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Initiation of solid explosives by laser

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ABSTRACT

Theoretical calculations are described to investigate the behavior of solid explosive when heated by continuous and pulsed laser. A one-dimensional model is proposed and the numerical solutions have been obtained for the time-dependent nonlinear heat equation with the appropriate initial and boundary conditions. Relationships between various ignition parameters are analyzed and possible ignition mechanisms are discussed. Theoretical calculations are applied to the primary solid explosive β lead azide. It has been argued that the initiation of β lead azide with low energy laser is thermal in origin.

1. Introduction

Detonation of explosives can be initiated by various mechanisms of delivering energy to it. These include among others, impact, friction, heat, spark, and intense light [1]. Aside from the fundamental importance of studying laser interaction with energetic materials, laser initiation has many advantages when compared to conventional systems [2]. Working with a coherent collimated beam of radiant energy, laser offers advantages in having a variable energy and power output with a negligible divergence leading to a specified spot size. This, in return, allows the use of small amount of explosive materials which reduces risk associated with various applications [3].

High explosives used as igniters in detonations should have chemical stability during storage and low sensitivity to thermal and mechanical actions. The primary explosive lead azide is considered as an ideal detonant; it detonates reliably at high pressing loads, small amount is needed to detonate an adjacent high secondary explosive and it has a good thermal stability. It is used extensively as a commercial and military detonator.

Aside from the growing interest in lead azide as an initiating explosive in missile ordinance system and its important role in the safe use of explosive design, once its fast reaction is initiated, rapid propagation occurs readily throughout the entire crystals while the propagation of reaction in high explosives (e.g., RDX, HMX, PETN), for example, requires preconfinement. Accounting for the preconfinement of the sample introduces extra complications into theoretical modeling [4].

Furthermore, extensive studies of the gas phase dynamics of the detonation products of lead azide have been proved that this primary explosive is a suitable energetic material where a potential laser agent (Pb) and a fuel precursor (N_3) are inherently mixed [5,6].

Although the initiation of reaction in solid explosive by intense light is commonly believed to be thermal in origin as most of the incident light energy is assumed to be absorbed in a thin surface layer of the material and light energy is degraded into heat leading to self-heating, for some primary explosives (e.g. heavy metal azides) photodecomposition may be the initial step. A reaction mechanism with energetically chains was proposed for low-threshold initiation of lead azide by a neodymium laser. The initiation mechanism of explosives by long and short laser pulses was subject to comprehensive analysis where the dependence of the initiation delay upon the characteristic time within which traps are filled by holes was investigated [7–9].

In this preliminary study, an attempt is made to present a simple theoretical one-dimensional model to study the behavior of solid explosive when heated by continuous and pulsed laser. Numerical solutions have been obtained for the time-dependent nonlinear heat equation with the appropriate initial and boundary conditions. The theoretical model is applied to the primary solid explosive β lead azide. Rrelationship between various ignition parameters are analyzed and possible ignition mechanisms are discussed.

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