

Abstract

Machines used in daily life are generally affected by scratches or local impacts, resulting in cracks. Traditional flexible protective layers need to be replaced after damage. This study mainly explores whether strength and toughness can be combined with room-temperature self-healing in the same polymer network. The experiment uses isophorone diisocyanate (IPDI), polytetramethylene ether glycol (PTMEG, $M_n=2000$), and isophorone diamine (IPDA) for two-step solution polymerization to prepare polyurethane-urea elastomer (PUI). The formation of target bonding structure can be confirmed by Fourier transform infrared spectroscopy and proton nuclear magnetic resonance spectroscopy analysis. X-ray diffraction analysis shows that the material is mainly amorphous structure, and no obvious macroscopic phase separation is observed under scanning electron microscopy. The various performance values of the material obtained from the tensile curve are: tensile strength of 6.98 MPa, elongation at break of 1579%, and toughness of $70.28 \text{ MJ} \cdot \text{m}^{-3}$, indicating that the material can dissipate mechanical energy through large deformation. At 25 °C, the surface scratches are nearly closed after 6 hours. A completely cut and reattached specimen exhibited a toughness recovery of 91.70% after healing for 6 hours, as calculated based on the integrated areas of the stress-strain curve. The repaired specimen can withstand a static load test of 1 kg. These results indicated that the PTMEG soft segment moves at room temperature and forms a reversible hydrogen bond network with the urethane and urea groups, which can form a synergistic effect between load bearing and interface reconstruction. Frequency scanning also further shows that the material has obvious viscous energy dissipation components. Finally, this study conceptually demonstrates PUI as a protective layer for the foot and leg surfaces of quadruped robots. This study has been validated through molecular design, structural characterization, mechanics and healing evaluation, but further verification is needed for real impact testing, fatigue cycling, and long-term environmental stability.

Keywords: self-healing; Polyurethane urea; Dynamic hydrogen bonding; High resilience; anti-collision