

Thèse : Mécanismes de déformation et fracture d'élastomères à réseaux interpénétrés

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Laboratoire d'accueil :

Laboratoire de Sciences et Ingénierie de la Matière Molle (UMR 8213)

Ecole doctorale :

École Doctorale Physique et Chimie des Matériaux (ED 397)

Sujet de thèse :

Mécanismes de déformation et fracture d'élastomères à réseaux interpénétrés

Thématique de recherche :

Recent studies have shown that hydrogels (swollen hydrophilic polymer networks containing 90% water) synthesized with two interpenetrating networks with very different levels of crosslinking have a fracture toughness significantly enhanced relative to a single homogeneous networks. This enhancement has been attributed to the possibility of breaking the bonds in the bulk of the more crosslinked and highly stretched minority network while avoiding crack propagation through the less crosslinked and unstretched majority network. In other words the stiff network would act as a reinforcement, providing stiffness and the soft network would provide extensibility. This design principle has been transposed to elastomers during the thesis of Etienne Ducrot at the SIMM laboratory of the ESPCI. This work has shown that using a two or three stage procedure to synthesize dual or triple interpenetrating network elastomers by UV polymerization leads to remarkable enhancements of both stiffness and fracture toughness. At intermediate concentrations of the first network, the elastomer remains completely elastic and the modulus can increase from 1 to 2 MPa with an increase in G_c from 50 J/m² to 3 to 5000 J/m². The mechanism of toughening is believed to be due to the prestretching of the chains of the first network and should be quite general for unfilled elastomers. However many questions remain on the details of the reinforcement mechanisms and on the limits of the method and applicability to other types of chemistry.

Compétences requises :

Pour effectuer ce travail, nous recherchons un candidat qui ait effectué un stage dans le domaine des polymères avec une formation de base en physique et chimie et une formation de niveau master en physique et chimie des matériaux. Un gout pour l'expérimentation est nécessaire ainsi qu'une bonne connaissance de l'anglais.

Description du sujet :

The main scientific objective of the thesis is twofold : to elucidate more quantitatively and with molecular arguments the physical principle behind this toughening effect of dual and triple network design principle in fully hydrophobic elastomer networks to explore the limits of the toughening effect, in terms of molecular design and in other conditions than uniaxial extension as for example resistance to cavitation or to crack propagation in fatigue. The primary objective is not here to develop alternative chemistries but rather to elucidate what are the key mechanisms preventing



crack propagation. In particular it is not clear what controls the increase in initial modulus : prestretching of chains of the first network, additional trapped entanglements between the first and the second network, transfer reactions between networks. Several molecular parameters can be explored more quantitatively within the range of free radical UV polymerization : the degree of crosslinking of the first network, the degree of crosslinking of the second network, the presence of solvent during the synthesis of the first network, the compatibility between first and second monomer used. The entanglement density of the first and of the second network. In Etienne Ducrot's thesis the main techniques used to characterize the materials were uniaxial extension and fracture tests in single edge notch. Several other techniques have been explored but only applied a to a very limited number of materials. In particular neutron scattering under uniaxial stretching, solid-state NMR; digital image correlation at the crack tip and the incorporation of chemoluminescent molecules into the network to detect bond fracture before macroscopic fracture. Several or all of these techniques will be applied to the double and network elastomers to gain a better insight in the molecular and microscopic mechanisms (damage zone) leading to enhanced toughness.

Contact

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Accès

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