Nanostructured Materials for Energy and Biomedical Applications

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The first part of this talk is concerned with developing next generation anodes for Li-ion batteries through the use of continuum mechanics. Although Si has 3-10 times the capacity (~4200mAh/g) of commercially used graphitic (372mAh/g) anodes, it suffers a 400% volume expansion during Li-insertion, which leads to fracture from the first electrochemical cycle and a significant capacity loss. In order to limit this fracture and form design criteria that can predict the most stable configurations, fracture mechanics and damage models are employed. Based on the theoretical predictions new materials configurations of nanostructured Si and Sn based anodes have been fabricated that can lead to over a 90% capacity retention during electrochemical cycling.

The second part of the talk will describe the various applications that nanomaterials have in biology. Of particular interest is the effect that the mechanical properties and microstructure of scaffolds have on biocompatibility. Two examples that will be illustrated are (i) the dependence of myocyte adhesion on the pore size, and elasticity of electrospun nanofibers, which are developed for use as heart patches, (ii) how the viability of neurons on micropatterned surfaces, which can be used as electrodes in deep brain stimulation, is affected by the surface pattern and stiffness. In concluding, it will be shown how the materials properties of the extracellular matrix affect cell migration. A specific example that will be presented indicates that cell invasion in gels with pore sizes >5 μm increased with higher gel stiffness, whereas invasion in gels with smaller pores decreased with higher gel stiffness. These findings may be important for optimizing the recellularization of soft tissue implants or for the design of 3-D invasion models in cancer research.