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Doctoral project

Shear-coupled grain boundary migration in magnesium alloys: the role of solute segregation.

– In situ SEM bicrystal mechanics and disconnection-based micromechanical modeling –

Description of the doctoral work:

Magnesium (Mg) alloys are attractive lightweight materials for transport and energy applications. However, their limited ductility at room temperature restricts processing and use. A key strategy to address this limitation is dilute alloying. In Mg alloys, solute atoms often interact with grain boundaries (see Xie et al. 2026 for a review). Hence, such complex interactions can impede or modify grain boundary mobility. Grain boundary migration is an important plastic deformation mechanism, which is intrinsically coupled to shear under mechanical stress and temperature. A quantitative understanding of shear-coupled grain boundary migration in the presence of solute segregation in Mg alloys is still lacking and is the object of the present PhD thesis.

This doctoral project will be carried out at the Laboratoire d'Étude des Microstructures et de Mécanique des Matériaux (LEM3, Metz, France). It is part of the project SILA2, funded jointly by the Agence Nationale de la Recherche (ANR, French National Research Agency) and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation). The work will be done in collaboration with the Institut für Metallkunde und Materialphysik (IMM) of RWTH Aachen University.

The objective is to quantify how grain boundary character, temperature and solute segregation of zinc and yttrium control shear-coupled migration in magnesium bicrystals. Bicrystalline samples will be first produced at IMM. Then, the PhD candidate will perform *in situ* tensile and compression tests in a scanning electron microscope (SEM) from room temperature to 300°C, using interrupted loading protocols. Grain boundary displacement will be tracked by electron backscatter diffraction (EBSD), and local lattice distortions will be measured by high-resolution EBSD (HR-EBSD), notably to characterize the density of geometrically necessary dislocations (GND) and elastic strains. In addition, dislocation-grain boundary interactions during shear-coupling GB migration will be observed by electron channelling contrast imaging (ECCI) (see e.g. Mouhib et al. 2026). Micro-scale digital image correlation (DIC) will also be explored to study how grain boundary mobility, activation parameters and shear-coupling factors, which will be extracted from these measurements, will be influenced by solute segregation. These experimental data will be used to help the development and the extension to HCP-based Mg bicrystals of a thermodynamics-based micromechanical model initially developed in Berbenni et al. (2013) (see also Barik et al. 2026 for a recent application to FCC-based Al bi-crystals) to capture plastic strain, stress drop magnitudes, dissipated energy during a migration step, considering grain boundary motion mechanisms, as well as the influence of solutes distribution on the driving force for stress-induced migration.

Some related references:

Z. Xie, J. Guénolé, H. Wang, J. Petrazoller, F.Z. Mouhib, A. Guitton, T. Richeton, S. Berbenni, T. Al-Samman
Atomic-scale modeling of defects in magnesium and its alloys: A review; Journal of Magnesium and Alloys, 2026, 14, 101954

F.Z. Mouhib, H. Wang, J. Guénolé, S. Berbenni, T. Al-Samman, T. Richeton, Z. Xei, A. Guitton
Investigating twin boundary-dislocation interaction in MgY using quasi in-situ nanoindentation and electron channeling contrast imaging;
Journal of Magnesium and Alloys, 2026, 22, 102205

S. Berbenni, B. Paliwal, M. Cherkaoui. *A micromechanics-based model for shear-coupled grain boundary migration in bicrystals;* International Journal of Plasticity, 2013, 44, 68–94

R.K. Barik, G.B. Bizana, S. Berbenni, L. Baralles-Mora. *Data-driven atomic scale structure-property correlation for shear-coupled grain boundary migration in FCC aluminium bicrystals,* Acta Materialia, 2027, 322, 122859

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Your skills

The following qualifications are required:

- Master's degree (or equivalent) in materials science, mechanical engineering or physics.
- Solid background in crystal plasticity, dislocation theory and continuum mechanics.
- Programming skills (Python) for data processing and modeling.
- Good command of written and spoken English.

- **Desirable qualifications:**
  - Experience in scanning electron microscopy, in particular EBSD and/or ECCI.
  - Experience in mechanical testing, ideally *in situ.*
  - Experience in image analysis or digital image correlation.

We offer

A 36-month full-time doctoral contract (French public-law doctoral contract, Université de Lorraine) is available, ideally starting on 01/10/2027. An earlier start can be considered. The contract includes social security coverage and paid annual leave. The gross monthly salary is 2300 €. The position is embedded in a French–German collaboration between LEM3 (Metz) and IMM (RWTH Aachen) and is supervised by Prof. Antoine GUITTON and Dr. Thiebaud RICHETON. The doctoral researcher will acquire expertise in *in situ* scanning electron microscopy, advanced diffraction-based characterization (EBSD, HR-EBSD, ECCI) and micromechanical modeling, providing a strong basis for a career in academia or industry.

The doctoral school:

As PhD student, you will be registered at the Université de Lorraine and will be part of the C2MP (***C**himie, **M**écanique, **M**atériaux, **P**hysique*: Chemistry, Mechanics, Materials, Physics) doctoral school. You will have the opportunity to benefit from a wide range of training programs during your PhD.

The local team of SILA2 includes:

- **Dr. Stéphane BERBENNI**, CNRS professor, expert in micromechanics of materials, thermodynamic based shear-coupled migration
- **Dr. Julien GUÉNOLÉ**, CNRS researcher, expert in atomistic simulations
- **Prof. Antoine GUITTON**, full professor, expert in microscopy and materials plasticity
- **Dr. Thiebaud RICHETON**, CNRS professor, expert in continuum modeling of materials mechanics
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Additionally, the team includes another doctoral researcher at LEM3, as well as collaborators from the partner team at the Institut für Metallkunde und Materialphysik (IMM), RWTH Aachen University.

Host laboratory of the doctoral researcher:

The LEM3 laboratory (***L**aboratoire d'**É**tude des **M**icrostructures et de **M**écanique des **M**atériaux:* Laboratory of Study of Microstructures and Mechanics of Materials) is a joint research center of the Université de Lorraine, the French National Center for Scientific Research (CNRS), and the engineer school Arts et Métiers. LEM3 is one of the largest research institutes for the physics of materials and engineering in France. It is located in Metz, near the tripoint along the junction of France, Germany, and Luxembourg, and forms a central hub for science in Europe. Over 250 scientists from France and around the world work at LEM3 to perform world-class research in materials science, mechanics, and processes. By conducting both fundamental and applied research, researchers at LEM3 work on long-term solutions for the major challenges facing society, industry, and science.

Application:

Please send a detailed CV, a cover letter, and transcripts of your Bachelor and master's degree to the email addresses provided in the header. Recommendation letters are not required, but please include the contact information of your references.

Applications without the requested attachments may not be considered.