

# Toughening effect of liquid natural rubber on the morphology and thermo-mechanical properties of the poly(lactic acid) ternary blend

Mohd Bijarimi<sup>1</sup> · Sahrim Ahmad<sup>2</sup> · A. K. M. Moshiul Alam<sup>1,3</sup>

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**Abstract** In this work, poly(lactic acid) (PLA) was melt blended with liquid natural rubber (LNR) and linear low-density polyethylene (LLDPE) to fabricate a PLA–LNR–LLDPE ternary blend. The torque rheology demonstrates the melt mixing behavior of PLA–LLDPE binary and PLA–LNR–LLDPE ternary blends. Mechanical properties of ternary blend illustrate the highest toughness as compared to neat PLA and PLA–LLDPE binary blend. Fracture morphology reveals the plastic deformation behavior in the ternary blend which is illustrated in TEM micrograph. The cold crystallization temperature of the ternary blend appears at a lower temperature as compared to the binary blend. The thermal stability of PLA is improved due to blending with LLDPE and LNR. The ternary blend exhibits greater storage modulus in the glassy state as well as in the rubbery state as compared to neat PLA and binary blend. Finally, LNR performed as an effective compatibilizer between PLA and LLDPE.

**Keywords** Blend · Mechanical properties · Rheology · Morphology · Thermal properties

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✉ Mohd Bijarimi  
bijarimi@ump.edu.my

✉ A. K. M. Moshiul Alam  
akmmalam@gmail.com

<sup>1</sup> Faculty of Chemical and Natural Resources Engineering, Universiti Malaysia Pahang, Gambang, 26300 Kuantan, Malaysia

<sup>2</sup> Faculty of Science and Technology, School of Applied Physics, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

<sup>3</sup> Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh

outstanding enhancement of elongation at break and impact strength of the ternary blend. Therefore, the toughness of the ternary blend obviously improved which was the key aim of this work. Morphology of ternary blend revealed apparent compatibility of PLA and LLDPE in the presence of LNR compatibilizer. Besides, the polyolefin long chains inhibited the molecular motion of PLA in the binary blend as a consequence enhanced the cold crystallization temperature of blends. Short chain of LNR performed as a nucleating and plasticizing agent which influenced the mobility PLA molecules retrieving the cold crystallization temperature in the ternary blend. Polyolefin and LNR jointly enhanced the thermal stability of PLA blends as was observed from TGA and DTG thermograms. In DMA thermograms, the ternary blend illustrated the highest storage modulus and the lower  $\delta$  peak temperature as compared to binary blend. So, it can be concluded that LNR played a key role in developing good interaction between PLA and LLDPE polyolefin besides enhancing the thermo-mechanical properties of the ternary blend.

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