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PhD position in the Centre for Doctoral Training for Advanced Characterization of Materials (CDT – ACM): **In-service catastrophic failure: or controlling the grain boundary network evolution**

Hardmetal tools are a key for our production industries relying on cutting, milling, drilling, and turning. Cemented carbides (WC-Co) are one of the most prominent powder metallurgy processed materials use for cutting tool applications. This is due to a combination of excellent hardness/wear resistance and toughness with low cost compared to alternatives such as polycrystalline diamond. During service (e.g. in machining) , however, the composite structure is subjected to a combination of high mechanical and thermal loads, where hard carbide particles are joint by soft cobalt binder, deforms until excessive wear and fracture reduce the performance and lifetime. Crack paths in WC-Co predominantly follow WC/WC and WC/Co grain and phase boundaries at low cobalt concentrations[1]. While the WC grain boundary character, the grain boundary network, is characterised for differently doped cemented carbides[2–5], **knowledge of how the grain boundary network evolves during service and ultimately allows for crack formation along grain boundaries is absent**.

To understand the grain boundary network evolution, we have developed an analysis workflow verified in a case study on Mg_2SiO_4. During torsional deformation the GB network interacted with dislocations, leading to overall material weakening[6]. We will follow this study to understand the evolution of the GB network with increasing deformation (Fig. 1).

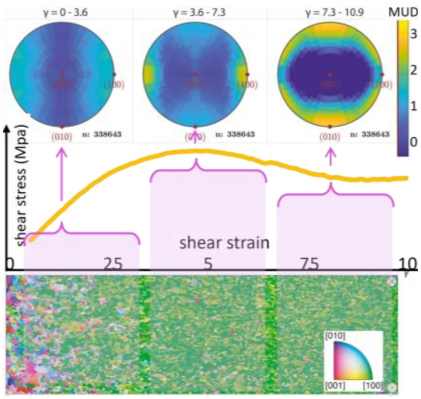

Fig.1: Torsion deformed Mg_2SiO_4. Bottom: EBSD map of the deformed sample. Middle: stress-strain graph, indicating weakening during deformation. Top: grain boundary network evolution. Three strain intervals shown.

References
1.Emmanuel, M. et al. *Jom* **73**, 1589–1596 (2021). 2. Kim, C.S., Massa, T.R. & Rohrer, G.S. *J. Am. Ceram. Soc.* **91**, 996–1001 (2008). 3. Yin, C. et al. *Materials (Basel).* **14**, (2021). 4. Yuan, X., Rohrer, G.S., Song, X., Chien, H. & Li, J. *Int. J. Refract. Met. Hard Mater.* **44**, 7–11 (2014). 5. Kim, C.-S. & Rohrer, G.S. *Interface Sci.* **12**, 19–27 (2004). 6. Ferreira, F., Hansen, L.N. & Marquardt, K. *J. Geophys. Res. Solid Earth* **126**, 1–20 (2021).

The student will work in a team with experts in various fields and a spirit of working together. While the group has common overarching goals, we work on independent projects. In this project the student's role will be to use to produce samples at SECO during an extended industry internship. They will subsequently characterize these samples using novel scanning electron microscopy techniques as developed for electron backscatter diffraction (EBSD) and precession electron diffraction (PED) along low dose high resolution scanning transmission electron microscopy (HR-STEM). Furthermore, this characterization will allow to identify the most failure relevant interfaces for subsequent mechanical testing and characterization. Additionally, atom probe tomography (APT) will be employed to study the interfacial structure and composition of the ceramics at the bulk and nm-scale.

During their PhD the candidate will become proficient in ceramic processing, mechanical testing at the µm scale, as well as structural and chemical characterization techniques. They will develop strong skills in the scientific approach, problem solving, and the communication of scientific results and in collaborative working in an international team.

Project Partner: Seco Tools AB operates within the metal working industry and is a part of Sandvik Machining Solutions, a global market-leading manufacturer of cutting tools materials and tooling systems for advanced manufacturing applications. The main production units are located in Sweden, France and the Netherlands and the company has overseas production operations in the USA and India and hosts several technical competence centres around the world including an Innovation Hub in the United Kingdom, located in Alcester. The latter, Seco Tools (UK) Ltd, is heavily focusing on developing machining solutions for the aerospace manufacturing industry.Our R&D in Sweden collaborates closely with large scale facilities hosting synchrotron light sources such as MaxIV laboratory in Lund (Sweden) and Petra III in Hamburg (Germany) topics related to the development of in-situ/in operando material characterisation methods.

We are seeking applications from excellent, motivated, and curious candidates with a minimum 2:1 (or equivalent) first degree in Materials Science, Physical Chemistry, Mineral Physics or Applied Geosciences for a four-year PhD studentship, eligibility criteria can be found on the webpages below. The project will be based in the Centre for Advanced Structural Ceramics (http://www3.imperial.ac.uk/structuralceramics) and the Centre for Doctoral Training for Advanced Materials Characterization (http://cdt-acm.org/) at the Department of Materials at Imperial College London (Katharina Marquardt, Finn Giuliani) and Seco Tools (Rachid M'saoubi).
For questions or further details regarding the project, please contact Dr Katharina Marquardt, k.marquardt@imperial.ac.uk .

To apply for this PhD opportunity in the CDT for ACM and the eligibility criteria please visit:
https://www.cdt-acm.org/phd-opportunities/ and look at: http://www.cdt-acm.org/imperial-and-ucl-projects/ Engineering materials: In-service catastrophic failure: or controlling the grain boundary network evolution