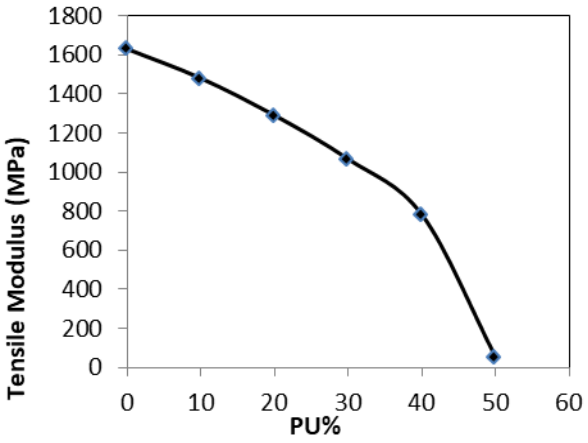

Figure 2: Tensile modulus versus PU content of PU/epoxy IPNs.

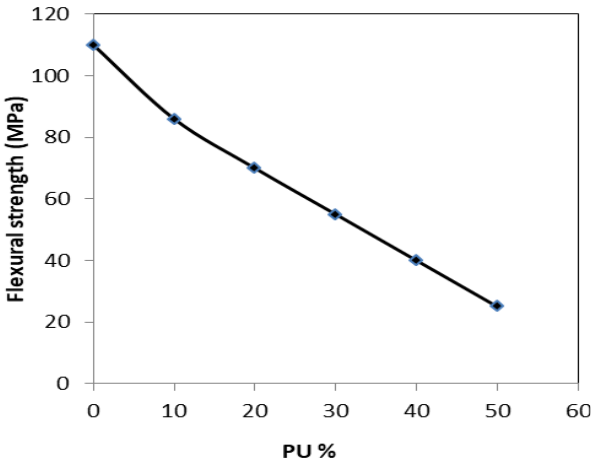

Figure 3: Flexural strength versus PU content of PU/epoxy IPNs

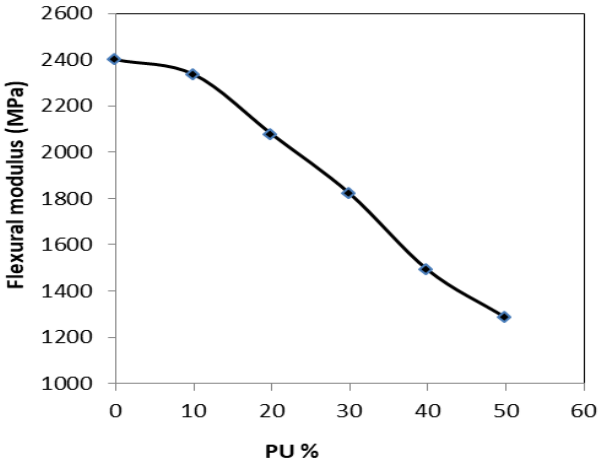

Figure 4: Flexural modulus versus PU content of PU/epoxy IPNs

From these figures, it can be seen that there is a continuous decrease in the tensile strength, tensile modulus, flexural strength and flexural modulus with an increase in PU content. This can be explained because the hard segments of epoxy appeared to have higher strength and modulus properties, and the soft segments of PU appeared to have lower strength and modulus properties; hence, the higher the PU content, the lower the tensile and flexural properties of IPNs. The addition of polyurethane decreases the elastic tensile modulus and flexural modulus of the tested IPN's, implying a softening effect. The softening of the compositions as indicated by the decrease of the elastic modulus was induced by the additional free volume. Moreover, with the increase of PU prepolymer content, the total fractional free volume increased.

Figure 5 shows the thermal conductivity of the IPNs as a function of the PU % weight part. The thermal conductivity decreases almost monotonically, from 0.461 W/m.K (PU = 0%) to 0.406 W/m.K (PU = 50%). The results indicate that the thermal conductivity of all the composites decreases with increasing the content of the polyurethane. However, the trend of thermal conductivity of all samples is nonlinear. The values of specific heat capacity with the increase of PU content are shown in Fig. 6. As the PU content in these IPNs increases, the specific heat increases initially and then decrease. The C_p value of the PU /EP IPNs with 10/30 weight % PU content are the larger value.

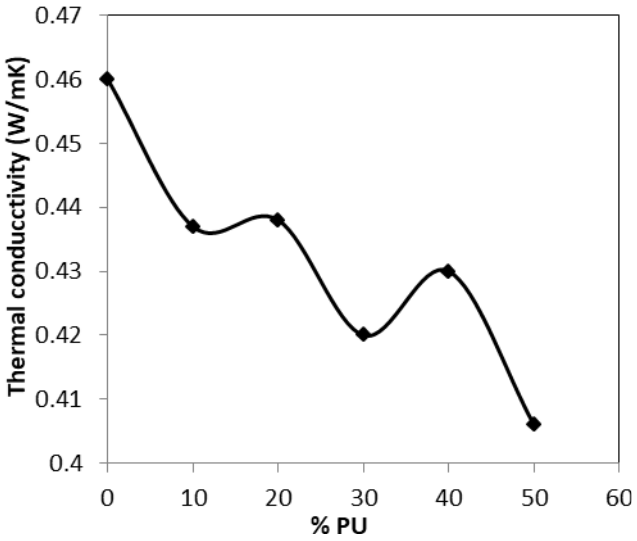

Figure 5: Thermal conductivity of PU/EP IPNs

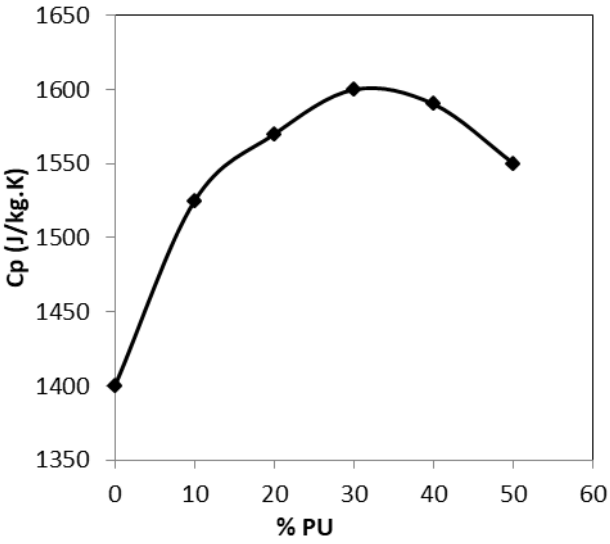

Figure 6: Specific heat of PU/EP IPNs

Conclusions

Polyurethane/Epoxy interpenetrating polymer networks were prepared by a simultaneous polymerization method and the effect of urethane/epoxy weight ratio of the mechanical and thermal properties of the IPN system was studied. The tensile results show that PU/EP IPNs have lower tensile and flexural strength and modulus than those of the pure epoxy. In addition, tensile and flexural strength and modulus of IPNs decrease with the increase of PU prepolymer contents. Furthermore, the effect of polyurethane in the epoxy as a toughener was investigated in terms of thermal properties. Thermal conductivity decreases in nonlinear trend as a function of PU contents. Specific heat capacity values increase until a maximum one of 30% PU content, then it goes to decrease manner.

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