THE FORMATION AND EVOLUTION OF CRACKS DURING NANOINDENTATION OF FUSED QUARTZ

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Brittle materials such as fused quartz and other silicate glasses are commonly used in photovoltaics, semiconductors, and consumer electronics in the form of thin films. In these applications and a variety of others there is a need to understand how cracking occurs in these inherently brittle materials during contact and impact with hard, sharp objects. To this end, nanoindentation, high resolution scanning electron microscopy (SEM), and focused ion beam cross-sectioning (FIB) have been used to characterize the formation and evolution of surface and subsurface cracks in fused quartz (GE 124, Momentive). A series of experiments was performed using five three-sided pyramidal indenters with varying centerline-to-face angles (35.3°, 45°, 55°, 65.3°, and 75°) and peak indentation loads ranging from 10 to 500 mN. Distinct threshold loads below which no cracking could be observed were established, and a detailed set of experiments using FIB cross-sections to examine the sub-surface behavior was performed with the 45° indenter to document how cracking evolves as a function of load from sub-threshold all the way up to spalling and chipping. Finite element simulations were used to illuminate the stresses that may influence the cracking behavior. Relevant results and observations are discussed and compared to previous indentation cracking studies conducted at larger scales using Vickers and spherical indenters. The new results are used to assess prevailing models for indentation cracking and the origin of indentation cracking thresholds.

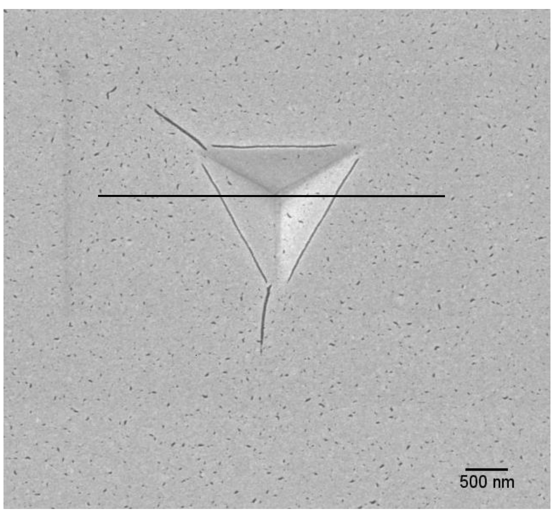

Figure 1: A 20 mN 45-degree indentation on the surface of fused quartz. The surface was gold coated after indentation and before focused ion beam milling. The black line indicates the position of the cross section view in Figure 2.

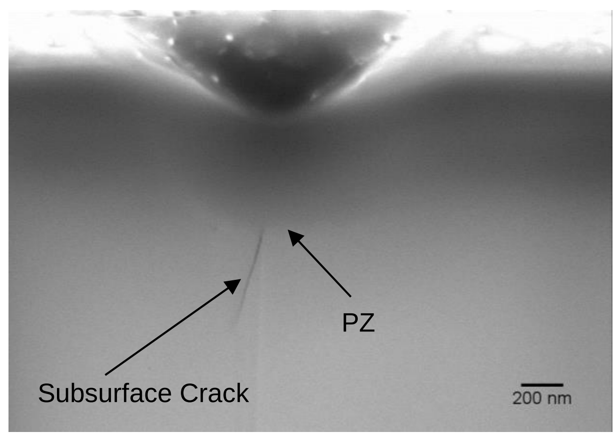

Figure 2: Subsurface view through the center of the indentation in Figure 1. A plastic zone (PZ) and subsurface crack are observable in this view.