Steel degradation in nuclear plants leads to formation of new phases that is very important to monitor at nm level

Steel Corrosion in Nuclear Plants

nuclear power plant

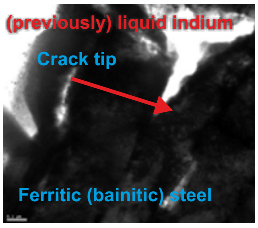
Generation IV reactors (Gen IV) are a set of theoretical nuclear reactor designs currently being researched. Most of these designs are generally not expected to be available for commercial construction before 2030. Current reactors in operation around the world are generally considered second- or third-generation systems, with most of the first-generation systems having been retired some time ago.

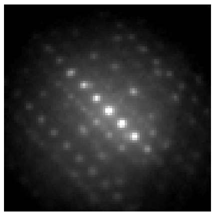
Relative to current nuclear power plant technology, the claimed benefits for 4th generation reactors include:

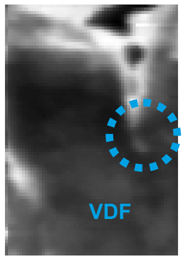
- Nuclear waste that remains radioactive for a few centuries instead of millennia
- 100-300 times more energy yield from the same amount of nuclear fuel
- The ability to utilize existing nuclear waste in the production of electricity
- Improved operating safety.

Fourth generation reactors are not yet fully designed and current research is exploring among other solutions the ability to use liquid metals as caloporters. Embrittlement of steels with liquid metals is a known phenomenon, and an issue of crucial importance for this development. Here, liquid indium was put in contact with a carbon steel, and the resulting damage was investigated in relation to the microstructure of the bainitic steel. A fine analysis of all diffraction patterns allow to identify the presence of carbides at the crack tip as seen on the virtual bright field reconstructed with ASTAR.

While waiting for the 4th generation to be ready, it is important to study how Nuclear Centrals are ageing ! Here is reported some observation of aged stainless steels aged 55000 h (6 years and 3 months) at 600°C. The specimen was prepared using FIB technique to select a specific area containing ferrite phase.





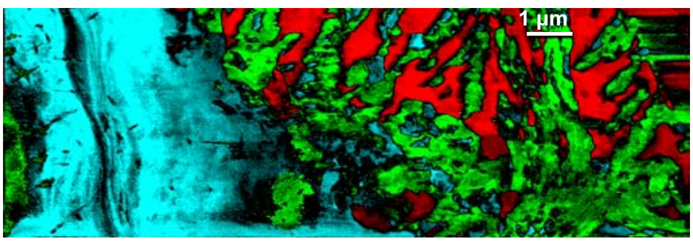


Crystal Structure

1	red	Bank_[fe bcc]_50_1_r3
2	cyan	Bank_[fe fcc]_50_1_r3
3	green	Bank_[Cr23C6]_50_0.3_r

The challenge: Identify orientation / phase in a thick specimen

Solution: ASTAR technique coupled with precession electron diffraction



Experimental Data

TEM type: Jeol 3010
Map resolution: < 10 nm
Scanned area: 18 x 6 µm

figure 1

Analysis of all the FIB section (step of 20nm, size of the map : 16x6 µm to record) : ASTAR phase map combined with phase reliability. On the left, an austenitic grain is seen, on the right, a previously ferritic grain has decomposed into austenite and carbides.

blue = austenite fcc,
red = ferrite bcc,
green = carbides

Courtesy Dr. T. Auger, Ecole Centrale Paris
Courtesy Dr. F. Delabrouille, EDF Paris