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Modelling of the microstructure and of the physical properties of heterogeneous media

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The prediction of the mechanical and transport properties of heterogeneous media requires both an accurate description of the microstructure and fast EDP solvers, such as those based on spectral methods.

In this talk, we examine in detail various numerical and theoretical techniques used to model and simulate random microstructures and their local and homogenized properties.

We first describe how probabilistic segmentation techniques, coupled with image formation analysis, are applied on material images obtained by SEM, FIB-SEM, tomography or MET. The methods are illustrated by various applications in porous media, mortars, fiber composites or polycrystals. Morphological transformations, derived from image analysis techniques, are used to provide microstructure-sensitive criteria. These criteria allow one to derive and optimize realistic microstructure models, i.e. models that are representative of the real microstructure. In turn, models of random structures are combined with fast Fourier methods based on the Lippmann Shwinger equation. We detail some of the recently-introduced discretization techniques employed for evaluating the Green operator in the Fourier domain.

In a first part of the talk, we focus on the determination and simulation of probabilistic and multi-scale models, with applications to n-phases microstructures used in fuel cell applications.

In a second part, we show how spectral (image-based) Fourier methods can be used in complement of microstructure simulations to predict the mechanical and transport properties of heterogeneous materials, in the context of homogenization.