Understanding the improved glass-forming ability of several sulfur-bearing bulk metallic glasses via thermophysical characterization methods

PhD Thesis

Lehrstuhl für Metallische Werkstoffe LMW

Prof. Dr. rer. nat. Ralf Busch
Lehrstuhl für Metallische Werkstoffe

Campus C6 3, 5. Etage
66123 Saarbrücken

Tel: +49 (0) 681 302 2408
Fax: +49 (0) 681 302 4385
Mail: r.busch@mx.uni-saarland.de
Website: www.lmw.uni-saarland.de

Metallic glasses are usually complex multi-component alloys that stand out from their crystalline counterparts by their high fracture strength, high elastic strain limit, high hardness and improved corrosion resistance. These properties make them predestinated for miniaturized high-strength applications such as micro-electromechanical systems.

Recently, our group has discovered a new family of metallic glass-forming alloys – sulfur containing bulk metallic glasses [1]. From the various alloy compositions with improved critical casting thicknesses that were found, the alloys to be investigated in this work stem from the Pd-Ni-S, Ti-Ni-S and Ni-Nb-S system. These three systems are chosen exemplarily, as the currently known maximum in the glass-forming ability (GFA) was identified at different sulfur contents: A high amount of sulfur of more than 20 at.-% was added to the base alloys that showed only solid-solution formation and no glass-formation (Pd-Ni), a medium sulfur content below 10 at.-% was required for the system with regions of marginal GFA (Ti-Ni) and minor additions of a few at.-% sulfur were needed to improve the GFA of systems that already allowed glass-formation without sulfur (Ni-Nb). Given that there is no similar feature between the binary phase diagrams that could explain the different sulfur content necessary for glass-formation, the reason behind their GFA needs to be examined more closely.

In general, the critical cooling rate and thus the glass-forming ability of metallic systems is understood to be governed by three temperature dependent parameters [2] - with varying contributions depending on the specific alloy composition: The thermodynamic driving force, $\Delta G_{l\rightarrow x}$, the viscosity, η, reflecting the microscopic diffusivity of the undercooled liquid, and the interfacial energy, $\gamma_{l\text{-}x}$, between the primary forming crystal and the undercooled liquid.

The objective of this scientific project is to determine these quantities by a series of different calorimetry and thermomechanical analysis experiments that will help to understand the origin of the GFA of the three different model systems compared to the base alloys.

Beside the experiments, you will also be trained to prepare the samples from the raw elements to the final glassy samples by various processing techniques, such as inductive melting in silica tubes and suction casting in water-cooled copper moulds in high-purity Argon atmospheres. Good skills and experience for manual labor is required for reproducibly creating samples with the same quality.

As this is a collaboration project between three universities (Westfälische Wilhelms-Universität Münster, Deutsches Zentrum für Luft- und Raumfahrt Köln and our university in Saarbrücken), you will also work together with other PhD students and learn about various other techniques for the characterization of glassy and liquid metallic materials such as radiotracer diffusion experiments, X-ray and neutron scattering experiments, etc.

[1] KUBALL, A. *et al.*: Sulfur-bearing metallic glasses: A new family of bulk glass-forming alloys. *Scripta Materialia* **146** (2018) 73-76.
[2] GROSS, O. *et al.*: On the high glass-forming ability of Pt-Cu-Ni/Co-P-based liquids. Acta Materialia **141** (2017) 109-119.

Start: as soon as possible
Duration: 3 years

UNIVERSITÄT DES SAARLANDES