Hysitron Inc
Nanomechanical Testing Instruments

Technical Note:

Measuring the Radius of Curvature of a Probe Tip

Motivation:

The radius of curvature of a diamond probe tip can be very important in selecting the proper tip to use with a specific application. Softer samples and bulk samples do not require a sharp tip, and often a sharp tip can cause wear when imaging. Sharper tips can also break or blunt easier. On the other hand, very thin coatings require a sharper tip to find good hardness values. The sharper tips will provide more plastic deformation while keeping the elastic zone to a minimum. A good estimate of the radius of curvature will also allow a user to get more repeatable data when changing tips.

Method

The tip is calibrated in the same way that is done for a standard tip calibration. Refer to the user manual or request document NRL-M-001 from Hysitron for further details on this. The only difference is that the Area vs. Depth data is fit to a shape represented by a spherical area function rather than the polynomial fit suggested in that procedure.

Deriving a Spherical Area Function

Figure 1 below shows a sphere intersecting with a plane. The projected area of the sphere at a depth “h” is represented by the blue shaded area.

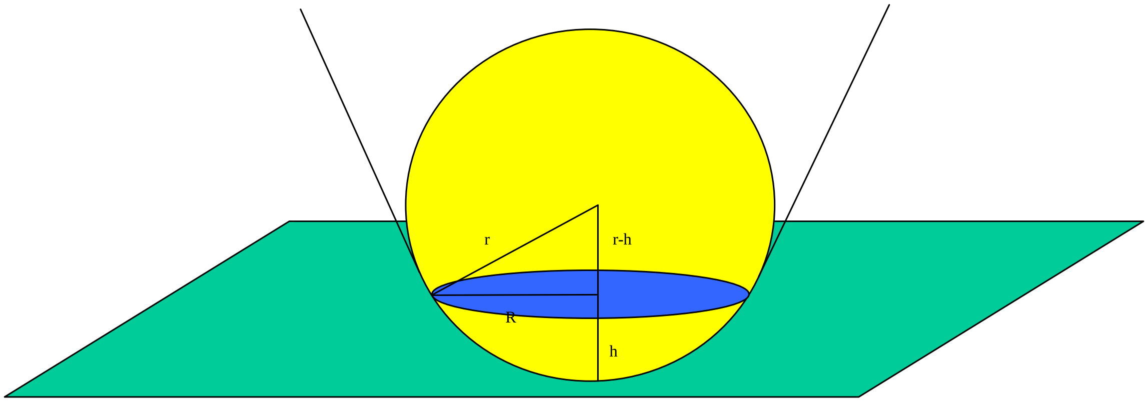

Figure 1: Projected area of sphere

The projected area is given by the equation:

$$A = \pi R^2 \qquad \text{Equation 1}$$

Using Pythagorean's Theorem, the radius of the area is also given by:

$$R^2 = r^2 - (r - h)^2 \qquad \text{Equation 2}$$

Solving equation 2, and substituting *R* into equation 1 yields the following function for Area vs. Depth:

$$A = \pi h(2r - h) \qquad \text{Equation 3}$$

This can be rewritten then as:

$$A = -\pi h^2 + 2\pi r h \qquad \text{Equation 4}$$

so if this is fit using the standard tip area function equation, C0 = $-\pi$ and C1 = 2πr. The standard area function calculation in the TriboScope or TriboScan file can then be used to estimate the radius of curvature of any probe tip.

To determine the Area function, a series of indents must be made in a standard sample (typically fused quartz). The contact area of these indents is found using the standard modulus equation:

$$A = \frac{4S^2}{\pi E_r^{\ 2}} \qquad \text{Equation 5}$$

The contact area is then plotted verses the contact depth. Using a curve fitting routine, the data should be fit to equation 3 above. The contact area is only in the spherical regime for a short time before the contact area is on the pyramidal or conical area of the tip (depending on the tip geometry). Usually this occurs at a depth of R/3. Therefore, any indents made with a contact depth greater than R/3 should not be used in the fitting. Example data from a tip with a 38nm radius of curvature is shown in figure 2 below.

