

Industrial Doctorate at HZDR & Technische Universität Dresden

HZDR Innovation GmbH (HZDRI) & TU Dresden (TUD) are seeking a highly motivated graduate student to enrol in an Industrial Doctorate hosted at the Institute of Process Engineering and Environmental Technology at TUD, Germany and the Department of Cement Process and Systems R&D at FLSmidth A/S, Denmark. The project is part of the international doctoral training network entitled "Valorization of CO₂ for low carbon cement (CO2Valorize)", funded by the Marie Skłodowska-Curie Action of the European Commission. The complete programme consists of eight international PhD projects who perform individual research projects to identify technological solutions that help significantly reduce carbon dioxide emissions in the cement industry. HZDR Innovation GmbH is a technology transfer company for the incubation of spin-offs, development and production of prototypes and small series, as well as for the realisation of service and production orders from industry, drawing on the know-how and infrastructure of the Helmholtz Centre Dresden-Rossendorf (HZDR). We turn innovative ideas into marketable high-tech products. (<https://hzdr-innovation.de/en/>).

Scientific Project of Doctoral Candidate No. 3

DC3 | Title: Aqueous carbonation of mineral tailings: reaction mechanisms and in-situ compositional analysis using Raman spectroscopy.

The project focuses on the in-situ characterisation of the carbonation process by Raman spectroscopy aiming at the solution species and precipitates. This is closely coupled with analysing the reaction mechanism of the carbonation reaction of calcium and magnesium bearing minerals in tailings streams, e.g. olivine, serpentine or brucite. In a first step, experiments are performed in Hele-Shaw cells where defined mineral arrangements (linear or as sphere) are exposed to a CO₂ front. Progression of the reaction is monitored by analysing the temperature front which propagates because of carbonation. To do so, concentration and temperature fields are measured interferometrically and the data is used to further develop existing models. In the second step, detailed carbonation experiments are carried out in close collaboration with project DC5 using new 3-phase reactors developed. A careful characterisation of the feed (mineral tailing) and product streams is additionally to confocal Raman Spectroscopy performed by Mineral Liberation Analysis (MLA) and X-Ray Diffraction (XRD). Furthermore, Raman spectroscopy is applied in-situ to follow the composition of the product phase and to provide pathways for incorporating Raman on-line analysis in the upscaled process for the purpose of process digitisation and advanced process control possibilities.

A period of 30 months is at the company HDZRI, Germany, another 6 months the candidate is seconded at NTNU, Norway. Throughout the entire project, the candidate is enrolled as a PhD candidate at TUD with a working contract at HZDRI GmbH.

Position Requirements

We are seeking a highly motivated candidate who is passionate about understanding aqueous mineral carbonation and its utilisation as a way to drastically reduce high CO₂ emissions associated with the cement production. The project will involve research activities related to vibrational spectral and interferometric analytical techniques and specialised set-ups for carbonation reaction characterisation in-situ. Competences in the field of chemistry or chemical engineering, spectroscopic measurement techniques and mineral carbonation are highly welcome. Interest in process modelling and intense collaboration with numerically oriented doctoral candidates is expected. Engineers with an outstanding MSc in Chemical



Engineering or individuals with a proven science background in physics or chemistry with a main interest on the future of cement production are encouraged to apply.

Eligibility Criteria

We welcome applications from PhD candidates from any country fulfilling the following criteria:

- Eligible candidates must not have resided or carried out their main activity (work, studies, etc.) in the country of their host institution for more than 12 months in the 3 years immediately before their recruitment by the host institution (i.e. the starting date indicated in the employment contract/equivalent direct contract).
- Eligible candidates shall, at the date of recruitment by the host institution (i.e. the starting date indicated in the employment contract/equivalent direct contract), be in the first 4 years (full-time equivalent research experience) of their research careers and not have been awarded a doctoral degree.
- Eligible candidates must have a Master's degree relevant to the chosen position (including chemical engineering, civil engineering, mechanical engineering or physics) or its equivalent that would entitle them to a doctorate.

Candidates must have a high proficiency in written and spoken English, which will be assessed with the motivation letter and interview.

