Multiscale computational modelling in electromagnetism

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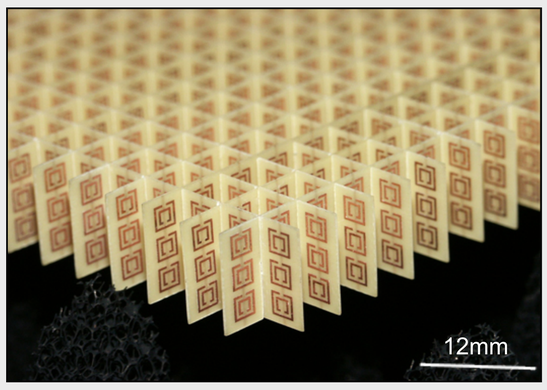
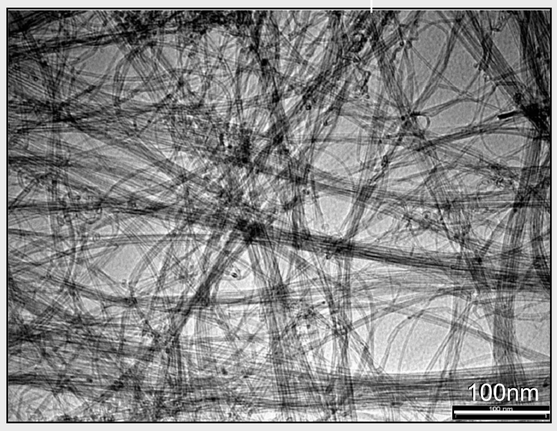
Novel engineered materials: from imaging to optimal design



Metamaterials: dielectric or metal artificial periodic structure with strong anisotropy, plasmon frequencies or even negative index.



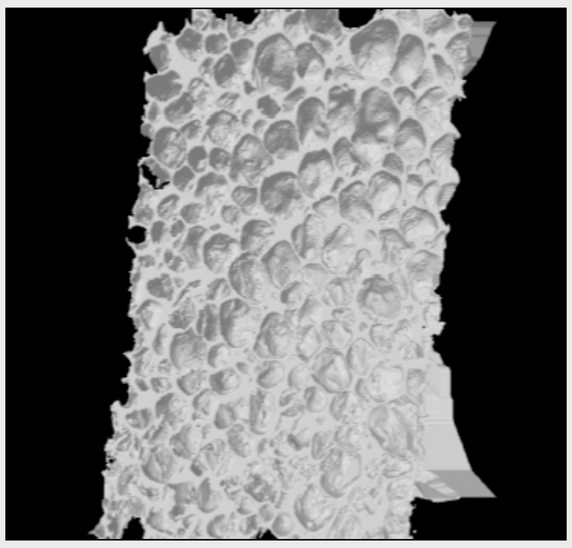
Carbon nanotubes (CNTs)
Highly heterogeneous advanced nano-composites with characteristics that depend on the dispersion in the polymer matrix of a reduced quantity of nano-fillers (CNTs or nano-clays).

Material synthesis is an example of emerging technology that urgently needs efficient multi-scale methods for numerically determining the effective properties of novel engineered materials, i.e. their constitutive law.

Artificially synthesized materials exhibit exceptional macroscopic properties that are directly linked to their micro-structural complexity:

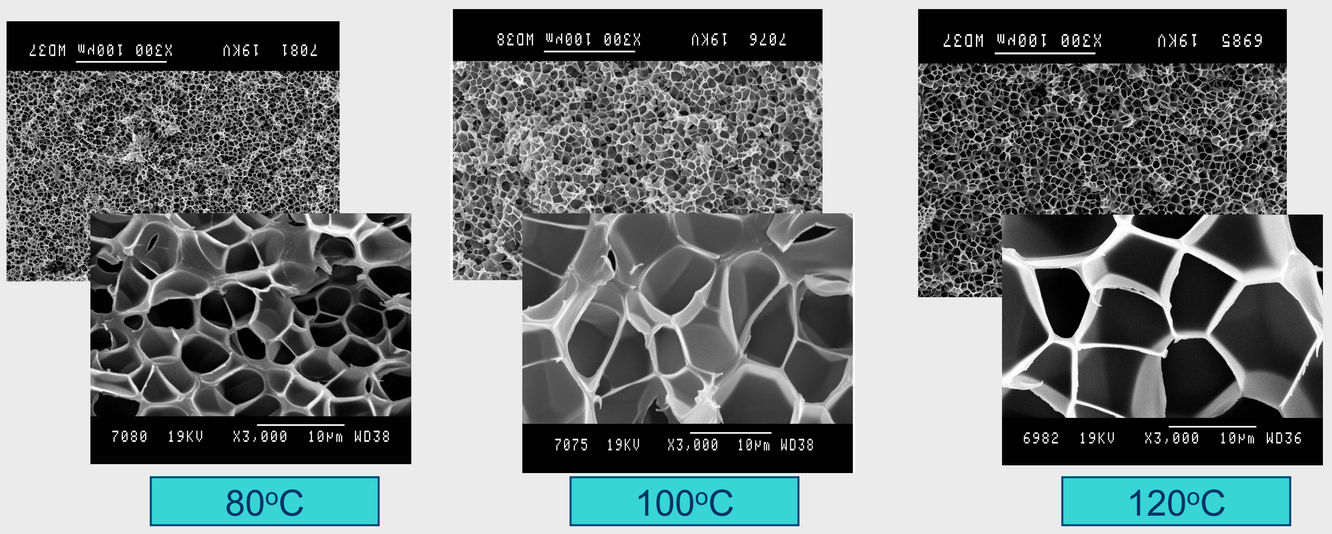
✓electromagnetic/optical: resistivity, ε (EM shielding), ε<0 and μ<0 (lens without diffraction);
✓mechanical: resistance, E, Poisson coefficient <0;
✓thermal: conductivity.

