Mechanical Properties of Aging Erbium Tritide Films

by **J. A. Knapp and J. F. Browning**

Motivation—The mechanical properties of metals containing dispersions of small gas bubbles are of fundamental interest for understanding the effects of nanometer-sized inclusions on strength, and for applying materials to applications involving tritium, such as neutron tubes. The tritium slowly decays into ^{3}He, which is either released from the film, leading to vacuum problems in a sealed tube, or if retained, forms high pressure bubbles that may eventually fracture the film. Not only are the conditions leading to fracture of interest, but the mechanical properties of the layer before fracture are of fundamental importance for understanding how to control early ^{3}He release. We have been using fully tritiated ErT_2 model films deposited on Si to study the property changes to be expected for an aging neutron tube target film.

Accomplishment—We are using ultra-low load nanoindentation, combined with finite-element modeling (FEM) to separate the nano-mechanical properties of the 500 nm ErT_2 layers from those of the underlying substrate. The ^{3}He bubbles which form as the film ages act as barriers to dislocation movement, hardening the material, but not dramatically affecting the elastic properties. Figure 1 shows a TEM micrograph of one of the films 62 days after hydriding with tritium. The ^{3}He bubbles form as thin platelets oriented along (111) planes.

The nanoindentation/modeling approach to measuring the hardness and elastic properties of thin films has been developed over the last several years with application to a number of thin film material studies. These samples are indented in an instrument especially modified for tritium safety concerns, and then the data are fitted using FEM in order to separate the properties of the thin layer from the independently measured substrate properties. By modeling the ErT_2 layer as an isotropic, elastic-plastic solid with the Mises yield criterion, the nanoindentation data is shown to correspond to an increase of nearly 2x in strength after aging for over a year, followed by a slow decrease in strength with further aging. Figure 2 shows the deduced hardness of the layers as a function of aging after hydriding with tritium. The strength saturated at ~8.5 GPa, followed by a slow decrease with further aging.

The nanoindentation procedure also determines the elastic properties of the ErT_2, in particular the Young's modulus, from which the shear modulus can be calculated. The latter is very useful as an input parameter for models being developed to understand film aging, and is not available anywhere else for these materials. While the yield strength and hardness have changed substantially over the course of the study, the elastic properties have remained largely unchanged.

Significance—These measurements provide hitherto unknown information about the mechanical evolution of tritiated films as they age. Such knowledge is providing important insights into the aging process for these films, and when combined with ion beam analyses and electron microscopy, as well as models of film aging, will lead to solutions for problems associated with aging and ^{3}He release.

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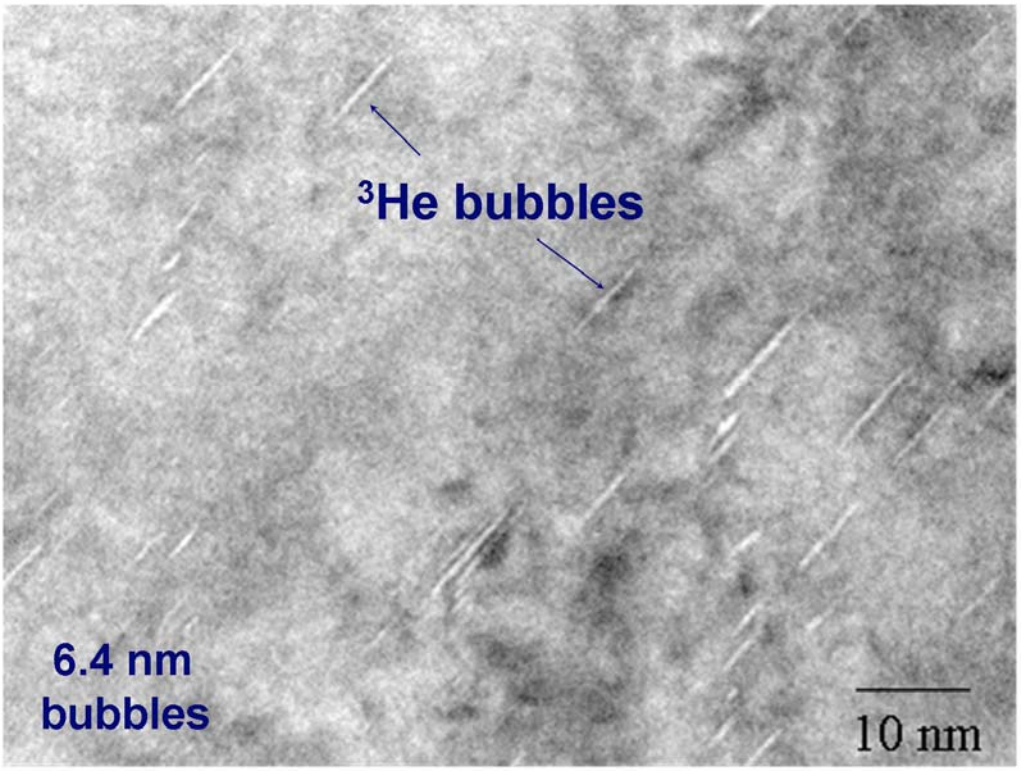

Figure 1. Bright-field Transmission Electron micrograph of ErT_2, in cross-section, along a {110} zone 62 days after hydriding with tritium. TEM done with G. Bond, New Mexico Institute of Mining and Technology.

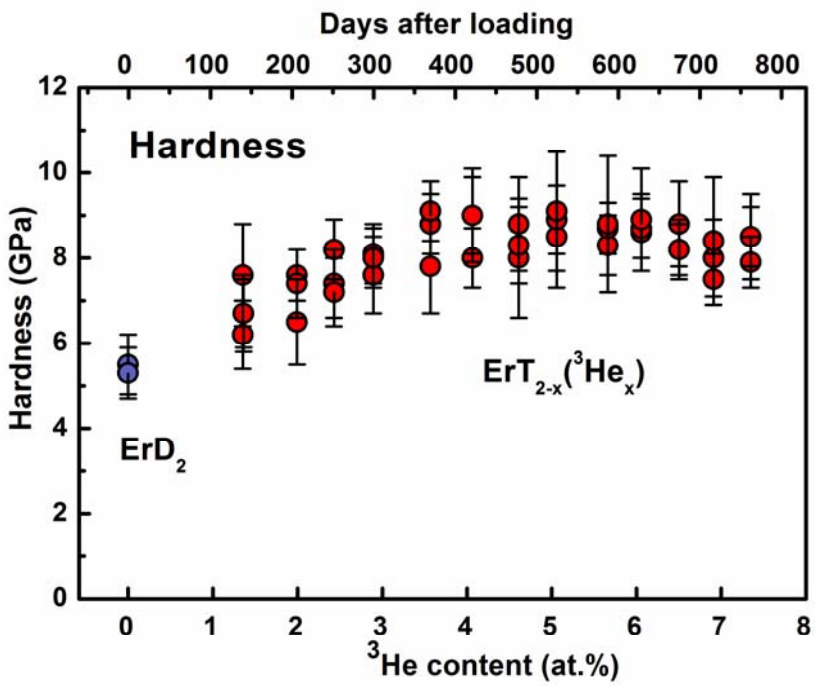

Figure 2. Material hardness determined by finite-element modeling of indentation data for ErD_2 and aging ErT_2.