Influence of thermal conditions on Argon behavior in TiC matrix

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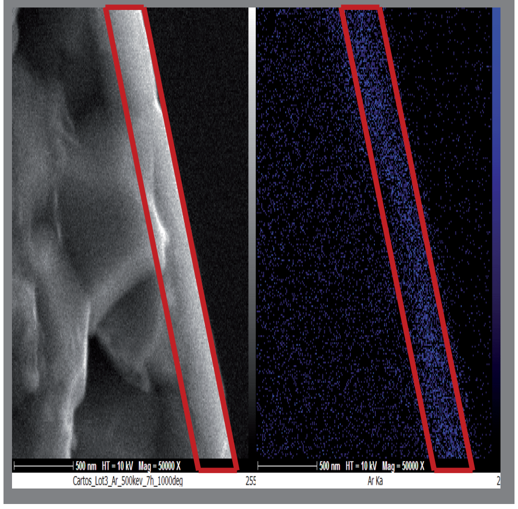
Introduction

In 2001, nine countries gathered into the GenIV International Forum, an initiative of the U.S. Department of Energy (DoE) that was in charge of determining what the future of nuclear energy could and should be. They defined six different projects of nuclear reactors, some of which have been selected by France to work on. This means new materials able to with stand extreme conditions of those future reactors, such as high temperature or high levels of displacement per atom (dpa), have to be developed. They also have to be mechanically and chemically resistant and prevent from fission products release. IPNL, which is a part of CNRS/IN2P3 in charge of these researches with also CEA, studied the effect of the temperature on the behavior of gases products. This study was done on a refractory ceramic (TiC) that could be used as a diffusion barrier in GenIV reactors and even in current reactors to improve safety:

SEM layout showing (red rectangle areas) higher concentration near the surface on 500 keV Argon implanted during 7h at 1000°C sample.



Material and methods

Ion implantation technique was used. It consists in the incorporation of species through an IMIO400 accelerator (IPNL). It is a good way to simulate what the materials in the nuclear core will undergo during the nuclear fission. It especially simulates the emission of fission products with creation of structural defects (dpa for instance). Argon was chosen for its chemical inertness and its ability to create dpa near the surface. Moreover, its behavior inside the material could be compared to another rare gas, i.e. Xenon, which is an abundant fission product. This Xenon is responsible for many potential problems such as cracks and bubble nucleation. Argon was implanted under several different temperature conditions (while the duration was the same each time): one implantation was done at room temperature; the second at high temperature (870°C to simulate temperature deep in the core) and the third was done at room temperature and then was annealed at 870°C. A fourth sample was implanted at 1000°C at 1 Mev, while the others were at 500 keV. The duration of this fourth implantation was 3h instead of 7h. The aim of these experiments was to study the influence of temperature on Argon depth distribution. To follow the movements of Argon in the TiC, the samples were cut in two parts and analyzed by SEM (Scanning Electron Microscope) on the (transversal section). SEM had two advantages during the study. First, its high resolution power should allow distinguishing details of the scale of the supposed size of the biggest bubbles of Argon. Secondly, it can be coupled with X-Rays to establish mapping depending on the concentration of any desired chemical elements.

Conclusion

With only 6.75×10^{16} atoms/cm² implanted, Argon is not concentrated enough to form bubbles visible by SEM on transversal sections that would be distinguishable during SEM analysis. Nevertheless, the use of X-Ray detection allows us to understand the formation of the 300nm wide deteriorated area under the surface. Calibrated especially to look after Argon, it shows us a high concentration of Argon on this part. As Argon is supposed to be distributed in a 700 nm wide area beneath the surface, it means Argon migrated into the surface under the effect of the temperature.

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