The ability to simulate numerically the properties of novel materials is an invaluable help for **design optimization** and can avoid expensive and time-consuming trial and error tests.

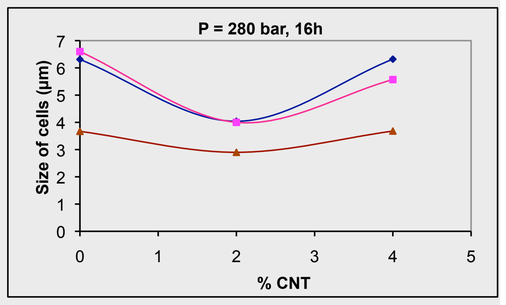


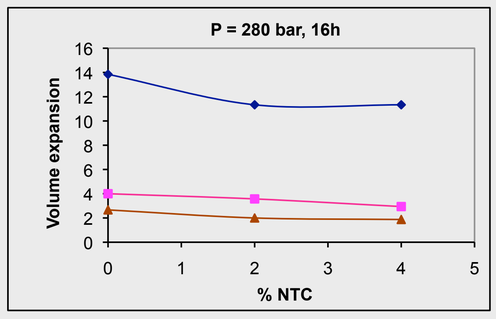
3D image reconstruction of polymer foam

Polymer foam structure depends highly on fabrication process



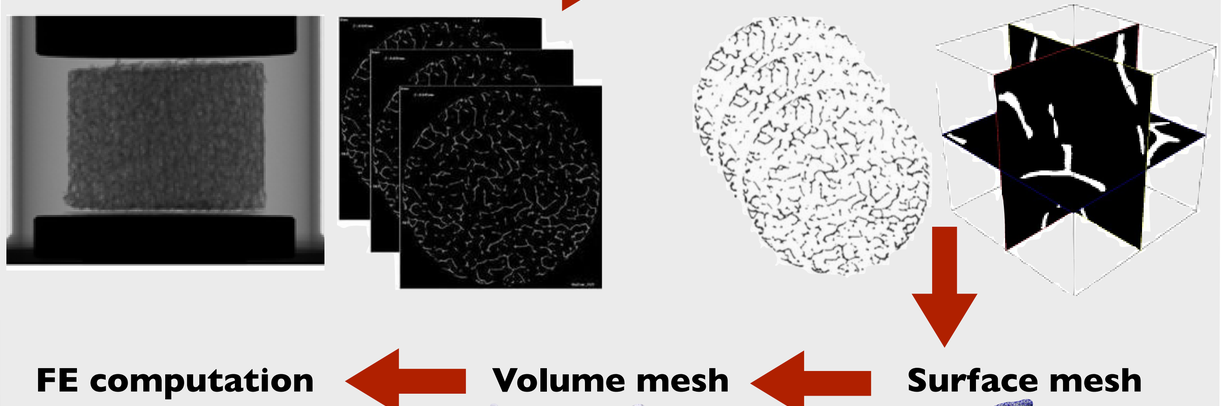
80°C | 100°C | 120°C



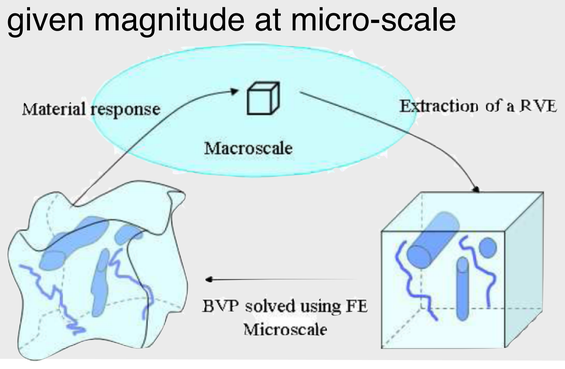


Project methodology

Image acquisition → **Image treatment: 2D to 3D** → **Surface mesh** → **Volume mesh** → **FE computation**

