Recent applications of transient grating spectroscopy for inferring radiation-induced evolution of nuclear materials

S.E. Ferry[1], K.B. Woller[2], C.A. Dennett[1], and M.P. Short[1]

[1]Massachusetts Institute of Technology, MA, USA
[2]Plasma Science and Fusion Center, MA, USA

Transient grating spectroscopy (TGS) is a non-contact, non-destructive optical heterodyne detection technique used to quickly obtain acoustic and thermal transport properties in materials. In recent years, efforts have been underway to develop TGS as a tool for detecting and characterizing radiation damage-induced changes in nuclear materials with greater ease and speed than is afforded by traditional post-irradiation examination (PIE) techniques [1-3]. Here, we present results from three recent *ex situ* TGS studies.

In the first study, single-crystal niobium was successively irradiated with Si^{3+} ions up to 1.9 dpa [4]. After each irradiation, TGS was used to measure sample thermal diffusivity. An initial 70% drop in thermal diffusivity was observed at 0.006 dpa, likely due to point defects, which are the dominant defect mode at low dose and which are very efficient at scattering electrons. At 0.02 dpa, thermal diffusivity partially recovered (to 50% of its initial value) and remained constant thereafter. This likely corresponds to the conglomeration of point defects, formerly distributed throughout the bulk, into larger mesoscale defects. Thus, TGS can be used to quickly gain insight into defect evolution as a function of dose in irradiated materials.

In the second study, TGS was used to measure the thermal diffusivities of AISI 304 steel samples irradiated with neutrons in the core of EBR-II up to 28 dpa. These results were compared with prior transmission electron microscopy (TEM) measurements of radiation defect populations in the samples. The trends that emerged suggest that TGS-measured thermal diffusivity has the potential to be a useful tool for more efficient identification and quantification of radiation-induced defect populations in common alloys.

In the final study, a polycrystalline tungsten sample was exposed to a helium plasma at fluences ranging from 1E24 to 5.3E24 He/m^2. TGS-measured surface acoustic wave (SAW) speed was observed to drop precipitously at intermediate fluence values. Scanning electron microscopy (SEM) examination of the tungsten surface confirmed that this drop corresponded to the onset of tungsten fuzz, a surface morphology phenomenon of particular concern in fusion applications. TGS could therefore be a valuable tool for rapid, non-contact detection and monitoring of tungsten fuzz.

[1] Short, Michael P., et al. "Applications of transient grating spectroscopy to radiation materials science." *JOM* 67.8 (2015): 1840-1848.
[2] Dennett, Cody A., et al. "Bridging the gap to mesoscale radiation materials science with transient grating spectroscopy." *Physical Review B* 94.21 (2016): 214106.
[3] Dennett, Cody A., and Michael P. Short. "Thermal diffusivity determination using heterodyne phase insensitive transient grating spectroscopy." *Journal of Applied Physics* 123.21 (2018): 215109.
[4] Ferry, S.E. et al. "Inferring radiation-induced microstructural evolution in single-crystal niobium through changes in thermal transport." [*Submitted*]