NANOINDENTATION STRAIN RATE JUMP TEST-BASED PREDICTION OF FRACTURE AND THE BRITTLE TO DUCTILE TRANSITION IN TUNGSTEN

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Methods to predict material fracture frequently rely on large experimental datasets tuned to the properties of one material or are based on computationally expensive modeling. Both methods are time-intensive and do not adapt well to changes in material chemistry or processing. Development of analytical models with easily measured, physically meaningful parameters are key to alleviating bottlenecks in new materials development. In this work, I will describe the use of nanoindentation strain rate jump tests to predict the fracture behavior of macroscale tungsten single crystals. These techniques were applied at low temperature (-100 °C) and high temperature (50-300 °C) to measure activation parameters, effective stress and activation volume, as a function of temperature. The activation parameters, in combination with an analytical model for the strain energy release rate, accurately predict the brittle-ductile transition temperature along particular fracture systems in single crystal tungsten. Activation parameters measured from indentation of the (100) surface of single crystal tungsten accurately predicts the brittle-ductile transition and fracture toughness along the {100}<011> fracture system of macroscale tungsten single crystals. Use of data from bulk tension of single crystal tungsten from the literature accurately predicts the fracture toughness in the {110}<110> fracture system of macroscale tungsten single crystals.

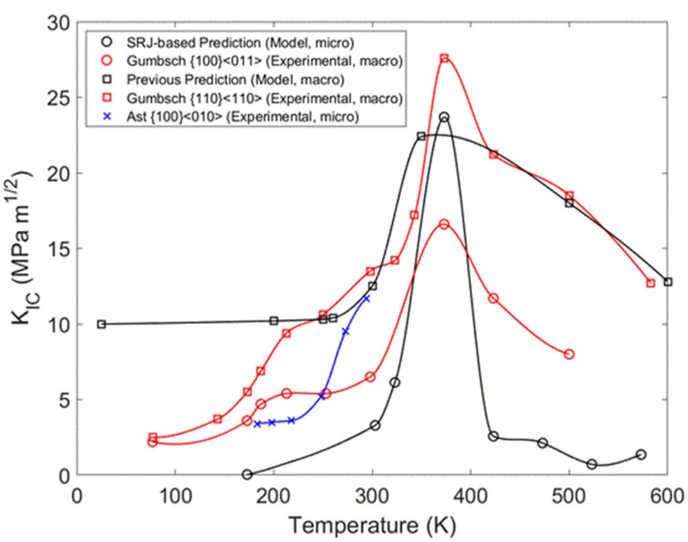

Figure 1- Predicted fracture toughness of single crystal tungsten. Prediction based on data from nanoindentation strain rate jump tests (black circles) closely matches experimental macroscale fracture toughness from Gumbsch [1] (red circles). Notably, the BDT of microscale tungsten [2] is shifted to lower temperatures than bulk fracture experiments or our predictions.

[1] P. Gumbsch, J. Riedle, A. Hartmaier, H.F. Fischmeister, Controlling Factors for the Brittle-to-Ductile Transition in Tungsten Single Crystals, Science (80-.). 282 (1998) 1293–1295. https://doi.org/10.1126/science.282.5392.1293.

[2] J. Ast, J.J. Schwiedrzik, J. Wehrs, D. Frey, M.N. Polyakov, J. Michler, X. Maeder, The brittle-ductile transition of tungsten single crystals at the micro-scale, Mater. Des. 152 (2018) 168–180.