INDUSTRIAL DEVLOPMENT PROJECTS

Internal strains in Mo-based silicides for sustainable heating applications measured by neutron and synchrotron diffraction

THE INDUSTRIAL CHALLENGE

$Mo(Si,Al)_2$-based elements are used for electric heating up to 1830 °C in demanding environments, and will therefore likely be an integral part of the desired electrification of industrial heating processes. The upscaling in power required for many such applications will, however, cause significant increases in element dimensions, and thereby higher mechanical loads.

The thermal expansion and anisotropy of the phases in $Mo(Si,Al)_2$ are still unknown, but based on experience from similar materials differences in the thermal expansion of the constituent phases could cause internal strains and ultimately crack initiation and failure. This is expected to have an increasing negative impact on element lifetime when the mechanical loads increase. Understanding the origin of internal strains and crack initiation can enable development of approaches to reduce anisotropy and improve the lifetime.

WHY USING A LARGE SCALE FACILITY

Phase-specific anisotropic thermal expansion can only be obtained from *in situ* diffraction measurements. The required penetration depth for heavy Mo-based materials can only be achieved by neutrons or high energy X-rays at synchrotrons.

HOW THE WORK WAS DONE

In situ diffraction measurements were performed using both high energy X-rays at the P21.1 beamline at Petra III, Germany, and neutrons at the GEM experimental station at ISIS Neutron and Muon Source, England. Heating elements in both solid form, and ground to powders, where measured while heating to temperatures around 1300 °C.

The large penetration depth and gauge volume of neutrons allows full-size heating elements (10 mm diameter) to be investigated, and the standard ISIS furnace provided high vacuum and easy operation. However, the long measurement times means that only 5-6 temperatures can be measured during heating.

High energy X-rays, on the other hand, allow very fast measurements (several hundred during a heating cycle), but the sample environment (a Linkam TS1500) required complicated sample mounting in glassy carbon crucibles, and lower vacuum. Both these factors limited the quality of the data above around 1000 °C. For spatially inhomogeneous materials, the small sample (1 mm) and beam size (100 μm) could potentially be a problem, but no such effects were observed in this study,

THE RESULTS AND EXPECTED IMPACT

The project provided the first direction-dependent thermal expansion measurements of the majority phase $Mo(Si,Al)_2$, as well as the minority phase $Mo_5(Si,Al)_3$. While the majority phase is isotropic, the minority phase exhibits significant anisotropy in the thermal expansion, which explains previously reported observations of oriented cracks in this phase. In all, this points to the need for controlling the anisotropy, which could potentially be achieved by introducing additional elements into the alloys.

Comparing the two types of radiation, X-rays provided significantly better signal for the $Mo_5(Si,Al)_3$-phase, and synchrotron diffraction is therefore the recommended technique for future studies of samples alloyed for anisotropy-reduction.

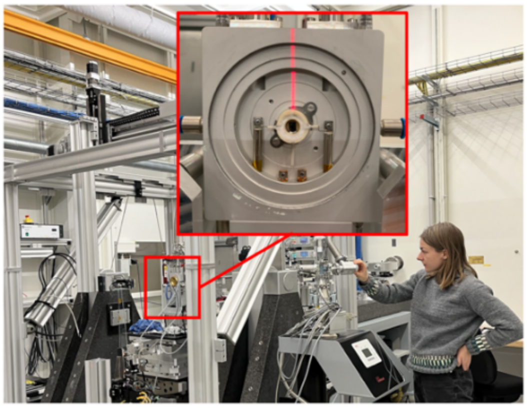

Figure 1. Aina Edgren from Kanthal at the P21.2 beamline at Petra III. The inset shows the sample environment used for the synchrotron experiment (a Linkam TS1500 furnace) with open lid.

KANTHAL® CHALMERS DESY.

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