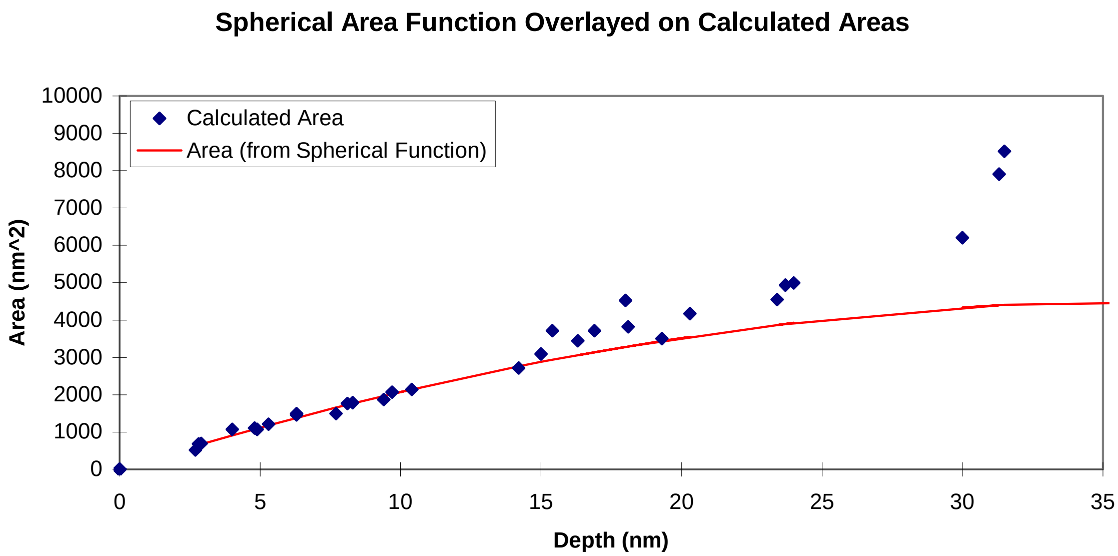

Figure2: Spherical area function overlayed on indentation data

As can be seen from the data, it fits very well to the spherical area function at depths below 15nm or so, which is approximately R/3. Above this value, the data deviates from the spherical function because it is past the rounded end of the indenter tip.

To measure the actual radius, the user would fix C0 to –3.14, and then fit the data using only two coefficients. Because C0 is fixed, only C1 would be calculated. C1 can then be divided by 6.28 to determine the nominal radius of curvature of the tip.

Faster Method used for approximating the radius

Because of their geometry, tips with lower radius of curvature (sharper tips) will go deeper into a sample with a given load. An experiment was set up with 8 different 90 degree probe tips with different radius of curvature. The radius of each tip was measured using the above procedure. Indents were then made with each tip at loads of between 10 and 100uN, and the maximum depth of the indents noted. The maximum depth of the indents should be proportional to the radius of curvature of the tips. A graph of the data taken using cube corner tips is shown in figure 3 below. There is a very strong correlation between the radius of curvature and the maximum depth at the different applied loads. Using this chart, the radius of curvature can be estimated from the maximum depth of indents at the different loads.

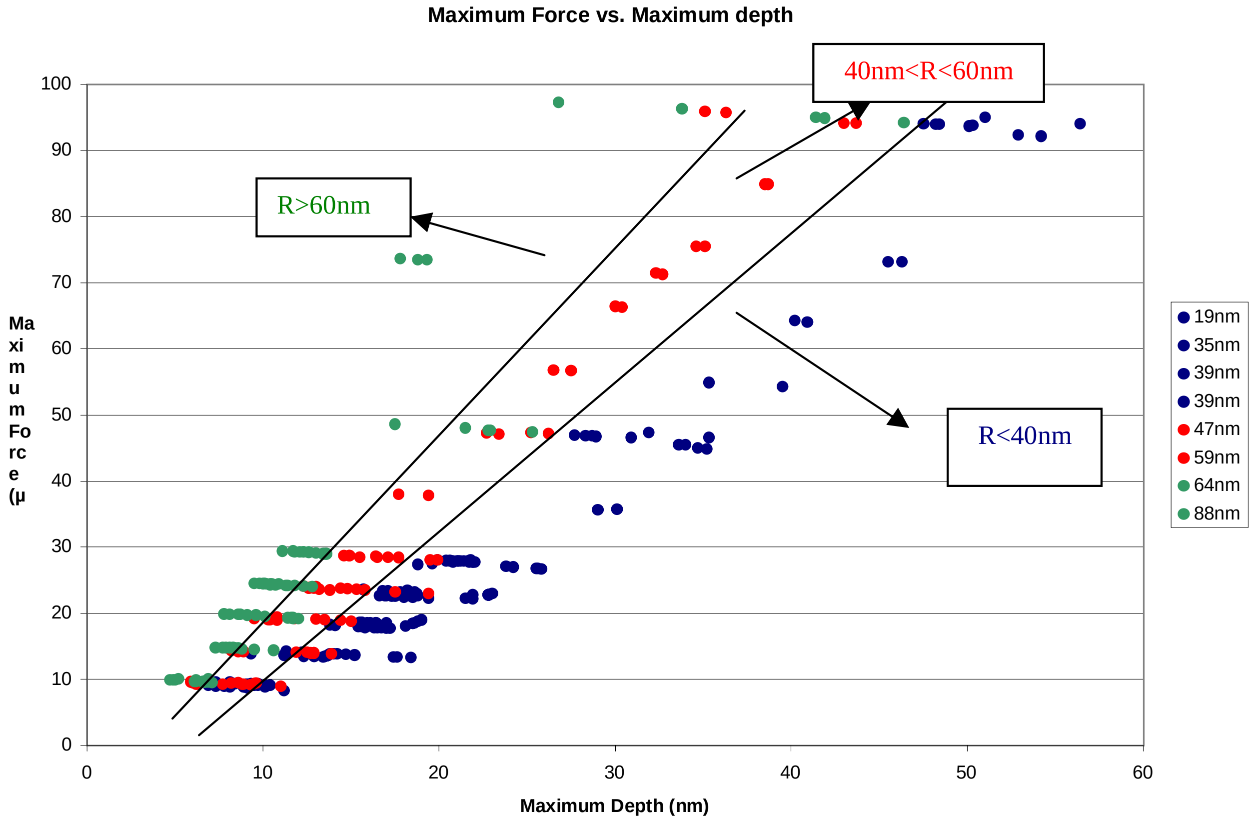

Figure 3: Graphs of Maximum depth vs. Maximum force for 8 different 90 degree tips.