Imperial College London

Minimal surfaces in porous materials: wettability design for optimal flow performance

Supervisors: Prof Martin Blunt (m.blunt@imperial.ac.uk); Dr Branko Bijeljic, Department of Earth Science and Engineering; Prof Jerry Heng, Department of Chemical Engineering.

Home Department: Department of Earth Science and Engineering at Imperial College London (South Kensington Campus)

Funding and Deadline: To be eligible for support, applicants must be "UK Residents" as defined by the EPSRC[1]. The studentship is for 3.5 years starting no later than October 2023 and will provide full coverage of standard tuition fees and an annual tax-free stipend of at least £17,609. Applicants should hold or expect to obtain a First-Class Honours or a high 2:1 degree at Master's level (or equivalent) in any relevant engineering or science subject. Funding is through the project InFUSE (Interface with the future: underpinning science to support the energy transition), funded by the EPSRC and Shell.

Project summary

Minimal surfaces with zero total curvature are found naturally in emulsions, soap films and holly leaves; they have been a subject of mathematical and scientific fascination for centuries. Topologically, phases on either side of the surface are well-connected. Porous media whose internal surface is a minimal surface ensure good connectivity of both the pore space and the solid skeleton and have been used to manufacture artificial bone (the solid is strong, while the pore space allows blood vessels to grow and perfuse the structure) and catalysis.

Recent research has Imperial has discovered that minimal surfaces exist between two fluid phases within mixed-wet porous rocks. This was associated with efficient fluid displacement and recovery. We have also seen minimal surfaces between gas and water in fibrous gas diffusion layers (used in fuel cells) with a mix of hydrophobic and hydrophilic surfaces, which again explains their favourable performance.

In this PhD project you will explore the conditions under which minimal surfaces form in multiphase flow, apply this to a variety of natural and manufactured systems, including rocks, soils and fibrous materials, and, finally, propose a design of the structure and wetting properties of the solid (controlled by surface chemistry) to optimize multiphase flow for a range of applications, from agriculture to electrochemical devices. There is the opportunity to transform the design and performance of a wide range of devices, including fuel cells, electrolysers and catalysis, as well as provide insight into efficient fertiliser dispersal in agriculture.

You will apply lab-based and synchrotron multi-scale X-ray imaging to determine pore structure and multiphase fluid configurations, including accurate measurements of interfacial curvature. This will be complemented by sub-micron imaging at a synchrotron to explore surface properties and wettability. You will study both fluid configurations using time-resolved imaging and chemical changes in designed materials where a mixed-wet state is controlled through wettability changes on displacement. This will be complemented by direct finite element simulation of multiphase flow at the micron to mm scale. You will work in a large active research group working on various aspects of flow in porous media. You will be expected to publish your work in the open literature.

Informal enquiries about the post and the application process can be made to Prof. Martin Blunt by including a motivation letter and CV. For further information on the research group with recent papers and presentations see:
https://www.imperial.ac.uk/earth-science/research/research-groups/pore-scale-modelling/

Eligibility for student funding: https://www.ukri.org/councils/esrc/career-and-skills-development/funding-for-postgraduate-training/eligibility-for-studentship-funding/