# Structural Materials for MCF Reactors

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## PRESENTATION

My name is Andrea Impagnatiello, PhD student of the University of Manchester under the main supervision of Dr Enrique Jimenez Melero. I am based at the Dalton Cumbrian Facility: a new state-of-art experimental facility of the Dalton Nuclear Institute, where academia and industry meet to carry out world-leading research focus on radiation science and nuclear engineering decommissioning [1]. The aim of my project is to investigate the creep properties of vanadium alloys under irradiation at the expected operating temperatures in future nuclear reactors based on magnetic confinement of the plasma.

## INTRODUCTION

### Fusion Energy

Fusion energy provide the solution to the clash of today's increasing energy demand with the continuous decrease of fossil-based energy sources, whose use is harmful for environment [2]. Fusion energy is analogous to fission energy: both produce energy from mass conversion in nuclear processes, but the operational nuclear reactions are different in both cases. Fusion reactors can produce more energy than fission, using only hydrogen isotopes and lithium as fuel elements, but the fusion reactor will be operating in very extreme conditions of temperature, stress, radiation and corrosive media. Figure 1 shows a sketch of the ITER experimental fusion reactor, under construction [3].

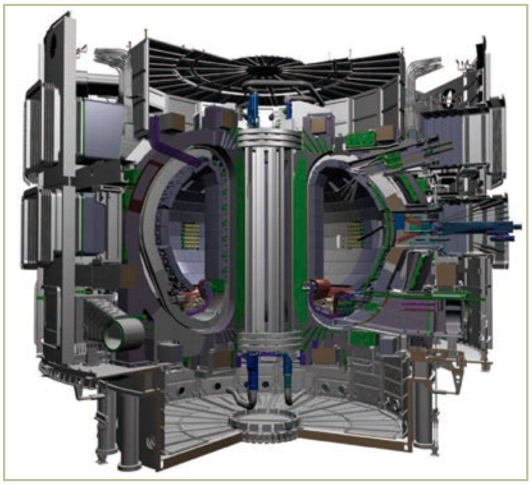

Figure 1. Sketch of ITER [3]

### Issues for the Materials

Materials for fusion reactors are required to maintain their structural integrity in operating conditions of temperatures up to 800°C under 14 MeV neutron irradiation that could reach a power flux of 3.4 $MW/m^2$ [4], enough to boil in 3 minutes the water contained in a 2 meters deep pool. Vanadium alloys are candidate materials for the first wall. The high melting point of vanadium (1910°C) confers exceptional mechanical strength at high temperatures. Moreover, the neutron absorption cross section of vanadium is very low allowing neutrons to pass through the surface layer to be absorbed at the coolant interfaces, and thus minimizing the generated heat. This also reduces the generation of radioactive isotopes and its subsequent nuclear waste disposal, conditions of temperature, stress, radiation and corrosive media. Figure 2 compares radioactivity of four materials after their use in the first wall of a commercial fusion reactor [5]. The full-remote and full-hands-on recycle limits are shown to indicate the guideline for recycling and reuse. V-4Cr-4Ti alloy remains between both safeties after 1000 years.

### Research on Vanadium

Recent research efforts have identified V-4Cr-4Ti as the most promising vanadium alloy for application in the first wall of the vacuum chamber of the nuclear reactor [5]. The evolution of its microstructure, specially

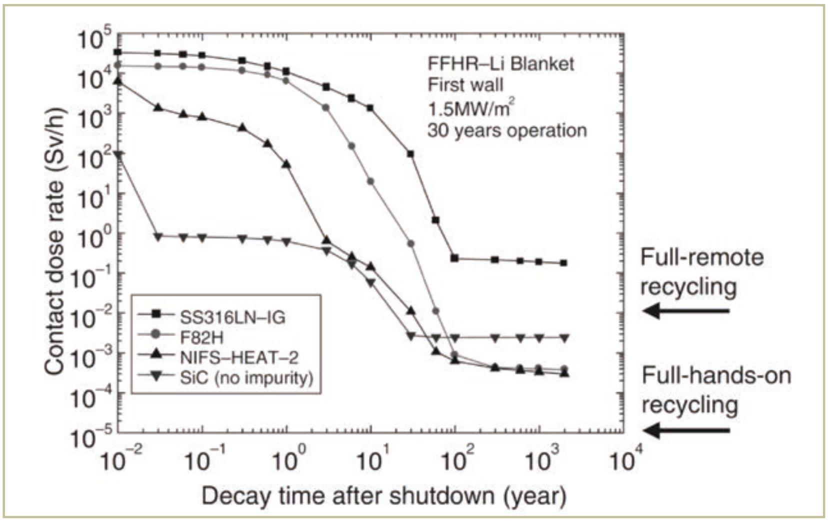


Figure 2. Radioactive levels of four fusion reference materials after use as first wall materials in a commercialfusion reactor: SS316LN-IG (the reference ITER structural material), F82H (a candidate RAFM steel), NIFS-HEAT-2 (a V-4Cr-4Ti alloy heat) and SiC/SiC composite assumed to be free from impurities [5].

the formation and dissolution of nano-precipitates of Ti with interstitials atom (O, C and N), has been widely studied during annealing with and without external neutron irradiation, together with the effects on the principal mechanical properties of the alloy. However, the mechanism taking place at the micro to nano scale in these alloys during thermal and irradiation creep at variable temperatures up to 800°C still remain largely unknown. This constitutes nowadays a bottleneck to extend the operating temperature window of these alloys in future fusion reactors, and to predict their structural performance during the lifetime of the reactor.

## CURRENT RESULTS

Results from experimental studies on V-4Cr-4Ti after different heat treatments will be presented. Electron microscopes analysis of the precipitation behaviour of V alloys have been carried out for samples with different thermal treatment together with in-situ X-rays chemical analysis. Precipitates with abnormal size have been revealed and the related electron diffraction pattern showed a crystallographic phase that differs from that mentioned in literature. The study of the precipitation behaviour is going to be enforced by positron annihilation experiments and atom probe chemical analysis in progress at the Tohoku University in Japan, inside a collaborative project with the University of Manchester. Figure 3a is a high resolution transmission electron microscope image obtained with the Fegnai 20 at the labs of the University of Manchester, Figure 3b is the related small angle electron diffraction pattern.

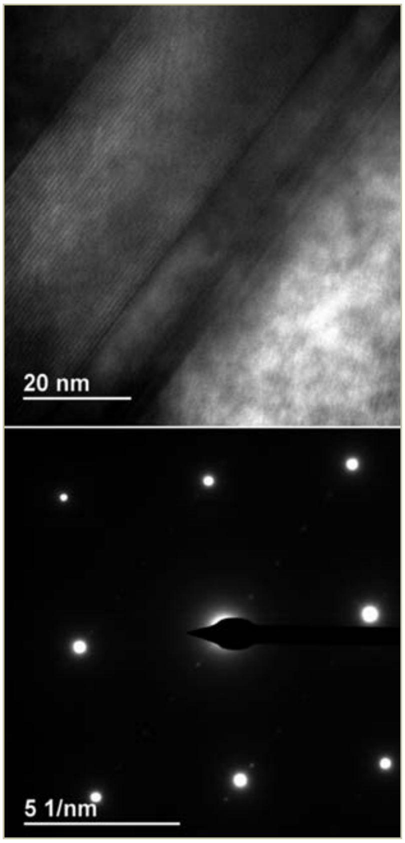


Figure 3. (a) High resolution transmission electron microscope image of precipitates found in V-4Cr-4Ti alloys after annealing at 900°C. (b) Related small angle electron diffraction pattern

## REFERENCES


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