

Hardness Testing at Multiple Length Scales

Hardness is a measure of a material's resistance to localized plastic deformation (e.g. a small dent or a scratch). Hardness testing is considered a non-destructive test, because it does not destroy the sample as tensile testing does, but rather leaves only a small indentation. This allows hardness to be measured on actual fielded components. For this reason, hardness testing is often used instead of tensile testing to provide a non-destructive measure of a component's relative tensile strength, which is also a measure of the material's resistance to plastic deformation.

The most common type of hardness testing for metals is Rockwell hardness testing. Rockwell hardness testing is conducted according to ASTM Standard E-18 "Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials," which is available in the library. There are several different Rockwell scales which are given as Rockwell C (HRC), Rockwell Superficial 15T (HR-15T), etc. In this laboratory, you will test the hardness at different length scales using Rockwell hardness, Vickers microhardness, and Nanoindentation.

First, you will test your sample at the macroscale using the Rockwell hardness tester. The aluminum should be tested with the Rockwell 15T scale. Test five locations and take the average and standard deviation. Rockwell testing requires only that you set the scale, the major and minor loads, install the indenter, and push "Test" in order to have the hardness measurement displayed. Try another scale as well.

Second, you will repeat the tests at the microscale using a Vicker's microhardness tester, and note the features that the indentations are obtained from. You will calculate the Vicker's microhardness, HV , by measuring the length of the diagonals for the indent.

Finally, you will test your specimen at the nanoscale using an instrumented nanoindenter, the Triboindenter from Hysitron. For the nanoindenter, you will calculate the Hardness, H , and Reduced Modulus E_r by

selecting a portion of the unloading curve to fit the power law relation, $P = A(h - h_f)^2$ then taking the derivative with respect to h at the maximum P to obtain S and using the predetermined area function $A(h_c)$

$$E_r = \frac{\sqrt{\pi}}{2\sqrt{A(h_c)}} S \quad \text{and} \quad H = \frac{P_{\max}}{A(h_c)}$$
in . You will also be able to observe the indent and microstructure of the material using the integrated Scanning Probe Microscopy capability of the nanoindenter.

Questions:

- 1) What is the difference between the Rockwell Scale and the other scale you chose?
- 2) What was the standard deviation on the Rockwell scale? How does it compare with the average? If it is relatively high, why might that be the case?
- 3) How does the hardness of your specimen change with length scale (i.e., Rockwell to Vickers microhardness to Nanoindentation)? Why do you think it is changing? **IMPORTANT: This is asking you to compare measurements – to do that you may need to think of some way to convert the scales.**