Benefits

- Three-year full-time employment contract (salary according to MSCA regulations for Doctoral Candidates and their family status at the time of the recruitment).
- Gaining experience abroad. 36 months at HZDR Innovation GmbH, Germany. 6 month secondment at NTNU, Trondheim or a different partnering organisation during the employment period.
- Enrolment in a PhD programme at TUD and opportunities for participation in national and international scientific meetings.
- Enlarged professional network and improved future scientific career perspective in academia and the private sector.
- Shared research and innovative multidisciplinary and multisectoral training from senior scientists, experts and experienced trainers from academia and industry.
- A structured training programme consisting of research-related courses, soft skill courses, targeted workshops, social events and networking.

Application and Selection Process

Applications must be in English and should include: a CV, a letter of motivation (1 page), Bachelor's and Master's degree certificates (please include the transcript of the academic records in English) and indicate in your application: nationality, gender, countries where you have resided for the last three years (indicate periods), research experiences, any additional information such as awards, fellowships, internships, extracurricular activities, qualifications etc. In case of questions, please contact Dr. Martin Rudolph. If interested, please send your application as a single PDF file to: m.rudolph@hzdr.de with SUBJECT line 'CO2Valorize PhD position'.

A selection committee will rank eligible applications based on CVs and merits. The 3 best candidates for each position will be invited for a virtual interview in October / November 2022, where the final candidates will be selected. Applicants with a positive evaluation but not selected will be included on a reserve list to cover eventual future positions and might be



contacted at a later stage. Each applicant may apply to three positions out of eight available positions in the CO2Valorize programme.

Timeline

The opening date of the position is 01 September 2022. Deadline date for receiving the documents via email as a single PDF file is 31 October 2022, 17:00:00 CET. Interviews will take place in October/ November 2022. The tentative start of the fellowship is March 2023.



European Industrial Doctorate (EID)

"Valorization of CO₂ for low carbon cement (CO2Valorize)"

as part of the Marie Skłodowska-Curie Action of the European Commission.

Summary

Cement production is responsible for 8 % of global CO₂ emissions, which mainly come from the processing of limestone. CO2Valorize proposes a new approach to drastically reduce these emissions by partly replacing some of the limestone content with supplementary cementitious materials (SCM). Such materials are additionally carbonated using captured CO₂, so this part-replacement process utilises captured CO₂. Promising calcium silicates rich SCM can come from waste materials such as mine tailings and recycled concrete, all of which are available in large quantities. The carbonation process of such materials is complex and barely understood to date. Our networks aim to lay the scientific foundations to create fundamental knowledge on the mechanisms, reaction kinetics, the physico-chemical subprocess, and the performance of the modified cement in order to provide a proof-of-concept and show that a CO₂ reduction by 50 % per tonne of cement produced is feasible. The project is driven by leading companies that represent important parts of the value chain and ensure a fast uptake of the results with the potential to commercialise new equipment, processes and software during and after the project. The structured approach combines complementary research for each individual project in the academic and industry sector. This is accompanied by a balanced mix of high-level scientific courses and transferable skills delivered by each partner locally and in dedicated training schools and workshops at network level. This way, each doctoral candidate builds up deep scientific expertise and interdisciplinary knowledge to deliver game-changing cleantech innovations during and after the project. CO2Valorize is impact-driven and strives for portfolios of high-class joint publications in leading journals and patents. The transfer of the results into first-of-its-kind engineering solutions contributes to the next generation of cement processes that can mitigate climate change.

Individual Research Projects

DC1 | Title: Characterisation of raw materials, carbonated components, and cementitious products. The specific objectives are: 1) To develop protocols to support the optimisation of enhanced carbonation of a variety of raw materials towards their performance in cementitious systems, such as mortar and concrete; 2) To improve our understanding of the reactions of enhanced carbonated materials when used in cementitious systems. Employment periods: 1) 15 months at FLSMIDTH AS, Denmark; 2) 21 months at NTNU, Norway. Secondment at CEMMAC AS, Slovakia or a different organisation during the second employment period.

DC2 | Title: Supplementary Cementitious Materials (SCMs) from Waste Concrete: Carbonation Kinetics in a Semi-Dry Stirred Reactor. The objectives of the project are: 1) Experimental carbonation of standardised waste concrete fines in a semi-wet stirred autoclave with continuous sampling and temperature, pressure, pCO₂, pH₂O monitored. Sample analysis with XRD, TG-FTIR. 2) Design of a plant configuration consisting of energy and material balanced individual components based on literature and data from the partners. 3) Scenario calculations based on the plant model, estimated scale-up factors and costs. Employment periods: 1) 15 months at FLSMIDTH AS, Denmark, 2) 21 months at KIT, Germany. Secondment at CEMMAC AS, Slovakia or a different organisation during the second employment period.