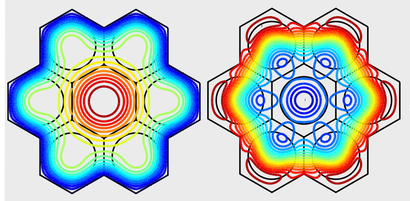


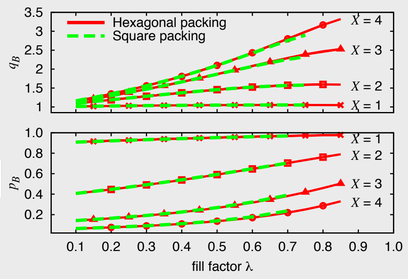
✓2D images obtained by TEM or RX tomography of a RVE of material
✓Image treatment applied to reconstruct a 3D mesh: surface to volume
✓Numerical method applied to determine a given magnitude at micro-scale
✓Multiscale: micro-scale + macro-scale
✓Experimental measurements to validate material properties



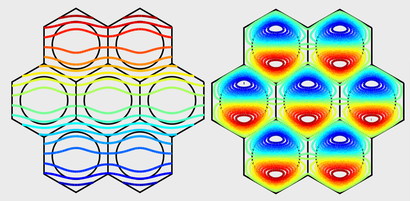
Homogenization: windings & laminations

Skin effect flux patterns
unit net current imposed in each conductor via electrical circuit eqs.





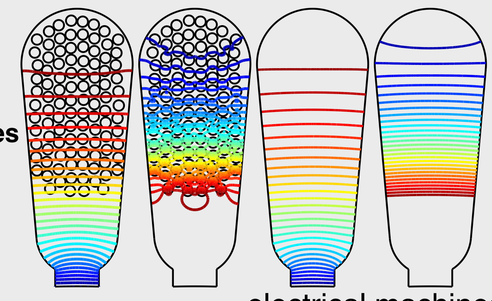
Proximity effect flux patterns
unit average induction imposed (e.g. horizontally) via boundary conditions



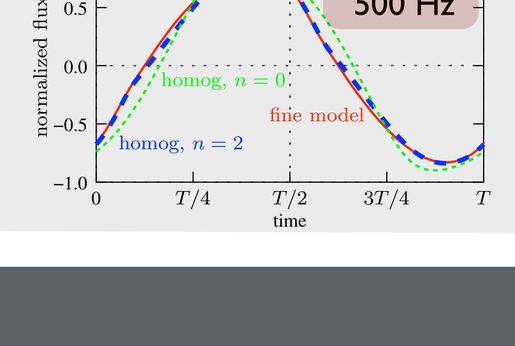
[R. Sabariego et al, IEEE Trans. Mag., 44(6):1302–1305, 2008]

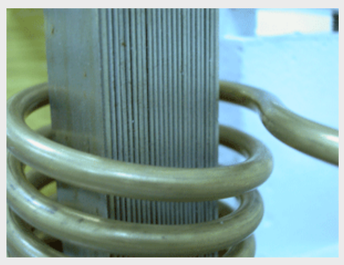
3KW induction motor

Flux lines

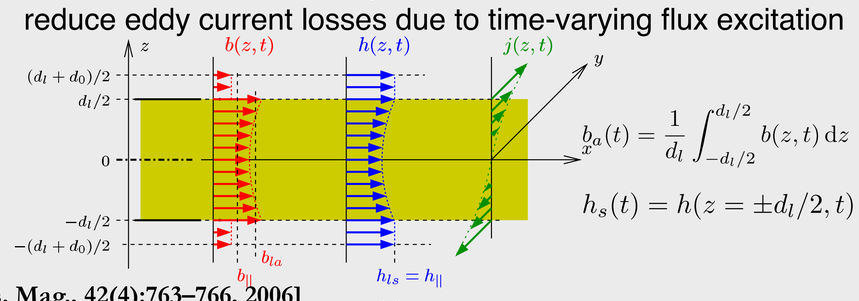


Joule losses

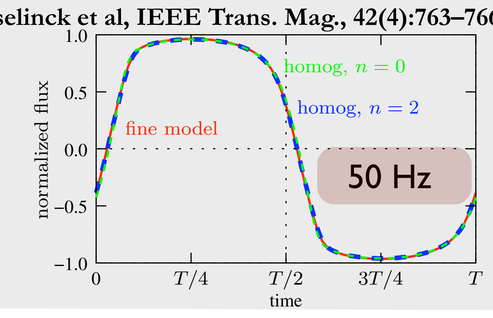




electrical machines usually have a **laminated iron core** to reduce eddy current losses due to time-varying flux excitation



[J. Gyselinck et al, IEEE Trans. Mag., 42(4):763–766, 2006]



LMS Durham Symposium: Numerical Analysis of Multiscale Problems
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