Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Mechanical response of self-ion irradiated, single crystal, FCC micropillars

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ABSTRACT

Increasing energy demands and regulations on cleaner and more efficient energy sources has reinvigorated research into next generation nuclear reactors. The safe and optimal operation of the various proposed reactors requires the cladding and structural metals to perform under a combination of extreme environments including radiation damage levels >100 dpa. This presentation will highlight a rapid screening technique developed at Sandia National Laboratories to determine the relative merit of implementing various advanced structural alloys and composites in high radiation environments. In addition to an overview of the technique and the wealth of alloy systems it has been applied to, this presentation will focus on the detailed mechanisms that can be elucidated from the micropillar compression of ion irradiated single crystal copper and nickel. Single crystal Cu micropillars self-ion irradiated up to 190 dpa at the end of range were compressed along the <110> to 10% strain. To elucidate the interaction of different length scales on the mechanical response, three specimen configurations were explored: large 10 μm tall, intermediate 5 μm tall, and small 4 μm tall pillars. In a similar manner, pristine and self-ion irradiated <111> Ni pillars were subject to in-situ microcompression in a scanning electron microscope (SEM). By performing these experiments during real time SEM observation a direct correlation between the mechanical responses and the pillars' structural evolution can be obtained. Specifically, the dynamics resulting from the defect free channel formation and subsequent localization can be associated with heterogeneous plastic flow. This presentation will highlight the multiple length scale effects that are active during the micropillar compression of self-ion irradiated, single crystal, FCC micropillars. These results will be discussed in the context of an end of range effect, a damage gradient effect, and size effects, as well as compared to other small scale mechanical testing methods of ion and neutron irradiated materials. Finally, the benefits and limitations of applying these methods to rapidly screen advanced materials for potential future nuclear reactor applications will be discussed. This study is supported by the Division of Materials Science and Engineering, Office of Basic Energy Sciences, U.S. Department of Energy. Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.