



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Mechanical Properties and Fracture Behavior of Nanoporous Au

J. Biener, A. M. Hodge, Y. M. Wang, J. R. Hayes,
A. V. Hamza

June 24, 2005

MRS fall meeting 2005
Boston, MA, United States
November 28, 2005 through December 2, 2005

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Mechanical Properties and Fracture Behavior of Nanoporous Au

J. Biener, A.M. Hodge, Y.M. Wang, J.R. Hayes, A.V. Hamza

*Lawrence Livermore National Laboratory, Nanoscale Synthesis and Characterization
Laboratory, Livermore, California 94550, USA*

Nanoporous metals have recently attracted considerable interest fueled by potential sensor and actuator applications. From a material science point of view, one of the key issues in this context is the synthesis of nanoporous metals with both high tensile and compressive strength. Nanoporous gold (np-Au) has been suggested as a candidate material for this application due to its monolithic character. The material can be synthesized by electrochemically-driven dealloying of Ag-Au alloys, and exhibits an open sponge-like structure of interconnecting ligaments with a typical pore size distribution on the nanometer length scale. However, besides the observation of a ductile-brittle transition very little is known about the mechanical behavior of this material.

Here, we present our results regarding the mechanical properties and the fracture behavior of np-Au. Depth-sensing nanoindentation reveals that the yield strength of np-Au is almost one order of magnitude higher than the value predicted by scaling laws developed for macroscopic open-cell foams. The unexpectedly high value of the yield strength indicates the presence of a distinct size effect of the mechanical properties due to the sub-micron dimensions of the ligaments, thus potentially opening a door to a new class of high yield strength – low density materials. The failure mechanism of np-Au under tensile stress was evaluated by microscopic examination of fracture surfaces using scanning electron microscopy. On a macroscopic level, np-Au is a very brittle material. However, microscopically np-Au is very ductile as ligaments strained by as much as 200% can be observed in the vicinity of crack tips. Cell-size effects on the microscopic failure mechanism were studied by annealing experiments whereby increasing the typical pore size/ligament diameter from ~100 nm to ~1 μ m.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract of No.W-7405-Eng-48.