INDUSTRIAL PILOT PROJECT

Luminescent YAG:Ce^{3+} particles in the surface oxide layer on FeCrAl(Y) steel studied with synchrotron X-ray diffraction

THE INDUSTRIAL CHALLENGE

FeCrAl(Y) alloys have been developed by Kanthal as an important class of high-temperature alloys having excellent oxidation properties and corrosion resistance. They are used as, for example, resistive heating elements, as radiant tubes in furnaces, shielding tubes, furnace furniture and as construction components. Further, they are essential to the ongoing electrification of industrial processes. Primarily being designed for use in the 800-1300 °C temperature range, there is often a need to measure and monitor the alloy temperature. As a new concept, it has been hypothesized that $Y_3Al_5O_{12}$ (YAG) nanoparticles, that form spontaneously on the FeCrAl(Y) surface upon heat treatment, may be doped with luminescent rare-earth ions. This would create a strongly temperature dependent luminescent signal, which can be then used for measuring the temperature. However, the formation mechanism and concentration of YAG particles on the surface of FeCrAl(Y) alloys is unclear and require investigations.

WHY USING A LARGE SCALE FACILITY

Using high-resolution transmission electron microscopy, it has been reported that exposure of FeCrAl(Y) alloys in air at >900 °C results in the formation of a protective Al_2O_3 surface layer with dispersed sub-micron YAG particles. X-ray diffraction (XRD) techniques are relevant for studies of oxides, but to investigate very thin surface oxide layers (100 – 2000 nm) and the possible formation of presumably very low concentrations of YAG particles in FeCrAl(Y), the much higher photon flux at synchrotron radiation sources compared to the home based XRD equipment is needed.

HOW THE WORK WAS DONE

In-situ XRD measurements upon heating from room temperature to 1000 °C were conducted on FeCrAl(Y) alloy samples from Kanthal at the Swedish beamline P21.2 at the PETRA III synchrotron in Hamburg, Germany. Measurements were done approximately every 100 °C, after a thermal annealing time of 10-60 minutes. The temperature was controlled using a Linkam heating stage, which was supplied by PETRA III and that is shown in the Figure.

THE RESULTS AND EXPECTED IMPACT

The XRD measurements on the FeCrAl(Y) material did unfortunately not reveal the formation of YAG particles, possibly because of too short annealing times at each temperature. The concentration of YAG particles should increase by annealing the samples at higher temperature, and for a longer time. Additionally, the probability of detecting YAG particles should increase by performing the experiment in grazing incidence geometry, which was not done. Future work may therefore focus, first, on *ex-situ* measurements with an optimized geometry and on samples that have been annealed for a longer time. Once the conditions for XRD measurements to observe YAG particles have been established, the formation of YAG particles could be investigated by variable temperature *in-situ* measurements under grazing incidence geometry, on the same beamline. This will require the preparation of polished surfaces with a small slope error, which is not trivial.

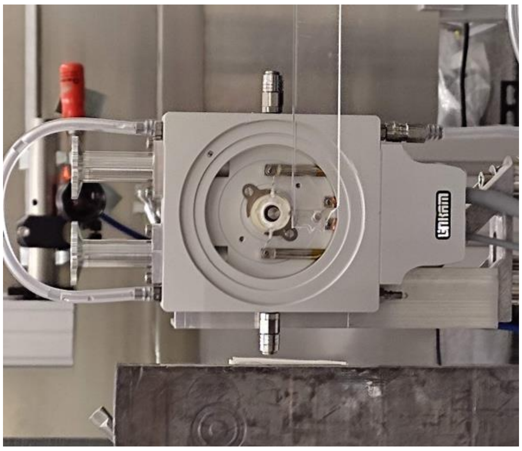

Figure. Image of the cylindrically shaped FeCrAl(Y) samples (5 mm in diameter) placed in the Linkam heating stage at P21.2 at PETRA III in Hamburg, Germany.

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Vinnova's project No: 2019-05306 **Duration:** March 2020 – December 2021

Funded by Sweden's Innovation Agency, Vinnova, in order to build competence and capacity regarding industrial utilisation of large-scale research infrastructures such as MAX IV and ESS.