NANOMECHANICALTESTING OF BCC MICROPILLARS:
POWER LAWS AND LATTICE RESISTANCE CORRELATIONS

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It is now well established that the compression plastic flow stress, σ_p, of metallic micropillars increases with decreasing sample diameter. With fcc metals, if the pillar flow stress and pillar diameter are normalised by the shear modulus resolved onto the active slip system, μ, and Burgers' vector, b, respectively, the data follows an empirical relation of

$$\frac{\sigma_p}{\mu} = A\left(\frac{d}{b}\right)^n \qquad (1)$$

with a "universal exponent" of approximately n = -0.67.

Specimens from bcc metals tested in microcompression show significant differences in their behaviour with size exponents showing a range from -0.2 to -0.8. It is generally believed that the difference in the behaviour of bcc and fcc metals is related to the behaviour of dislocations in the different lattices. In fcc materials dislocations are highly mobile, show similar mobility for edge and screw character and show little need for thermal activation. However, in bcc materials the dislocation core structure of a screw dislocation leads to a significantly higher Peierls' stress and lower mobility compared to edge dislocations, requiring a degree of thermal activation. In which case a different relation may be more appropriate with:

$$\sigma_p - \sigma_b = A' d^{n'} \qquad (2)$$

Where, σ_b, is the temperature dependent lattice friction stress that must be overcome to allow plastic flow.

Here we will show that if the data is plotted in the form of equation (1), if equation (2) is valid there should be a strong correlation between the slope of the log(σ)/log(d) plot (*n* in equation 1) and the proportionality materials constant *A*. This prediction is shown to be consistent with micropillar compression experiments carried out on a range of bcc metals over a range of testing temperatures in this study (figure 1) and to also hold true for data in the published literature. Further analysis of the data can be used to predict a "natural power law" for micropillar compression, *n'* in equation 2, which for the case of bcc materials is found to be close to the empirical value of -0.67 determined for fcc materials.

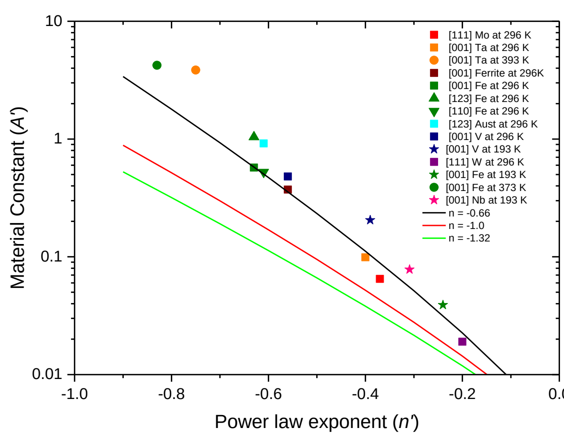

Figure 1 – Correlation between the power law exponent, n, and the materials pre-exponent constant, A, for a number of bcc metals