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First Principles Analysis of Materials Response of Amorphous Glassy Polymers to Nanoindentation

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We examine here the material response to constant strain rate ($\dot{P}/P$ = 0.1 s^{-1}) nanoindentation with Berkovich tip of four glassy polymers – photo-lithography fabricated ~ 82 % (post-exposure baked) and ~ 95 % cross-linked (hard baked) SU-8 and commercial grade PC and PMMA. The SU-8 samples were gold-coated to preclude tip adhesion and hold time was long enough to prevent viscoelasticity effects during unloading. Contact area was obtained via first principles of empirical contact geometry. The stiffness was estimated via rigorous analysis of the unloading load-displacement curve. We have examined the conventional method, along with subsequent soft-material corrections available in the literature. These yield approximate estimates of reduced modulus (E_r) and hardness (H) values for glassy polymers. However, they do not adequately account for structure dependent plastic flow effects on contact area, and incorrectly indicate that the lower cross-linked SU-8 is harder and has a higher E_r and H than higher cross-linked epoxy. Our more rigorous method, based on an accurate analysis of deformation geometry, provides superior quantitative estimates of the nanoindentation response measures for glassy polymers.

Keywords: SU-8; PC; PMMA; Hardness; Nanoindentation