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Investigation of indentation size effects in elastomers

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ABSTRACT

Indentation tests were performed on polydimethylsiloxane and natural rubber as two highly elastic materials at the micronanometer indentation depths to investigate the underlying depth dependent deformation of polymers at such length scales. It was observed that the deformation mechanisms at these small length scales are significantly different when compared with the mechanisms at macroscopic length scales. For both polymers, experimental results exhibited strong size effects with a very strong increase in the universal hardness for small indentation depths which cannot be predicted by the classical local continuum elasticity theory. These strong size effects were analyzed by a depth dependent hardness model (motivated by Frank energy type mechanisms incorporating rotation gradients) where good agreement was achieved between the experiments and the theoretical hardness model. Compared to other polymers in the glassy state, however, the indentation size effect in the elastomers was much stronger. The chains of polymers in the elastomers and other polymers in rubbery state have increased mobility to rotate resulting in a more pronounced rotation gradient part in the total deformation energy density of the polymer. According to this rationale, the indentation size effects should be significantly stronger in rubbers and other polymers in rubbery state, when compared with glassy polymers.