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Dynamic characterization of energetic materials with Ultrafast Transmission Electron Microscopy[1]

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Fundamental understanding and prediction capability of energy localization and evolution in reactive materials are limited by the lack of understanding of the details of the processes occurring at different time and length scales. Under impact, mechanical energy is localized due to the formation of stress-concentration sites such as localized contact points, friction, and void collapse inside the heterogeneous materials. Energy localization leads to localized temperature rise, and eventually the formation of hot spots that lead to ignition. While this general concept has been widely accepted, direct experimental evidence of such hot spots is exceptionally limited and the mechanisms for their generation are poorly understood. Such investigations in energetic solids have proven to be difficult due to the complexity of material microstructures, chemical reactivity of the solids and short lifetimes of transient hot spots and this requires advanced characterization tools with the temporal and spatial resolution of hotspots. Transmission electron microscopy is one of the techniques which has a great potential in investigating the dynamic processes in energetic materials. In-situ electron microscopy is moving forward at a rapid pace with the development of gas/liquid stages that permit reaction processes to be imaged and analyzed at atomic resolution. Moreover, the development of nanosecond and faster photoemission electron sources offers the chance to move the high spatial resolution world of electron microscopy into the ultrafast world of materials dynamics. In this presentation, examples of dynamic ultrafast transmission electron microscopy studies of energetic crystals, such as HMX, with embedded plasmonic nanoparticles will be presented. Additionally, the potential of novel in-situ stages in multimodal data acquisition scheme to push the envelope of electron microscopy for the investigation of materials under extreme conditions will be discussed.

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