WWU MÜNSTER

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Topic: Elucidating atomic transport in severely deformed materials

The lifetime of metallic materials depends on microstructural stability, mechanical integrity and chemical stability with respect to the atmosphere (corrosion and oxidation). Solid-state diffusion is one of the key steps in many time and temperature dependent metallurgical processes involved either in the manufacturing, joining or aging stages. Microstructure, temperature, stress-strain and elemental composition, can influence the atomic transport within that material. Such a transport is often described as a diffusion phenomenon. Study of the atomic diffusion in metals and its alloys has many potential applications in many industrial domains over a wide range of temperatures, varying from 300 °C for nuclear components to more than 1000 °C for aeronautic applications. The main output from our work is expected are Acquisition of quantitative data on diffusion in annealed and pre-strained alloys at wide temperature range and understanding of plasticity-enhanced diffusion with various SPD techniques.

We would like to introduce our work in 2 main parts,

I. The goal of this project is to study the effect of plastic deformation on bulk and grain boundary diffusion in pure and binary Ni, Ni-Cr-based alloys in a temperature range including low temperatures where the grain boundary diffusion cannot be easily measured (405-1300 K). The diffusion coefficients of Chromium will be measured by the radiotracer technique. The samples are prepared with and without strain (ECAP, Tensile tested). We are using pre-strained samples in order to study the effect of the dislocation network and its evolution during diffusion experiment. Stress-induced plastic deformation can modify the Chromium depletion profile by increasing vacancy concentration and thus enhancing Chromium diffusion in the Ni or Ni-Cr alloy by decreasing Chromium diffusivity due to vacancy annihilation as a result of the dislocation climbing mechanism. In the absence of strain, Ni-Bicrystals are specially designed to get the Grain boundary diffusion.

II. In this part we are focusing mainly on the specimens during creep deformation to understand the effect of dislocation on the atomic transport. The processing involves severe plastic deformation using High Pressure Torsion (HPT), Shear compression test (INSTRON). Two types of samples are prepared: (1) special designed samples of Nickel and Copper for Shear compression test (SCS) to analyse enhanced diffusion during creep deformation. And (2) sandwich samples of Nickel and Copper samples coated with the thin films of Chromium, Silver or Gold using Physical vapour deposition (PVD) and Electrodeposition techniques.

To unravel the influence of micro-structure evolution on the atomic transport, intermixing of elements and recrystallisation during deformation using multilateral approaches are used. These involve theory, experiments, characterisations and modelling. Radio tracer techniques will be used along with the Secondary ion mass spectroscopy (SIMS) to measure the diffusion and atomic transport in the materials. To reveal the microstructural evolution, lattice strain, strain fields, defects, porosity, grain size and highly sensitive Grain Boundary structure of Bicrystals and all other materials will be analysed on relevant length scales using Electron backscattered electron (EBSD), Scanning electron microscopy (SEM), transmission electron microscopy (TEM), and profilometry.