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Nanomechanical testing of ODS steels irradiated with 1 MeV/amu heavy ions

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**Work motivation**

ODS steels, reinforced by oxide nanoparticles, are considered to be the most perspective materials for fuel cladding in Generation IV nuclear reactors due to their enhanced radiation resistance and high temperature creep resistance compared to the conventional reactor steels. One of the key questions is the study of fission fragment impact on the structure of the nanoparticles and mechanical properties of ODS steels in general.

**Irradiation parameters:**
- 167 MeV Xe irradiation,
- 107 MeV Kr irradiation
- fluence: 1.10\textsuperscript{-2}-4.5.10\textsuperscript{15} cm\textsuperscript{-2}
- dose \~0.01 dpa
- irradiation mode:
  - direct irradiation,
  - irradiation through the Al filters of variable thickness
  - irradiation through bent filter

**Nanomechanical testing: ODS steels**

In order to find the valid region of radiation hardening estimation, measurements were performed in continuous stiffness measurement (CSM) with maximum indentation depth of 2 μm.

According to the Nix-Gao model two size effects were observed: indentation size effect (ISE) and soft substrate effect (SSE).

**Materials under study:**
- ODS alloys EP-450, Cr16 (VNIINM, Moscow),
- KP4 (Kyoto University)
- copper single crystal

**TEM observations**

YAM particles in KP4 are more stable against the dense ionization induced by heavy ion irradiation comparably to \(Y\textsubscript{2}Ti\textsubscript{2}O\textsubscript{7}\) oxides in EP-450 ODS steel. With high fluence (>10\textsuperscript{14} cm\textsuperscript{-2}) irradiation YAM particles become amorphous and can’t be identified as (Y, Al, O) compounds.

**Conclusions**

Nanindentation testing of the ODS alloys irradiated with 1.2 MeV/amu Xe and Kr ions strongly implies that radiation hardening level saturates at relatively low damage doses, around 0.01 dpa.

Similar dose behavior was found also for some pure metals irradiated with high energy heavy ions (Cu, Ni, Zr).

Detected radiation hardening is not associated with radiation-stimulated changes in the nanoparticle morphology.