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High-Temperature In Situ Straining Experiments in the High-Voltage Electron Microscope

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Abstract: Design rules are described here for high-temperature straining stages for transmission electron microscopy. Temperatures above 1000°C can be attained by electron bombardment of the specimen grips. Thermal equilibrium can be reached in a short time by carrying off the heat by water cooling. Some applications of this stage are described. Ferroelastic deformation was observed at 1150°C in t′ and partially stabilized zirconia, which changes the microstructure for successive dislocation plasticity. In the oxide-dispersion-strengthened alloy INCOLOY MA 956, dislocations are impeded by oxide particles and move smoothly between the particles. At high temperatures, both the resting and traveling times control the average dislocation velocity. In $MoSi_2$ single crystals of a soft orientation, dislocations with 1/2⟨111⟩ Burgers vectors are created in localized sources and move on {110} planes in a viscous manner. The dislocations in Al-Pd-Mn single quasicrystals are oriented in preferred crystallographic directions and move in a viscous way as well. On the basis of in situ observations, conclusions are drawn for interpreting macroscopic deformation behavior at high temperatures.

Key words: high-voltage electron microscopy, in situ straining experiments, high-temperature mechanical properties, dislocations, zirconia, oxide-dispersion strengthened alloys, molybdenum disilicide, quasicrystals

Introduction

In situ straining experiments using a transmission electron microscope (TEM) may reveal details of the mechanisms of plastic deformation that other methods cannot directly provide. For these experiments, a high-voltage electron microscope (HVEM) has two advantages compared to conventional microscopes: its large penetration power allows the observation of relatively thick specimens, thus the behavior of individual dislocations resembles that in bulk specimens. In addition, it provides adequate space in the specimen chamber for installing elaborate in situ stages. Investigation of materials for future technologies often requires temperatures above 1000°C. In the present report, we show that it is

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