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PROBING NANOSCALE DAMAGE GRADIENTS IN IRRADIATED MATERIALS WITH SPHERICAL NANOINDENTATION

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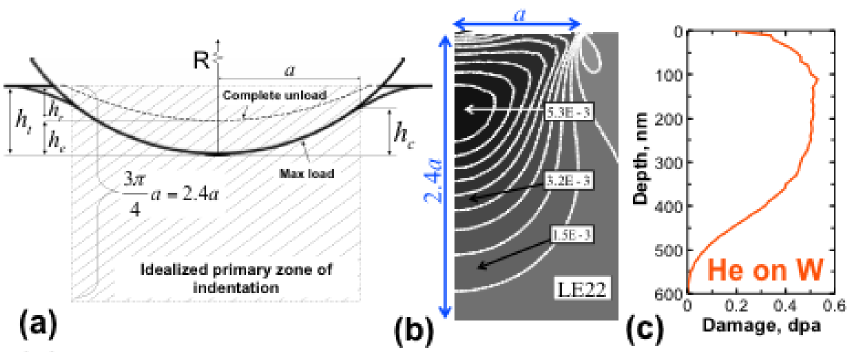
We discuss applications of spherical nanoindentation stress-strain curves in characterizing the local mechanical behavior of materials with modified surfaces. Using ion-irradiation on tungsten as a specific example, we show that a simple variation of the indenter size (radius) can identify the depth of the radiation-induced-damage zone, as well as quantify the behavior of the damaged zone itself. Using corresponding local structure information from electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM) we look at (a) the elastic response, elasto-plastic transition, and onset of plasticity in ion-irradiated tungsten under indentation, and compare their relative mechanical behavior to the unirradiated state, (b) correlating these changes to the different grain orientations in tungsten as a function of (c) irradiation from different sources (such as He, W, and He+W).



(d)

Indenter radius, R	Indentation depth, h_t	Contact radius, a	Indentation zone ~2.4a
1 µm	~10 nm	60 nm	144 nm
10 µm	~20 nm	250 nm	600 nm
100 µm	~40 nm	1,200 nm	2,880 nm
1000 µm *	>200 nm	12,800 nm	30,720nm

Figure 1 – (a) Schematic of spherical indentation showing the idealized primary zone of indentation. (b) Logarithmic strain field (along the indentation direction) for a spherical indenter in the indentation zone (~2.4a, where a is the contact radius) close to the indentation yield. The contact radius a, and the volume probed by indentation, can be controlled by chosen indenter radius. This approach is thus ideally suited for probing the (c) damage caused by He irradiation on a tungsten sample. (d) Table showing indentation depth (h_t), contact radius (a) and indentation zone size (~2.4a) at yield for W using 4 different indenter radii.

** For the 1000 µm radius indenter, the response was all elastic up to h~200nm (instrument limit).*