

CSC-RUB PhD Project Proposal

Title: Characterization of metal-physical interactions and short-range ordering effects in C and N alloyed high interstitial steels

Sector of research: Materials Science and Engineering

Degree awarded: Dr.-Ing. / PhD

Keywords: artificial microstructures; optimization algorithms; high-alloy tool steels; stereology; image analysis; powder metallurgy

Supervisor of PhD project: Prof. Dr.-Ing. Sebastian Weber, e-mail: sebastian.weber@rub.de

Research focus of supervisor:

The focus of my research is related to metallic materials, particularly high-alloy Fe-base systems. At the chair of materials technology, we develop new materials and optimize existing ones, assisted by several simulation methods, including the necessary manufacturing processes. A particular emphasis of my work is in the field of high-alloyed PM steels produced by inert gas atomization, hot isostatic pressing and additive manufacturing. Furthermore, high-nitrogen and high-interstitial steels are developed and investigated intensively including both, conventional and powder metallurgy. A conjunctive aspect of all research topics at the chair of materials technology is the correlation of chemical composition, primary processing, thermomechanical treatment, material and energy consumption, resulting microstructures and properties. Besides, all relevant aspects of technical application including aspects of circular economy are considered.

Publications:

Microstructural Changes During Short-Term Heat Treatment of Martensitic Stainless Steel-- Simulation and Experimental Verification, Schmidtseifer, Norina and Weber, Sebastian, Metallurgical and Materials Transactions A (2021), Volume 22A, Issue 8, DOI: 10.1007/s11661-021-06280-y

Uncovering process-structure relationships associated to the hot isostatic pressing of the high-speed steel PMHS 3-3-4 through novel microstructural characterization methods, Santiago Benito, Johannes Boes, Michele Matsuo, Sebastian Weber, Werner Theisen <https://doi.org/10.1016/j.matdes.2021.109925>

Hard Cladding by Supersolidus Liquid Phase Sintering: An Experimental and Simulation Study on Martensitic Stainless Steels, Farayibi, Peter Kayode and Blüm, Michael and Weber, Sebastian, Metallurgical and Materials Transactions A (2020), Volume 21, Issue 5, DOI: 10.1007/s11661-020-05953-4

Development of a recycling strategy for grinding sludge using supersolidus liquid phase sintering, Hankel, Jonas and Jäger, Sebastian and Weber, Sebastian, Journal of Cleaner Production (2020), Volume 263, DOI: 10.1016/j.jclepro.2020.121501

On the role of nitrogen on hydrogen environment embrittlement of high-interstitial austenitic CrMnC(N) steels, Egels, Gero and Fussik, Robert and Weber, Sebastian and Theisen, Werner, International Journal of Hydrogen Energy (2019), Volume 44, Issue 60, DOI: 10.1016/j.ijhydene.2019.10.109

Summary of research plan (ca. 300 words):**Background:**

High carbon (C) and nitrogen (N) alloyed austenitic High Interstitial Steels (HIS) exhibit a unique combination of highest strength, toughness and corrosion resistance. This results from increased metallic bonding character attributed to high contents of interstitial elements C and N, which at the same time enhance the strengthening behavior and ductility. Generally, the content of dissolved interstitial elements C + N can be maximized via a balanced C+N ratio.

Study objective:

The outstanding property combination of highest strength and ductility, however, ultimately depends on the nano- and microstructural distribution of the alloying elements. Within the scope of the project, the metal-physical properties are therefore to be examined in depth. Particularly, the entropy contributions and mutual interaction of the C and N atoms dissolved in the solid state shall be analyzed. In order to characterize the solution state, atomic disordering effects and the local distribution of the interstitial elements C and N, model alloys shall be characterized down to micro-, nano- and atomic scale.

Expected Results:

It shall be analyzed whether atomic clustering of the substituted elements Cr, Mn and Mo is present in the region of the interstitially dissolved nitrogen atoms. In addition, it will be examined to what extent segregation tendencies of the N or C atoms to defect structures such as grain boundaries, stacking faults or dislocations can be detected. New scientific findings must be published continuously throughout the course of the project.

Methods:

By means of thermodynamic simulations according to the CALPHAD method, suitable alloys will in the first instance be evaluated. Subsequently, various powder-metallurgical HIS are to be produced experimentally. An approximately single-phase austenitic, segregation- and defect-free bulk sample should be fabricated by means of hot isostatic pressing and suitable solution heat treatments. Experimental investigations down to the atomic level are to be carried out using high-resolution methods such as 3D atom probe tomography or transmission electron microscopy. The results are to be evaluated and validated with statistical methods. Thermodynamic simulations shall be used continuously to interpret the results.

Candidate Requirements:

- Outstanding program achievement in materials science and engineering
- Substantial knowledge of the physical metallurgy of Fe-base materials
- Thorough understanding of the thermodynamics
- High level of spoken and written English

Motivation for CSC application: The successful candidate will be working at the Chair of Materials Technology (Lehrstuhl Werkstofftechnik, LWT) at the Ruhr-University Bochum. LWT belongs to the School of Mechanical Engineering and is part of the Institute of Materials (IM) as well as of the Materials Research Department (MRD) at the RUB. At LWT and IM, the successful candidate will find all state-of-the-art processing and characterization methods in the field of Materials Science and Engineering with a particular emphasis on technologically relevant metallic materials. Besides the excellent technical equipment and facilities, we offer the opportunity to work in a new and exciting field of research, in an open, appreciative and constructive working atmosphere. We aim to provide students with an international and interdisciplinary platform to conduct high-level scientific research.