Multifunctional Energetic Materials*

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Summary

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With the inspiration drawn from many natural systems, Multifunctional Energetic Materials are evolving as a class of materials that integrate desirable characteristics of high energy density and rapid energy release properties along with at least one other designed functionality, for example, mechanical strength. Structural energetic materials, reactive foils for micro-welding, and structural propellants, are some examples of such materials. The challenge in designing multifunctional energetic materials lies in also improving their safety, reliability, and load bearing capability. The symposium on this topic included forty-nine presentations/posters delivered by scientists/engineers from the U.S., U.K., The Netherlands, Canada, France, and Singapore, mostly, covering research activities at departments of energy and defense, universities, and industrial centers, and especially in the latter case, small start-up businesses. Beginning from the first MRS symposium in 1992 on the topic "Structure and Properties of Energetic Materials", as Proceedings Volume 296, and two other intervening symposia, this most recently completed symposium is the fourth in the series on the topic of "energetic materials" and their uses.

In general, the current symposium covered basic material property evaluations for reactive materials, new techniques for synthesis of energetic materials including thermites, high explosive structures, self-assembled systems, nanometric aluminum and related metals and intermetallics, and polymer-coated particles. Particularly impressive were the innovative and creative applications of energetic materials. For example, Professor Timothy Weihs, Johns Hopkins University, talked about the use of reactive multi-layer foils for structural energetic applications. The use of mechanical milling for creating nanocomposite reactive materials, and their unique characteristics, was demonstrated as a useful method by various members of the group at the New Jersey Institute of Technology, as well as the Nanyang Technological University in Singapore. Professor Joseph Cochran, Georgia Institute of Technology, described the novel application of linear cellular alloys as exoskeletons for energetic materials, for possible control of their initiation characteristics. Tailoring the properties of particulate energetic materials, for example through polymer coatings, was described in an interesting presentation by Patrick Brousseau, from DRDC Valvartier, in Quebec, Canada. Characterization of the very early stages of reaction initiation is goal of the recently started MURI program led by the University of Illinois, as presented by Professor Dana Dlott, who described the new facilities aimed at capturing the ultrafast dynamics of nanoenergetic materials. Along the same lines, Dr. Steven Son described the theoretical and experimental nanoscale energetic materials research being performed at the Los

Alamos National Laboratory. Not forgotten amongst the otherwise beneficial attributes of nanoscale energetic materials, was the issue of toxicity of nanoparticles. Kevin Powers from the Particulate Research Center talked about *in-vitro* toxicity screening of Al nanoparticles. Professor Michael Zachariah, University of Maryland, talked about advances in chemical kinetics which provide the understanding that can enable tuning of the reactivity of nanoenergetic materials. Dr. Barbara Baschung described the work being performed at the Institute Saint-Louis in France, on the influence of the addition of inorganic nanoparticles to solid propellants, in which case the burning rate is observed to increase by nearly two orders of magnitude. Perhaps the truly "energetic" response of multifunctional energetic materials was best revealed in the presentation by Richard Ames, who showed examples of energy release characteristics of these materials upon impact. The effect of nanoscale structure on the reaction mechanism and ignition of energetic materials continues to be a subject of much study. Various presentations including those by Professor Jan Puzynski, Adam Cumming, Vitali Nesterenko, William Grise and several other groups from the New Jersey Institute of Technology, Texas Technological University, Georgia Institute of Technology, Delft University of Technology in The Netherlands, Los Alamos National Laboratory, and Steve Coffey at NSWC in Indian Head, described the many aspects of reaction initiation mechanisms. Much work is now also being focused on theoretical modeling of reaction initiation studies in energetic materials. Betsy Rice, Alejandro Strachan, Tommy Sewell, and William Proud, were amongst several others that described the state of the art in theoretical characterization and modeling of energetic materials, including atomistics and molecular dynamics studies.

The field of energetic structural materials is now maturing as innovative methods are enabling the diagnostics of rates of energy release or measurements of reaction products via femtosecond spectroscopy and extending to hot spot formation durations of microseconds; combustion rates from meters/s to detonations at km/s; and deformations from those resulting from drop-weight impacts to shock wave loading. Creation of biomedical skeletal structures, shell casings, metal foam structures, environmentally attractive igniters or cartridge primers, and missile components are providing a new dimension for the many touted applications of energetic materials. The presenters and audience members participating in this symposium appeared to leave in a properly energized state, of course, looking to the upcoming MRS Proceedings Volume 896 to provide a valuable resource.

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