DocMASE Project Proposal DAAD-2015-2

Project Title	***Nanostructured metal oxide / metal nitride / carbon composites for supercapacitors and capacitive deionization***
Main University and Advisor	Prof. Dr. Volker Presser (Saarland University: Nanotechnology of Functional Energy Storage Materials / INM: Energy Materials Group)
Associated Partner(s) (if applicable)	Prof. Dr. Frank Mücklich (Saarland University: Chair of Functional Materials / MECS)
Project Description (with **image**, if applicable)	Carbon and carbon hybrid materials ideally combine structural versatility and tunability with excellent electrochemical properties: they bring together properties that neither oxides / nitrides nor carbons would show separately. The INM Energy Materials Group is exploring electrochemical applications of functional carbon and hybrid nanomaterials for various applications, ranging from the synthesis of novel materials and materials characterization to the setup of small prototypes. Carbon materials can be optimized to reach extremely large surface areas (beyond 3000 m^2/g) with pore sizes below 1 nm and high electrical conductivity. Thus, there has been a tremendous interest in applying carbons in the field of energy storage (supercapacitors) or water treatment (capacitive deionization, CDI) that both utilize the phenomenon of ion electrosorption at the fluid/solid interface. Current research of energy storage materials, however, shows that the amount of energy stored in carbon electrodes is very moderate compared to batteries. Also, the performance for CDI and in aqueous supercapacitors suffers from hydrophobic nature of carbon. Metal oxides and nitrides, however, commonly do not provide sufficiently high electrical conductivity, stability, and specific surface area. Yet, compared to carbon, metal oxides and metal nitrides not only show a superior wetting behaviour but also highly reversible redox reactions that can be used to severely improve the charge storage capacity. The aim of this project is to develop hybrids of carbon with metal oxides or metal nitrides as next generation electrode materials for electrochemical applications. Nanoporous carbons will be synthesized from organic and inorganic precursors, such as phenolic resin and carbides. Various shapes of carbon materials will be explored, ranging from beads and powders to electrospun carbon nanofibers. Metal oxides and nitrides will be synthesized with atomic layer deposition (ALD) in a novel ALD system developed to coat in an inert atmosphere flat samples and powders. The PhD student will carry out materials synthesis and thorough materials characterization to provide a deep knowledge in experimental techniques (e.g., electron microscopy, gas sorption analysis, vibrational spectroscopy, electron / X-ray / light scattering and diffraction, chemical analysis, and electrochemical methods). The materials will be tested and optimized for the use in predominately aqueous electrolytes and energy storage (supercapacitors) and water treatment (CDI) will be intensively explored.
Previous Publications	1. D.M. Anjos, J.K. McDonough, E. Perre, G.M. Brown, S.H. Overbury, Y. Gogotsi, V. Presser, Nano Energy, 2 (2013) 702 - 712. 2. F. Beguin, V. Presser, A. Balducci, E. Frackowiak, Advanced Materials, 26 (2014) 2219 - 2251. 3. S. Porada, R. Zhao, A. van der Wal, V. Presser, P.M. Biesheuvel, Progress in Materials Science, 58 (2013) 1388 - 1442. 4. Y. Gogotsi, V. Presser, Carbon nanomaterials, 2nd Edition, CRC Taylor & Francis, Boca Raton, 2014.
Requirements of the candidates / Requirements during the doctoral programme (courses, seminars, etc.)	Very good English command. Bachelor in Materials Science, Chemistry, Physics or related disciplines. Master in Materials Science or related disciplines. Knowledge of German will be appreciated but not compulsory. The general requirements for the DocMASE program regarding courses, seminars, summer schools, etc. must be fulfilled. Particularly, 30 ECTS of lectures have to be validated at the end of the PhD. You are expected to publish the results of your studies in international peer-reviewed journals and present at international conferences.