Experimental Mechanics (2013) 53:1–2
DOI 10.1007/s11340-012-9689-y

GUEST EDITORIAL

Transparent Armor Materials

G. Subhash

Published online: 23 October 2012

The history of glass dates back to the Stone Age. It is believed that the first true glass was made in Mesopotamia or Ancient Egypt. Since its first use by humans almost five millennia ago, glass has been mostly a luxury material used for decorative or architectural purposes in the form of beads, glass vessels, mosaic tiles and window glass. In the last few decades, the use of glass for transparent armor applications has drawn increasing attention. While ceramics and metals have served effectively as armor materials, the need for increased visibility in hostile environments has drawn attention to transparent materials with high ballistic resistance. Applications of transparent armor glass include windows for armored vehicles, impact and blast resistant windows for buildings and vehicles, riot protection gear for law-enforcement personnel, solar panel windows capable of resisting hurricane debris impact, etc. Numerous materials have been identified that fulfill the above need. Some of these materials include transparent polymers (PMMA, polyurea), polycrystalline glass ceramics (e.g., AlON, spinels, transparent Al_2O_3), single crystals (sapphire), hardened glass etc. While the literature on mechanics of ballistic impact on hard and strong metals and ceramics is abundantly available, investigations on the damage mechanisms in some of these transparent armor materials, especially under ballistic impact conditions, are relatively few and recent. This special issue brings together latest research in this topical area.

It is fitting to start the special issue with a Feature Article by James McCauley, Strassburger, Patel, Paliwal and Ramesh, summarizing the work being carried out at the Army Research Laboratories, Aberdeen Proving Ground, MD. Using edge-on impact geometry, high-speed imaging and a modified Kolsky bar on laminated glass, sapphire and AlON, they summarize a series of investigations that focus on stress wave and damage front propagation characteristics in selected transparent armor materials impacted by spherical or cylindrical projectiles at velocities up to 925 m/s . Such well-characterized experiments coupled with high resolution microscale imaging can provide quantitative description of damage process which can be of significant value to the modeling community as well as design and development of advanced transparent armor systems.

Continuing on the same theme, Haney and Subhash, Steve Bless, Zikry et al., present impact response of various glasses, glass ceramics and transparent polymers. Haney and Subhash present in-depth ball-impact experimental investigation to explain the superior ballistic performance of spinel over sapphire despite the reported spinel's inferior mechanical properties. The study emphasizes the need for considering the mechanisms of deformation in addition to the mechanical properties in design and performance evaluation of transparent armor. In the next article by Steve Bless, depth-of-penetration tests are used to evaluate the relative performance of four types of armor-grade transparent materials, namely, borosilicate glass, soda-lime glass, glass ceramic, spinel and their laminates. The effect of projectile geometry and properties on single-hit and multi-hit performances is evaluated. Pearson, Labarbera, Prabhugoud, Peters and Zikry utilize drop tower test facility to conduct low-velocity impact experiments on PMMA sheets by positioning sensors at critical locations. They utilize these local measurements coupled with global measurements from quasistatic tests to conduct a detailed finite element analysis to uncover spatial and temporal evolution of damage in PMMA subjected to impact loading. The above investigations have significant implications for design of transparent armor and mitigation of impact-induced damage.

G. Subhash (✉)
Department of Mechanical and Aerospace Engineering,
University of Florida,
Gainesville, FL 32611, USA
e-mail: subhash@ufl.edu

The next set of three papers by Chen and Nie, Chocron et al., and Swab et al., deal with failure response of borosilicate and soda lime glasses under various mechanical and thermal loads. Chen and Nie utilize double pulse loading in Kolsky bar to investigate the failure response of borosilicate glass under different confinement levels, temperatures and strain rates. The evolution of shear zones in the damaged specimens and its relation to comminution of glass are discussed. Chocron, Anderson, Dannemann and Nicholls present a combined experimental and modeling study to characterize the response of intact and damaged soda-lime glass at high confinement pressures up to 2 GPa. They compare the reported data on several glasses (soda-lime glass, pyrex, and borosilicate glass) from confined quasistatic compression tests and flyer-plate impact experiments and present the validity of their pressure-dependent constitutive model. Lastly, Swab, Thies, Wright, Schoenstein and Patel investigate a more practical problem of how surface scratches on soda-lime silicate and borosilicate glasses influence the flexure strength. They also consider different thermal tempering treatment on the surfaces and reveal different deformation features (e.g., plastic deformation, chipping and cracking) at different loads. The flexure strength dependency on scratch load is investigated.

One of the major challenges in studying the impact or blast response of transparent materials is the spatial measurement of rapidly changing strain fields. To address this challenge, Periasamy and Tippur present a simple yet an elegant full-field optical method called Digital Gradient Sensing which utilizes elasto-optic effect of transparent solids under stress field and digital image correlation. They demonstrate the feasibility of the technique on PMMA sheets subjected to quasistatic and dynamic line loads and compare the results with finite element model computations. Continuing on the same theme of measuring rapidly changing strain and deformation fields under dynamic loads, Albrecht, Liechti and Ravi-Chandar present measurement of particle velocity and strain in a thin film of polyurea subjected to high rate of tensile stretches in split Hopkinson pressure bar. Such innovative techniques are of immense value to advance our understanding of the dynamic response of transparent materials.

Finally, Sundararajan, Biswas and Eswara Prasad discuss processing of transparent polycrystalline alumina (TPCA) using an environmentally benign thermal gel casting process. The properties of TPCA are compared to those of polycrystalline alumina made by conventional processes.

In summary, the special issue focusses on a range of topics encompassing testing, characterization, processing, diagnostic methods, and modeling the response of different transparent armor materials subjected to a variety of loads. Experts from research laboratories and academia have participated and brought different perspectives to the subject area.

Numerous people have contributed to bring this Special Issue to completion. This effort would not have been successful without the high-quality contributions from all the authors and rigorous peer-review of the manuscripts by many of my friends and colleagues in experimental mechanics community. They have been extremely cooperative in adhering to my deadlines and quickly responding to the requests making my job as Guest Editor enjoyable and helped improve the quality of the special issue. I also want to thank the staff at the SEM office who kept me on track with deadlines and requirements to follow to get this special issue to completion. Last but not the least, I want to sincerely thank Prof. Hareesh Tippur for inviting me to Guest Edit this special issue. His patience, guidance and encouragement at all stages of this issue have been exemplary. Finally, I hope this issue will expose interested researchers to the state-of-the-art in the field of transparent armor materials and inspire them to pave the way for exciting scientific advancements in this rapidly evolving subject area.

Ghatu Subhash
Guest Editor