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Coupled Mechano-Chemical Phenomena at Materials' Surfaces

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Surface stress is a concept in mechanics and thermodynamics that quantifies the elastic interaction of the matter at solid surfaces and interfaces with the adjacent regions of bulk solid. The impact of surface stress on the behavior of materials can be decisive when the microstructure scale reaches down to the nanometer range. This is particularly evident in the case of nanostructured electrodes, where the electro-chemo-mechanical coupling can be probed in experiments with cyclic variation of the electrode potential or of the strain. Nanoporous metal actuators (‘metallic muscles’) exploit the underlying potential-dependence of surface stress to achieve displacement amplitudes of several millimeters, making the action of the capillary forces visible to the naked eye. Modelling the performance of these materials raises intriguing issues in the field of mechanics of solids with curved surfaces and reduced dimensionality. At an atomistic level, the physics of bonding and relaxation in space-charge layers at charged metal electrode surfaces - with or without the presence of adsorbate - remains poorly understood. Besides their relevance for surface stress and actuation, thermodynamics also provides a quantitative link between these phenomena and the adsorption strength. This connects studies of electrocapillarity to a hot topic in catalysis, the coupling between the mechanical strain of a surface and its catalytic reactivity. Furthermore, surface-induced stresses interact strongly with the chemical equilibrium in the bulk. This significantly shifts the equilibrium phase diagrams of nanoscale metal hydrides. The talk will address topics from this field that are relevant to the mechanics of nanoporous materials for energy applications.

Keywords: nanoporous metal, capillarity, surface stress, electrocapillary coupling