DC3 | Title: Aqueous carbonation of mineral tailings: reaction mechanisms and in-situ compositional analysis using Raman spectroscopy. The objectives of the project are: 1) Quantitative characterisation of the reaction by interferometric measurements of temperature and concentration; 2) Characterisation of the composition of the product phase by Raman spectroscopy and MLA of feed and product streams; 3) Outline of a process sensor based on Raman spectroscopy for the purpose of process digitalisation and advanced process control. Employment: 36 months at HZDR Innovation GmbH, Germany. Secondment at NTNU, Norway or a different organisation during the employment period.

DC4 | Title: Investigation of the carbonation performance of cement-based materials at high temperatures. The objectives of the project are: 1) To optimise the feedstock conditions, i.e. bulk chemical composition, particle size, porosity etc.; 2) Optimisation of TGA conditions, temperature, residence time, CO₂, H₂O concentration; 3) TGA studies of interaction between different feedstock bulk ash chemistries and CO₂ (synthetic mixtures composed of Al₂O₃, Fe₂O₃, SiO₂ and CaO). Employment periods: 1) 15 months at FLSMIDTH AS, Denmark, 2) 21 months at DTU, Denmark. Secondment at CEMMAC AS, Slovakia or a different organisation during the second employment period.

DC5 | Title: Process optimisation of aqueous mineral carbonation using novel three-phase reactors. The objectives of the project are: 1) Develop a novel and fully instrumented 3-phase carbonation reaction employing principles known from flotation; 2) Measure fluid dynamics, mass transfer rates and temperature evolution in the reactor and composition feed/product streams; 3) Dynamic modelling of the process based on the large data sets of process and material data obtained. Employment: 36 months at HZDR Innovation GmbH, Germany. Secondment at University of Padova, Italy or a different organisation during the employment period.

DC6 | Title: Integrating state-of-the-art technologies for sustainable cement production. The objectives of the project are: 1) Develop a model-based design of experiments procedure for kinetic model discrimination and calibration in carbonation processes; 2) Integrate the kinetic model with mass and heat transfer information; 3) Validate model with real data. Employment periods: 1) 6 months at FLSMIDTH AS, Denmark, 2) 30 months at University of Padova, Italy. Secondment at Siemens Process Systems Enterprise, United Kingdom or a different organisation during the second employment period.

DC7 | Title: Integrating state-of-the-art technologies for sustainable cement production. The objectives of the project are: 1) Develop a flowsheet-based model of cement production including different capture technologies; 2) Develop a super-structure modelling framework for process integration and optimisation; 3) Integrate electrified facilities with power grid. Employment periods: 1) 6 months at FLSMIDTH AS, Denmark; 2) 30 months at the University of Padova, Italy. Secondment at Siemens Process Systems Enterprise, United Kingdom or a different organisation during the second employment period.

***DC8 | Title: Techno-economic analysis of CO₂-neutral cement plants.** The objectives of the project are: 1) Create a new prototype tool to assess the performance of these technologies in the context of a large-scale cement production facility; 2) Provide a means to predict the impact on overall plant carbon dioxide emissions and process economics; 3) Develop a prototype tool-kit for techno-economic assessment of future innovations in cement



production. Employment: 36 months at Siemens Process Systems Enterprise, United Kingdom. Secondment at University of Padova, Italy or a different organisation during the employment period.

**DC8: SPSE, United Kingdom, originally participated as Beneficiary and host of DC8. Currently, the UK is not associated with Horizon Europe and therefore SPSE is not eligible for funding and cannot be Beneficiary. For this case, the following contingency measure applies. The consortium decided that SPSE changes the status to Associated Partner and participates with its own funding. The UK government gives a Horizon Europe guarantee and funds the participation of SPSE through UK Research and Innovation (UKRI). DC8 will implement all research tasks, obtain co-supervision, participate in all network-wide trainings, conduct the local trainings, and contribute to dissemination, exploitation and communication activities - as described in the DoA.*

