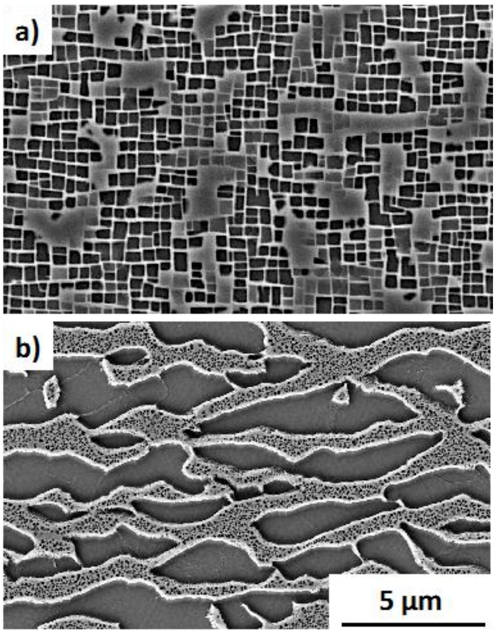
STUDY OF RHENIUM CONTAINING NICKEL-BASE SUPERALLOYS FOR SINGLE-CRYSTAL TURBINE BLADE APPLICATIONS

Vincent HULEUX
(2016 – 2019)

Industrial Partner: Safran Tech
Supervisors:
- **Loïc NAZÉ, Vladimir Esin, Alain KÖSTER, Vincent MAUREL (Centre des Matériaux – Mines Paristech)**
- **Virginie JAQUET, Jérémy RAME (Safran Tech)**



Microstructure of CMSX-4SLS (1 at. % of Re)
a) Before creep test
b) After creep test at 1150 °C / 90 MPa

- Understanding of the increase in high temperature mechanical properties of Re containing single crystal superalloys.
- Understanding of the effect of alloying elements (particularly Re) on microstructure characteristics, microstructure stability and mechanical properties (creep).
- Creep test at 760 °C up to 1150 °C.
- Analysis of microstructure evolutions by SEM.
- Analysis of deformation microstructures by TEM.

Abstract:

The properties of nickel-base superalloys have always been evolving with the aim of improving their mechanical resistance, microstructural stability, oxidation and corrosion resistance, as well as their microstructural compatibility with thermal barrier coatings.
These evolutions have led to the introduction of elements such as rhenium and ruthenium into nickel-base superalloys.
It is now widely admitted that the addition of rhenium in superalloy significantly improves creep properties at high temperature. However, the creep strengthening mechanism, brought by rhenium, still remains doubtful and needs to be clarified.

In this work, five commercial superalloys, different in their rhenium content (various generations, from 1^{st} to $3^{rd)}$, are investigated on the basis of multiscale microstructure analysis and creep tests.

The creep test temperatures are chosen to cover a wide range of applications for these alloys as well as to be able to investigate different deformation mechanisms occurring at low (760 °C), intermediate (950 °C) and high temperatures (1050 and 1150 °C). A number of those tests was stopped at different stages of the creep deformation in order to analyse the relevant microstructures. The microstructure evolution, particularly the rafting of γ' precipitates, and the formation of Topologically Closed Packed (TCP) phases regarding temperature and stress are studied using SEM. Additional chemical analyses of γ and γ' phases and the fine analysis of dislocation microstructures is carried out by observations performed by TEM.

Correlations between microstructural deformation mechanisms and rhenium content are attempted. Substantial microstructural transformations (γ ' rafting and TCP precipitation) are also studied by TEM and considered in the interpretation of the effect of rhenium on creep strength.

Moreover, optimised heat treatments were performed to study the defect effect on creep lifetime and microstructure evolutions. This will lead to conclude about the interest of optimising heat treatments, particularly the solution heat treatment, by removing all the eutectic aggregates and decrease segregation.