3D Atom Probe (3DAP) Studies in a Ti-6wt%Mo Alloy

Abstract

3D atom probe (3DAP) studies were conducted in a Ti-6wt%Mo model alloy to quantify Mo concentration across the hcp-bcc interface. Further, the interaction of alloying elements with interfaces was discussed for gain boundary segregation of C and P in iron model alloys.

As part of my Sabbatical I was as a Visiting Professor at IMR in the group of Professor Tadashi Furuhara from July 11 to September 12, 2022. My local host was primarily Professor Goro Miyamoto. The research stay was motivated by our joint research interests on the role of alloying elements on migrating interfaces in metallic systems, in particular steels and titanium alloys. My research emphasizes primarily steels but one of my recent PhD students, Mariana Rodrigues, studied phase transformations in titanium alloys which have a number of similarities to phase transformations in steels. The laboratory of Professor Furuhara has also particular expertise on titanium alloys and we were able to facilitate a research visit of Mariana at the IMR in 2019 where she initiated 3D atom probe (3DAP) studies in a Ti-6wt%Mo model alloy to quantify the interaction of Mo with the hcp-bcc interface during phase transformations in this alloy. Mo is an important alloying element in many industrial Ti alloys that stabilizes the bcc-phase, i.e. Ti alloys with dual phase bcc-hcp microstructures can be created with unique properties for aerospace and biomedical applications. The progress of these 3DAP studies was affected by the COVID pandemic and my research visit was designed to revitalize the 3DAP studies. We prepared at the University of British Columbia (UBC) a number of different Ti-6wt%Mo samples that had undergone different heat treatment scenarios. These samples were then prepared at IMR for the SEM/EDS and 3DAP studies that confirmed redistribution of Mo from the hcp (α) phase into the bcc (β) phase as well as an enrichment of Mo at the hcp-bcc interface, as shown in Figures 1 and 2. Mo partitioning and enrichment at the interface were characterized with respect to interface coherency, namely a presence of Burgers orientation relationship. Doing repeat measurements we were able to reproduce quantitatively the enrichment levels of Mo for the investigated heat treatment conditions. Further, we found that the Mo enrichment appears to be insensitive to the interface character, i.e. Burgers vs Non-Burgers crystallographic orientations. As a result of my research visit we have meanwhile completed these 3DAP studies and are in the process of preparing a brief manuscript for a referred journal publication.

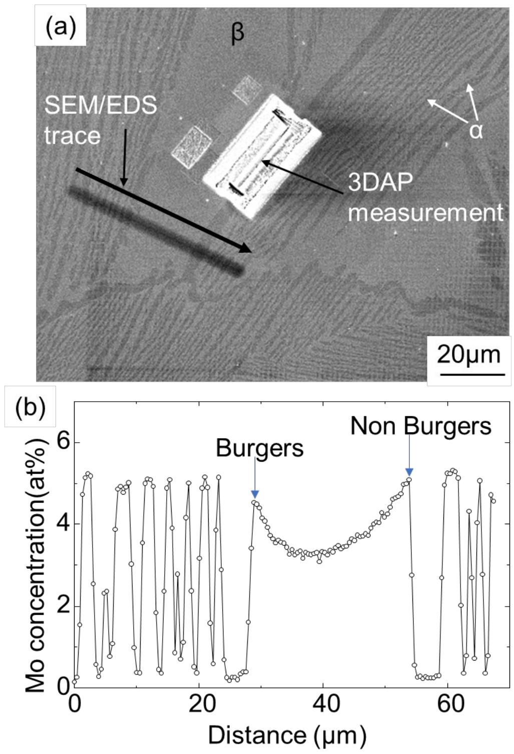


Fig. 1: (a)SEM images showing (α+β) microstructure and the locations for SEM/EDS and 3DAP measurement, (b) Mo concentration profile in the Ti-6wt%Mo alloy heat treated at 800 °C for 3 hours.

