Indentation of Elastically Anisotropic Half-spaces*

J. G. Swadener[1] and G. M. Pharr[2]

[1] swadenerjg@ornl.gov and [2] pharr@utk.edu

Oak Ridge National Laboratory

Metals and Ceramics Division

P. O. Box 2008 - MS-6116

Oak Ridge, TN 37831-6116 USA

and

The University of Tennessee, Dept. of Materials Science and Engineering

Spherical indentation of ceramic materials can be conducted in the elastic regime. Ceramic single crystals provide excellent calibration media, however they are generally anisotropic and the complete analysis is cumbersome [1]. In addition, indentation unloading behavior is generally modeled as being elastic. This study presents a simplified procedure for the determination of the indentation modulus for spherical indentation which is modeled to first order as a parabola of revolution. A similar procedure is also developed for conical indentation of anisotropic elastic media.

For the contact of a parabolic indenter on an anisotropic elastic half-space, the projected area of contact is known to be elliptical [1]. Willis [1] developed a solution to the problem using Fourier transforms, however his solution is given by a set of six nonlinear integral equations which must be solved simultaneously. In this study, the surface Green's function for an anisotropic half-space [2] is used to simplify the problem. Vlassak and Nix [3] previously used a similar technique for the special case of circular contact. In the present study, the analysis is carried further to reduce the problem of elliptical contact to contour integrals for the orientation of the ellipse, the length of the elliptical axes and the indentation modulus. These equations can then be solved in a sequential manner.

The same method is applied to conical indentation of an anisotropic elastic half-space. The contact is found to be elliptical and similar equations are determined for the size, shape and orientation of the ellipse. The technique determines parameters which are important to nanoindentation, such as indentation modulus and contact depth. Results for sapphire and other materials will be presented as examples.

References:

1. Willis, J. R., 1966, *J. Mech. Phys. Solids*, **14**, 163.
2. Barnett, D. M. and Lothe, J., 1975, *Physica Norvegica*, **8**, 13.
3. Vlassak, J. J. and Nix, W. D., 1993, *Phil. Mag.*, **67**, 1045.

* Research sponsored by the Division of Materials Sciences, U.S. Department of Energy, under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp. This research was conducted using the Shared Research Equipment User Facilities at ORNL.