

## **Energy-Based Hardness of Soda-Lime Silicate Glass**

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Hardness is a measure of mechanical resistance to deformation. It is obtained from the size of indentation impression after unloading and the indentation load. Although hardness of metallic material can be related to the yield stress of a given material, physical meanings of hardness for brittle materials, especially for glassy materials, are still unclear. Hardness is defined as the ratio of indentation load to the projected or surface area of the residual indentation impression. In general, the projected or surface area is estimated from the diagonal length of indentation impression after unloading. Because the diagonal length does not change so much during unloading, the estimated projected area is the area formed at the maximum indentation load. We must take care that depth recovery of indentation impression can not be ignored for brittle materials. In order to understand the mechanical resistance to inelastic deformation for brittle materials, quantitative evaluation of elastic recovery during an indentation test is indispensable. It is sure that inelastic deformation of brittle materials, such as glass, is important to assess its brittle or less-brittle characteristics. Energy-based hardness is the irreversible energy consumption to result in a unit volume of the indentation impression after unloading. In this study, energy-based hardness of soda-lime silicate glass is obtained from the work of indentation and the residual impression volume, which is measured by using a scanning probe microscope. The indenter shape dependence and the indentation load dependence of energy based hardness are investigated. Physical meanings of the energy-based hardness and the apparent hardness for brittle materials are discussed in terms of mechanisms of plastic deformation for brittle and glassy materials.