My research stay provided also an excellent opportunity to discuss individual research projects of faculty members, postdoctoral fellows and graduate students in the laboratory. In particular we discussed 3DAP results in Fe-model alloys where C and P grain boundary segregation was observed. For the quantitative analysis of these results we reviewed the role of the interface thickness that is somewhat obscured, in part, due to experimental broadening of segregation profiles. We emphasized that the interfacial excess is the relevant quantity,

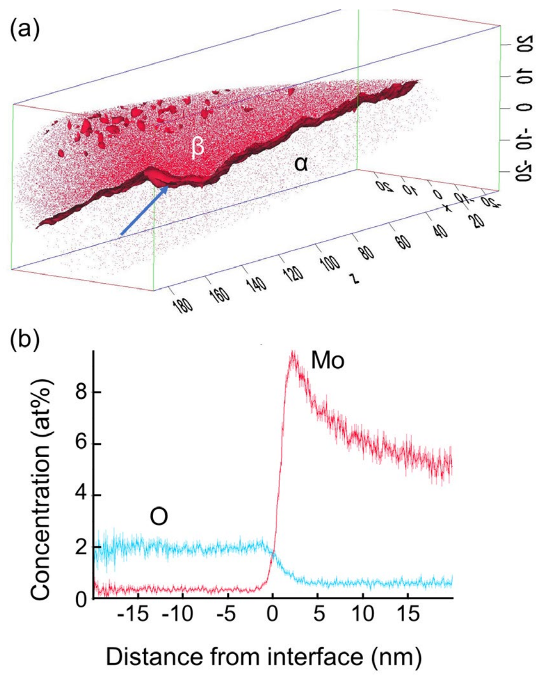


Fig. 2: (a)three-dimensional Mo atom maps, (b) Mo and O concentration profiles across bcc/hcp interface obtained with 3DAP in the Ti-6wt%Mo alloy heat treated at 800 °C for 3 hours. The isosurface of 3at% Mo is shown.

i.e. the projection of excess solute concentration per unit interfacial area. This approach is consistent with a multi-scale modelling analysis of solute drag in my group at UBC that we had proposed by analyzing experimental data on grain boundary motion during recrystallization of pure gold containing Bi and Fe impurities at the ppm-level [1]. With a seminar talk entitled "Interface-based Alloy Design – A New Frontier to Engineer Microstructures" I provided an overview on these research areas in my group at UBC.

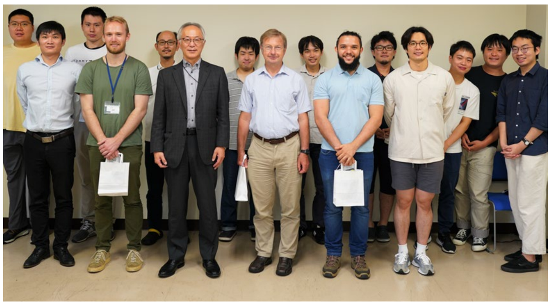
Further, I was able with the assistance of IMR to have in the period August 28 – September 1 brief visits to two steel companies, i.e. Nippon Steel and JFE, as well as the Tokyo University of Agriculture and Technology (Professor Yamanaka) and the Tokyo Institute for Technology (Professor Nakada). These visits were designed to exchange and discuss research topics related to ferrous metallurgy and computational materials science. I gave the following three lectures during these visits:

1. Interface-based Steel Design, Nippon Steel, Kimitsu.
2. Modelling of Microstructure Evolution, Tokyo University of Agriculture and Technology, Tokyo.
3. Microstructure Design of Advanced High Performance Steels, JFE, Chiba.

References

[1] A. Suhane et al., Acta Mater, 224, 117473 (2022)

Keywords: Phase transformation
Full Name Matthias Militzer
E-mail: matthias.militzer@ubc.ca
http://www.mtrl.ubc.ca



Group photo with Prof. Furuhara Group together with other ICC-IMR visitors (2022.9.8)