MICROMECHANICAL CHARACTERIZATION OF SINGLE-CRYSTALLINE NIOBIUM AT LOW TEMPERATURE

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Due to the significant interests in application of micro-electro-mechanical system to devices used in harsh environments, small-scale mechanical behaviors in different thermal environments have been extensively studied recently. Particularly, the study on mechanical behavior of body-centered-cubic (bcc) metals has received a strong attention because of the significant temperature dependence of screw dislocation mobility and its cross-slip probability. So far, most studies have been done in either room temperature or elevated temperature, but a low temperature study is relatively scarce. In this work, we present our recent development of in-situ cryogenic micromechanical testing system and the results of cryogenic micro-tensile tests on a [0 0 1] bcc niobium single crystal. The dog-bone shaped tensile samples were fabricated via focused-ion beam milling and were tested at room temperature, 100K and 56K. The decrease in temperature increased the flow strengths. In addition, stress-strain curves at room temperature were smooth, but those at 56 and 100K showed a few distinctively large strain bursts. Post-mortem scanning electron microscopy revealed that necking region of samples tested at room temperature underwent uniform and homogeneous plastic deformation, but that at low temperature underwent highly localized plastic deformation followed by brittle fracture with limited ductility. Thus, micro-tensile tests of niobium single crystal show the ductile-to-brittle transition. All the results will be discussed in terms of the temperature dependence of cross-slip and intrinsic lattice resistance of screw dislocation. Our results will enable a deeper understanding of the combined effects of sample dimension and temperature on plasticity and fracture processes in bcc metals.

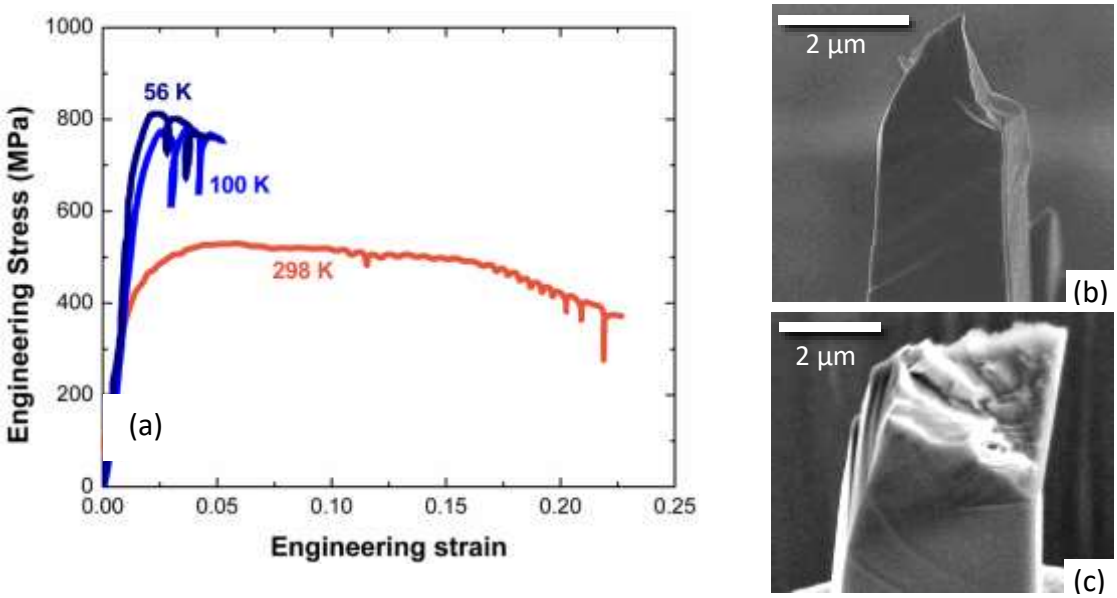

Figure 1 – (a) Tensile stress-strain curve of single-crystalline Nb at various low temperatures; SEM images of tensile fractured specimen at (b) room temperature and (c) 56K