Preface

This book, as a volume in the *Shock Wave Science and Technology Reference Library*, is primarily concerned with detonation waves or compression shock waves in reactive heterogeneous media, including mixtures of solid, liquid, and gas phases.

The topics involve a variety of energy release and control processes through heterogeneous reactive shock waves; a contemporary research field of detonation that has found wide applications in propulsion and power, hazard prevention, as well as military engineering. This volume contains six chapters. The first two chapters describe the detonation behavior of volumetrically dispersed multiphase explosive mixtures, and the subsequent two chapters deal with condensed multiphase composite explosives. Chapter 5 discusses the unique solid-state reactions in microscopic solid particle mixtures under high-pressure shock loading. The final chapter is fundamental in describing shock ignition behavior of solid and liquid particles. Each chapter is self-contained and can be read independently of the others, though they are thematically interrelated. They offer a timely reference for graduate students as well as professional scientists and engineers, by laying out the foundations and discussing the latest developments, including yet unresolved challenging problems.

The first chapter, by S.B. Murray and P.A. Thibault, discusses spray or liquid aerosol detonation. This chapter provides not only an updated review, but also offers a concise heuristic introduction to spray detonation for both high-vapor-pressure and low-vapor-pressure fuel. After an excellent introductory or refresher reading for any class on laboratory phenomena of confined spray detonation, the authors offer a state-of-the-art description on detonation of unconfined fuel spray in air and its future research directions. This is possibly the first article in the open literature that provides such a comprehensive summary of the unconfined spray detonation phenomenon and its various engineering approaches. The chapter, with many materials unpublished before, complements any of the previous review articles in the area of spray detonation.

The second chapter, by F. Zhang, presents an overview of the fundamentals of dust detonation or detonation in gas–particle flow. It begins with a historical introduction and this is followed by an in-depth description of the detonation theory for explosive systems composed of reactive particles dispersed in oxidizing gases and in reactive gases. The chapter further presents a review of profound experiments on the transition to heterogeneous detonation, heterogeneous detonation structure, quasi-detonation, and hybrid detonation. The discussion on theory and experiments has focused on the unique detonation physics and performance behavior inherent to these multiphase explosive mixtures. Most of the descriptions and discussions are valid not only for low-density gas–solid flow, but can also be applied to dense or condensed fluid–solid heterogeneous explosive mixtures. This chapter offers up-to-date information on the fundamentals and a database for the subject area.

The third chapter, by D.L. Frost and F. Zhang, provides a comprehensive topical review of slurry detonation. The term "slurry explosive" is used in a general sense to include water–gel, emulsion, and metalized slurry formulations and blasting agents. This constitutes an attempt to cover not only available commercial slurry explosives, but also to review the current state of the art and fundamentals for possible future candidates. The chapter first describes the composition of and manufacturing procedure for various slurry explosives, and this is followed by an in-depth review of slurry explosive performance with emphasis on the characterization and properties of the nonideal and heterogeneous detonation wave itself. It further offers a review of models and their unique requirements for slurry detonation propagation, which is dominated by mesoscale (grain-scale) shock wave dynamics coherent with local mechanical and thermal response, as well as chemical reaction of heterogeneous material. Many unique detonation behaviors of fuel-rich metalized slurry explosives are discussed on the basis of the authors' own experiences.

The fourth chapter, by M.F. Gogulya and M.A. Brazhnikov, deals with detonation in metalized composite explosives with emphasis placed on micrometric and particularly nanometric aluminum additives. This chapter offers a selective but profoundly informative review of recent advances in this complex area and many of the materials are taken from the authors' own acknowledged studies. It covers both positive and negative oxygen-balance explosives in binary and ternary formulations with aluminum additives of various particle shapes and in a wide size range of 0.04–100 μm. A two-heat release process (explosive detonation and aluminum particle afterburning) has been demonstrated to be a general energy release principle for the detonation of such metalized explosives. It is often characterized by a shock wave followed by a pressure wave. The chapter, with 33 figures and 24 tables, provides one of the most comprehensive summaries of explosive behavior and detonation properties for various aluminized explosives, including mechanical and shock sensitivity, brisance, heat of reaction or explosion, detonation velocity, failure diameter, pressure, temperature and particle velocity history, as well as plate and cylinder acceleration capabilities.

The fifth chapter, by Yu.A. Gordopolov, S.S. Batsanov, and V.S. Trofimov, is a status report on shock-induced solid–solid reactions and possible detonation (a self-sustained shock wave). Unlike the classic thermal detonation where the expansion of high-pressure detonation gas-phase products provides the work required to sustain the propagation of detonation, a solid–solid detonation describes the concept of a highly energetic explosion where a stable supersonic wave exclusively converts mesoscale or microscale solid particle reactants to high-speed solid-phase products. The intriguing phenomena and possibility of this mode of shock-induced energy release without expanding gases appeared in the 1950s and has grown since the 1980s, resulting in advances in solid-state chemistry under high-pressure shock loading down to microscopic scales. Gasless detonation properties were predicted theoretically using Hugoniot analysis in the 1990s, where the detonation speed appears comparable with that in conventional high explosives; however, negligible heat is produced through shock compression in spite of the high pressures. Experimentally, while supersonic reactive shock waves observed in metal–metallic oxide mixtures were often accompanied by the release of gas products, shock-induced inorganic solid-state reactions have been reported on microsecond timescales in various metal–sulfur mixtures and intermetallics, but observations have been scarce and preliminary to date. Recent advances in experimental efforts have been possible owing to the progress of nanometric powder technology. The mechanisms for solid–solid reactions and wave sustaining are not yet clear, but are hypothesized to be driven by high atomic or molecular mobility resulting from shock and particle interactions with subsequent superfast diffusion or high-speed momentum flux transfer, which is supported by chemical energy augmented by bond energy release if the system is under extremely high pressure. The authors are leading experts in this cutting-edge research field. This chapter is a testament not only to the wide-openness of experimental studies, but also to the necessity of exploring possible fundamental theories in order to describe the phenomena and underlying mechanisms.

The sixth chapter, by S.M. Frolov and A.V. Fedorov, is concerned with the shock ignition of particles. It offers a fundamental aspect for all the first five chapters and the field of heterogeneous detonation. This chapter provides a selective but profound review of recent advances in both solid metal particles and liquid fuel droplet ignition after being subjected to shock loading, with emphasis placed on theoretical fundamentals and mathematical models mostly taken from the authors' own in-depth studies. As the authors indicate, for problems dealing with transient modes of combustion such as ignition or extinction, the effects of finite-rate chemical kinetics must be considered. These processes are subjected to a number of local shocked flow and particle interactions where the influences of neighboring particles are considerable. The phenomena are further complicated by the particle breakup, fragmentation, and subsequent mixing with air accompanied by phase changes, thus creating extreme challenges for the mathematical modeling. The authors offer insightful critiques of current thinking, while applying simplified treatments of various shock and particle interactions to explore the fundamental behaviors of shock ignition. Prototypical samples include magnesium and aluminum particles as well as $n-$alkane liquid droplets. The chapter provides advanced reading on the fundamentals of particle shock ignition and therefore the basis for heterogeneous detonation.

The editor is indebted to all authors for their willingness to prepare and make available their timely and authoritative materials to a wide audience.

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