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Ultrafast time resolution in AFM measurements of charge transport in sustainable energy materials (I)

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One of the Grand Challenges for humanity in the 21st Century is sustainable energy generation and storage. This translates to major opportunities for AFM to help addressed relevant materials issues if ultrafast time resolution in the localized measurement of electronic properties can be achieved. In this presentation, I will give an overview of our recent successes at characterizing surface potentials using AFM-based techniques on time scales down to ps. The high spatial resolution of AFM in principle then allows the identification of rate limiting structures/defects, allowing the fundamentally important correlation of structure and processing with properties.

We have combined a UHV AFM system with a fs laser excitation system tunable in the optical spectrum. By developing a new pump-probe method we can measure ultrafast decay times using AFM/EFM as a spatial detector. We have applied this technique to organic and organometallic perovskite as well as GaAs to measure ultrafast charge carrier decay times as well as mobility. We will also discuss the fundamental time limits achievable using the AFM probe as a detector in pump-probe experiments. [see DOI: 10.1063/1.4975629]

A major challenge in the widespread deployment of sustainable energy sources such as solar and wind is maintaining grid stability. Distributed energy storage in electrical vehicle batteries connected to the grid is an option. A major issue inhibiting wide spread deployment is low charging rates. This is related to the poor current understanding of what determines mobility of Li ions in cathode materials. We have used a newly developed AFM/EFM technique to spatially determine variations in Li transport mechanism in LiFePO4, a model cathode material. We applied voltage pulses to the sample and observed the resultant fast time decay of the electrostatic forces due to the mobility of Li ions using a time averaging technique. By performing these experiments as a function of temperature we obtain spatially resolved activation barriers for Li transport. By combining our ultrafast AFM techniques with SEM, TOF-SIMS and EBSD as well as comparison to DFT calculations we show that ionic transport in these materials must be regarded as a collective effect due to the significant contributions by ion-ion and ion-polaron interactions to the measured activation energies. (Collaborators: A. Mascaro, Z. Wang, P. Hovington, Y. Miyahara, A. Paollela, V. Gariepy, Z. Feng,T. Enright, C. Aiken, K. Zaghib, K. Bevan)

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