SHOCK07-2007-000521

Abstract for an Invited Paper
for the SHOCK07 Meeting of
the American Physical Society

Reactive Nanolaminates as Model Materials for Controlling Initiation Thresholds under Shock and Electrical Loading

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Over the last ten years a group of researchers at Johns Hopkins University have demonstrated the ability to control and predict the initiation and energy of exothermic reactions that self-propagate in foils with nanoscale layering. These exothermic reactions can be ignited with mechanical, electrical, optical or thermal pulses of energy and provide model materials for systemically varying and predicting initiation thresholds. This presentation will describe our efforts to quantify and predict how the initiation and propagation of these reactions depend on the nanoscale spacing of the reactants and their heats of reaction for mechanical and electrical loadings. Studies of mechanical deformation will also be presented. The free-standing foils or sheets are fabricated using vapor or mechanical processing methods and range in total thickness from 10μm to 1000μm. The individual layers within the foils range in thickness from 10nm to 10,000nm. Rod and plate geometries can also be fabricated. A common chemistry for formation reactions includes Ni and Al while a typical chemistry for a reduction/oxidation reaction would include Al and CuO_x. The reactants and their spacing are chosen to enable exothermic reactions that self-propagate at velocities ranging from 0.1 to 10m/s with maximum temperatures above 1000 $^\circ$C. Using mechanical impact tests and electrical discharge experiments we have measured thresholds for initiating reactions in these foils, and we have shown that the thresholds increase significantly with reactant spacing and with pre-mixing between the reactants. These measurements are compared with numerical predictions and show strong agreement. The mechanisms controlling the initiation of the reactions will be reviewed and the metastable phases that appear within the self-propagating reactions will be identified using in situ XRD experiments. Lastly, the strength of these materials will be characterized as a function of reactant spacing using standard tension tests.