ABSTRACT

High performance polymer matrix composites, particularly for aerospace applications, are designed to withstand high thermal and aerodynamic stresses which calls for matrix resins with superior thermal and thermo-mechanical properties. Among the diverse thermoset resins, Bismaleimide resin stands out as a class of high performance addition curable polyimide resin having excellent thermal, physical and thermo mechanical properties. However, their inherent limitations including brittleness and poor processability are impediments for their wide acceptability necessitating their structural modification or co-reaction or blending with suitable compounds to obviate the shortcomings.

With the objective to toughen BMIs, the structural modification of BMI has been carried out for conferring low temperature cure characteristics and enhanced toughness by reacting with allyl functional compounds. Two different Bismaleimides have been co-reacted with allyl compounds (Diallyl bisphenol A (DABA) and Allyl novolac (AN)). 50 % allylated novolac was synthesized and characterized. The Carbon fiber and Glass fiber composites of BMIP/DABA and BMPM/AN systems have been fabricated and characterized. Thermal analysis of the BMIP/DABA cured blends showed that although the initial decomposition temperatures were in same range, the char residue increased with BMIP content. Glass-reinforced composites were prepared and DABA-BMIP in the ratio of 1:2 exhibited superior mechanical properties. The BMPM/AN system, the structure elucidation of AN was done by FTIR. The characterization of the blends was done by FT-IR spectroscopy DSC and TGA-DTA. Carbon fibre reinforced composites were prepared using all the BMI/AN resin systems and their mechanical properties were evaluated. The anaerobic char yield was enhanced with the maleimide content. The DMA of the composites showed only single transition indicating the existence of single phase and the Tg of the cured composite increased with maleimide content and so also the glassy modulus. The kinetics of the cure reaction was determined by
variable heating rate DSC method. The polymerisation kinetics of typical allyl dominated and maleimide dominated reactions as estimated by the Kissinger and Ozawa methods showed $E_a$ in the range of 105-122kJ/mol. The 2\textsuperscript{nd} curing process was evaluated by Kissinger and Ozawa–Flynn–Wall models and found that the activation energies obtained from two methods were consistent with each other.

An effort was made to synthesize novel BMI- Allyl single component oligomers and its characterization was carried out. BMI polymer systems, with a novolac back bone, containing both maleimide and allyl functionalities anchored to the same polymer chain was realized by appropriate synthesis strategy and was characterized. The percentages of Maleimide content in the synthesized systems were estimated to be 50, 60 and 70\% by elemental analysis. The oligomers manifested a two- stage curing, exhibiting broad cure exotherms starting at around 60\° C and 180\°C corresponding to the ene and Diels-Alder reactions. Kinetic evaluation of the system revealed that $E_a$ was found to be increasing linearly with conversion. Carbon fabric reinforced composites have been realized with the synthesized allyl- maleimide single component systems. Evaluation by DMA revealed that the highest $T_g$ (280\°C) was observed highest maleimide content system. Mechanical properties and impact strength of the composites at ambient temperature were found to be high for the less dominated blends, whereas the retention of ILSS at elevated temperature was found to be better for the high maleimide dominated system. As the maleimide content increased, the thermal stability and char yield of the blends increased marginally. Morphology images by SEM corroborated the findings of mechanical characterization for this system.

Another approach adopted for the toughening of BMI system was to blend with engineering thermoplastic ie Acrylonitrile Butadiene Styrene (ABS) in weight percentage (2-10 wt \%). The viscosities of the different compositions of the uncured blend systems are investigated. Since the viscosity increase is high which hampered the processability of the blend, the maximum wt\% loading of ABS was 10. Tensile and Impact performance showed that 6 wt. \% of ABS have the maximum values while maintaining high thermal stability for the MDA chain extended BMI and its carbon reinforced composites. The DABA/BMPM / Carbon fibre
composite system showed optimum mechanical performance at 8 wt. % loading of ABS in BMI while maintaining high thermal stability.

General introduction about Polymer blends, Toughening mechanisms of polymers, polymer composites and their processing are outlined in chapter 1. Detail literature review, objectives, methodology and scope of the present research are described in chapter 2. The materials, fabrication techniques and characterization methods used in this research are presented in Chapter 3. The modification of different BMIs with two types of allyl compounds and its composite preparation and characterization are discussed in chapter 4. The synthesis of single component BMI-Allyl oligomers and their characterization is discussed in chapter 5. The experimental results of the ABS toughened BMI neat cast resin and ABS toughened BMI composites reinforced with carbon fibre are presented in chapter 6. Summary of the research and recommendations for future work are briefed in Chapter 7.