Yield Strength as a Function of Dislocation Density

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Characterization of Advanced Materials

Introduction
Nanoindentation is used on samples of brass whose grain size and hardness is controlled in order to test the procedure’s viability on samples that have a moderate amount of dislocations.

Procedures and Methods
Before doing nanoindentation, the bulk properties of brass need to be determined so they can be separated from the nanoindentation data

- Cold Rolling—plastic deformation which occurs well below melting point
- Annealing—Heat treatment used for lowering dislocation density
- Grinding/Polishing—removes surface damage to produce reasonably flat, reflective surface
- Etching—reveals accurate, sharp definition of true microstructure of material
- Heyn Intercept Method—Fast and accurate technique for calculating average grain size diameter

Once the grain size of a sample is determined, the Vickers Hardness is found using a micro-hardness indenter, which uses a square pyramidal indenter tip.

Yield strength of a material is a very useful statistic to know, as it gives a good upper limit for the stress the given material can undergo before plastic deformation. Many metals’ yield strength follows the Hall–Petch relationship,

\[ \sigma_y = \sigma_0 + kd^{-1/2} \]

where \( k \) is a material-dependent constant and \( d \) is the average grain size diameter. The Vickers hardness number is in kgforce/mm², force per contact area. This must be converted to SI units and scaled so that it is force per projected area. The surface area of a Vickers indent is given by \( A = d^2/2\sin(136°)/2 \), where \( d \) is the average diagonal length of the indent. The projected area of this area is just \( d^2/2 \). Taking the ratio of contact to projected area and multiplying by the gravitational constant gives 10.57, divided by 3 for geometric scaling gives 3.52 as the multiplication factor converting from HV to \( \sigma_y \).

Results
Grain size and calculated yield stress are plotted and a curve fit is applied using the Hall–Petch equation to give experimental values for \( \sigma_y \) and \( k \).

![Graph](http://www.hardness testers.com/vickers.jpg)

Conclusions
Using nanoindentation, yield points can be found in materials with moderate dislocation densities while avoiding the use of electropolishing.

Literature Used

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A slightly different sequence of sample prep is needed to prepare a sample for nano-indentation

Normal order: Cold roll > Anneal > Grind, Polish > Etch > photograph
Nano-indent order: Cold roll > Grind, Polish > Anneal > Etch > indent
The sample is etched after annealing to minimize mechanical damage to the surface as much as possible