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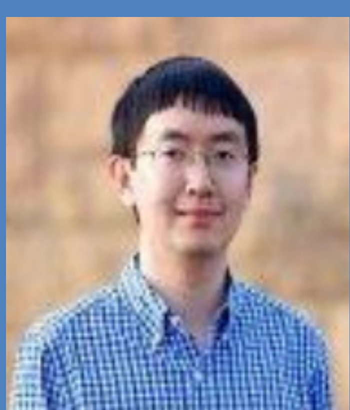

Electrochemical ion insertion for energy storage and low-power, neuromorphic computing

Dr. Yiyang Li

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Date: Friday, June 22, 2018 at 1:00pm

Location: ECEE 1B32

Abstract:

As global energy demands rise, the environmental impacts of traditional fossil-based energy sources are becoming increasingly clear. Therefore, it is essential to both improve energy efficiency and utilize more clean, renewable energy. Electrochemical ion insertion is a crucial technology towards achieving these goals. Here, an electrical current is used to insert a guest ion into a host crystal; when the current is reversed, the guest leaves the hostand reverses the chemical reaction. This dynamic and reversible change in the chemical stoichiometry is the foundational reaction underlying the Li-ion battery, which enables clean and renewable electricity to be stored and used for transportation. Ion insertion can be used to create low-energy neuromorphic computing hardware that emulate the human brain, which are orders of magnitude more energy efficient than traditional digital architectures. I will first present our study of ion insertion mechanisms in the model Li-ion battery material $LiFePO_4$, a promising cathode that uses nontoxic, earth-abundant materials. $LiFePO_4$ undergoes a first-order phase transformation upon lithium insertion and removal that affects the power and cycle life of the battery. As the battery charges and discharges, we use *in situ*X-ray imaging to monitor this phase transformation at the nanoscale within individual battery particles. Through direct visualization, we show how the phase transformation is controlled by a competition between the lithium insertion rate and the lithium surface diffusion rate. Such insights can be used to rationally design battery materials with improved (dis)charge kinetics, reduced mechanical strain, and superior cyclability. Next, I will utilize electrochemical ion insertion to design analog, non-volatile transistors for artificial neural networks (ANNs). ANNs are a powerful, rapidly growing technology, but are often limited by high energy consumption when implemented using CMOS technology due to the constant need to access memory. An alternative pathway to implement ANNs is to use analog transistors that also function as both logic and memory. We demonstrate how thin-film Li-ion batteries can be used as extremely low-power analog transistors by using the electrochemical insertion and removal of lithium to store and process information, with an estimated three orders of magnitude reduction in energy consumption. Such devices provide one avenue for creating computing architectures beyond the limits of Moore's Law, and reduce the overall energy demands of computation.

Bio:

YiyangLi is currently a Harry Truman Fellow at Sandia National Laboratories in Livermore, California. His research aims to understand the fundamentals of ion insertion in Li-ion batteries and novel devices and applications utilizing ion insertion. He received his BS in Electrical and Computer Engineering from Olin College and his MS and PhD in Materials Science and Engineering from Stanford University. He has been awarded the Gold Graduate Student Award by the Materials Research Society and the Young Scientist Award by the International Society for Solid State Ionics. Yiyangalso received the Walter J. Gores Award at Stanford University for his role in teaching and mentoring.

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