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Cracking in brittle materials during nanoindentation: New insights gained from cohesive zone finite element modeling

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Cracking during nanoindentation of brittle solids with sharp pyramidal indenters like the Vickers and Berkovich has been modeled and systematically examined using cohesive zone finite element simulations. Although the initial stages of crack initiation cannot be adequately captured by these techniques, the cracks that form eventually evolve into long-crack geometries that behave much like those observed in experiment, provided the crack length is approximately ten times greater than the cohesive zone size. Once this is achieved, the simulations accurately describe how cracks grow and change during loading and unloading and how the sequence of cracking events depends on material parameters like the elastic-modulus-to-hardness ratio and the fracture toughness. The modeling provides important new insights into indentation cracking such as the realm of material behavior over which the classic Lawn, Evans, and Marshall method for measuring fracture toughness from indentation crack lengths can be expected to work, as well as a predicted changeover in cracking geometry from radial-median dominated to Palmqvist surface cracking as the modulus-to-hardness ratio increases. Salient results are presented and compared to experimental behavior.