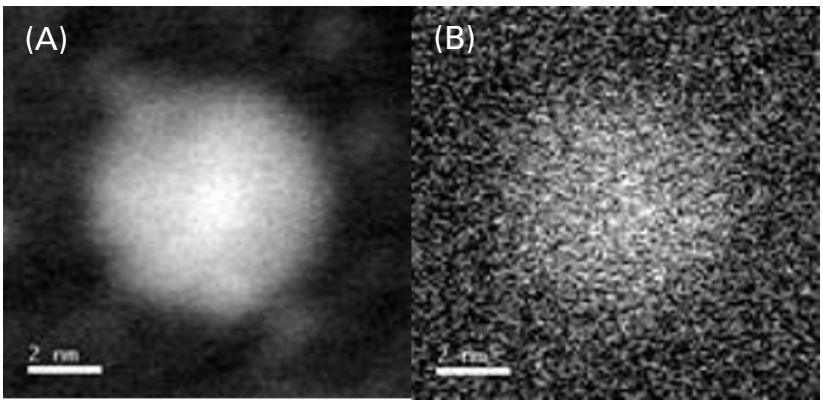
From He Nano-bubbles to Crack Propagation: Canadian Nuclear Laboratories Examines Ex-Service Inconel X-750

The **Canadian Nuclear Laboratories (CNL)** is the government research development lab for nuclear technology and science.

The Problem: Understanding the mechanism of embrittlement and mechanical property evolution of ex-service Inconel X-750 from nuclear reactors.

The Solution: Use transmission electron microscopes (TEMs) to determine the microstructure evolution of radioactive Inconel X-750 from within a nuclear reactor.

- He bubbles were discovered by TEM bright field imaging in the Inconel X-750, which leads to decrease strength of the material and eventual failure.
- Selected area electron diffraction (SAED) was utilized for secondary phase identification, and phase stability characterization to understand the effects of radiation and the He bubbles on the Inconel X-750 mechanical properties.
- Scanning TEM (STEM) Electron Energy Loss Spectroscopy (EELS) was used for elemental identification and distribution of precipitates, and the investigation of the intergranular fracture mechanism.
- STEM EELS was used to perform the quantification of the He atomic density in nano-scaled bubbles, down to one nanometer in diameter, found in the Inconel X-750 matrix.



He bubbles in ex-service Inconel X-750 matrix imaged with a (A) STEM High Angle Annular Dark Field (HAADF) detector and (B) EELS He K-edge map.

> "The collaborative tie between CNL and McMaster University/the CCEM will continue specifically for the reason that they [CCEM] are experts in the field of microscopy, the tools are maintained to the best operating levels, and the infrastructure is state of the art."
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> *Dr. Colin Judge, CNL 2018*

The Results:

- A high density of He bubbles on the nano-scale were found within the material's matrix and along grain boundaries from transmutations of the Ni within the reactor.
- We identified the He bubbles as the main instigator for Inconel X-750 failure.
- We now have a better understanding of the lifetime of the CANDU reactors, thus resulting in decreased waste and maintenance cost for Ontario's Nuclear power plants.

Instruments Used:

- FEI Titan 80-300 LB
- FEI Titan 80-300 HB
- Zeiss NVision40 FIB/SEM

References:

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