Effect of Preliminary Irradiation on the Detonation Sensitivity of Silver Azide and Lead Azide [1]

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Abstract – The purpose of the present work was to experimentally examine the possibility of controlling the heavy metal azide (HMA) sensitivity by means of a preliminary radiation treatment. A novel technique is proposed for studying the effect of radiation treatment on sensitivity of energetic materials, based on irradiation of specimens by a series of pulses on an electron accelerator. Data obtained in experiments with silver azide crystals (AgN_3) and lead azide ($Pb(N_3)_2$) crystals are reported. The explosion probability in irradiated specimens is shown to be a nonmonotonic function of the radiation dose, exhibiting a rise for low doses and a fall for high doses. The experimental data obtained agree with the divacancy model for heavy metal azide initiation.

1. Introduction

Aleksandrov *et al.* [1] discovered the effect of preliminary irradiation on the efficiency of laser-initiated detonation of the explosive decomposition of lead azide and explained the observed phenomenon by the radiolysis of this compound with the formation of nontransparent (absorbing) lead particles playing the role of "hot spots". Recently, Aduev *et al.* [2] formulated an alternative explanation of the effect of preliminary irradiation on the sensitivity of heavy metal azides with respect to subsequent detonation. According to the proposed model, the chain reaction of explosive decomposition starts when the initiating pulse creates a sufficiently large concentration of active centers representing charged divacancies (a divacancy becomes charged upon trapping an electron). Therefore, an increase in the content of existing charged and neutral divacancies increases the sensitivity of an explosive with respect to detonation, while an increase in the total cross section for the hole trapping on competitive defects decreases this sensitivity. Thus, using preliminary irradiation (creating new defects and producing recharge of the existing ones), it is possible to control the probability of subsequent detonation of such explosives.

The aim of this investigation was to judge between the two explanations mentioned above. For this purpose, we have studied the influence of preliminary irradiation on the sensitivity of silver azide and lead azide with respect to initiation by a pulsed electron beam. The pulsed electron beam generated by an accelerator had the following parameters: electron energy, 150 keV; pulse duration, 50 ps; beam current density, 1 kA/cm^2; absorbed dose per pulse, 15 krad. Such a pulsed action cannot heat colloidal particles to a temperature at which they play the role of hot spots [3, 4] and, hence, this method of initiation excludes the variant of explanation proposed in [1].

2. Objects and technique

The objects were silver azide whiskers with typical sizes 0,1 x 0,05 x 10 mm. and lead azide single crystals (whiskers) having average dimensions about 0,05 x 0,03 x 5 mm. The samples were close by geometrical sizes, transparent, without visual macrodefects. The samples were chosen from the same synthesis.

The specimen was placed in a vacuum chamber to be irradiated by pulses produced by an electron accelerator (150 keV, 50 psec). The registered (quantity was the number of the pulse under which the specimen finally exploded. If the specimen did not explode after 100 pulses, the experiment was terminated.

In reference tests, the initiation source was a pulsed laser (1064 nm, 30 psec, and 0.5 mJ), and the preliminary irradiation by electrons was performed on an "ARINA" setup.

The method of investigation, experimental procedure, and statistical principles of data processing are described in detail elsewhere |5].

3. Experimental results and discussion

The main experimental results are presented in the Fig. 1 as a plot of the detonation probability versus dose of preliminary irradiation. As can be seen, the experimental curve is nonmonotonic: the explosive sensitivity grows in the region of small radiation doses, exhibits a maximum, and then drops to nearly zero at large doses.

Thus, the preliminary radiation treatment of specimens on the "ARINA" setup affects their explosion sensitivity only at the initial stage, as long as the radiation dose is smaller than (or commensurable to) the dose accumulated during a series of initiating accelerator pulses. This result confirms the growth of the explosion sensitivity of silver azide specimens subjected to low radiation doses.

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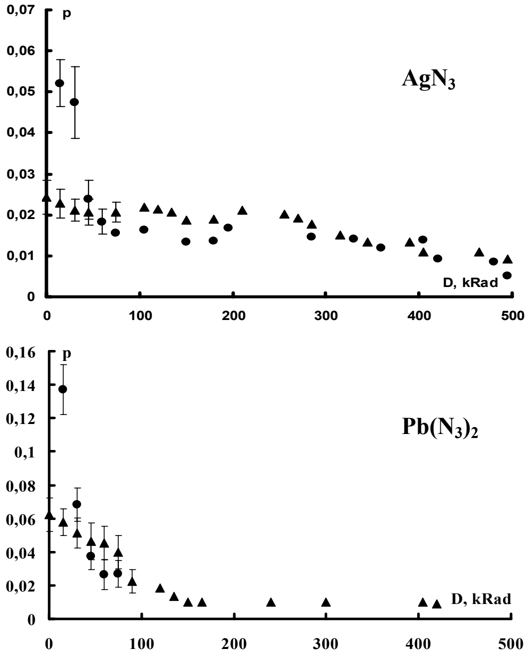

Fig. 1. A probability of an explosion *p* vs. the number of pulses of radiation pre-treatment (the dose for a pulse is 15 kRad).

1 – ▲ intact (unirradiated) samples

2 – ● samples preliminary irradiated by the dose of 25 kRad

The more evident result obtained at reduction of a dose of an irradiation per pulse of the accelerator with 15 kRad to 10 kRad on an example of preliminary unirradiated lead azide are presented in the Fig. 2.

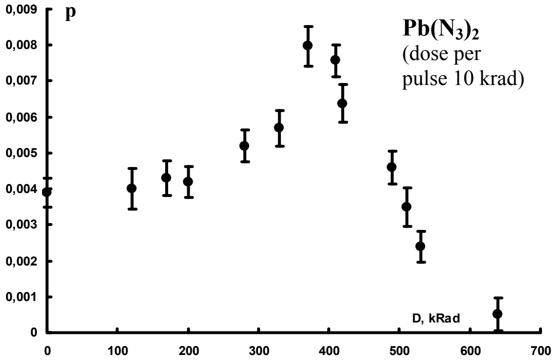

Fig. 2. A plot of the probability p of lead azide detonation initiated by a picosecond pulsed electron beam versus preliminary irradiation dose D

The given effect confirms the statement, that the dose accumulated by a crystal by means of consecutive impulses of the accelerator plays a role of a preliminary irradiation (radiation treatment).

4. Conclusions

The possibility of controlling the HMA sensitivity with the use of a preliminary radiation treatment is experimentally validated. The sensitivity versus the preliminary radiation dose behaves nonmonotonically, displaying a rise for low doses and a fall for high doses (see Fig. 1). From the viewpoint of the initiation model [2], this behavior seems to be quite natural. For low doses, the prevailing effect is recharging (electron capture by divacancies), which increases the sensitivity. For higher doses, effects caused by radiation-induced production and aggregation of defects are manifested, which can increase the integral cross-sectional area for hole capture by competing defects, thus, resulting in a lower sensitivity.

Such a relation between the dose dependences of recharging and radiation-induced production and aggregation of defects is well known in radiation physics [6].

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