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| *Author(s):* | Daniel N. Preston, Paul D. Peterson, Kien-Yin Lee, David E. Chavez, Racci Deluca, Gabriel Avilucea, and Stephanie Hagelberg |
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# EFFECTS OF DAMAGE ON NON-SHOCK INITIATION OF HMX-BASED EXPLOSIVES

**Daniel N. Preston, Paul D. Peterson, Kien-Yin Lee, David E. Chavez, Racci Deluca, Gabriel Avilucea, and Stephanie Hagelberg**

*Dynamic and Energetic Materials Division, Los Alamos National Laboratory, Los Alamos, NM 87545*

**Abstract.** Structural damage in energetic materials plays a significant role in the probability of non-shock initiation events. Damage may occur in the form of voids or cracks either within crystals or in binder-rich regions between crystals. These cracks affect whether hotspots generated by impact will quench or propagate under non-shock insult. For this study, we have separately engineered intra-crystalline and inter-crystalline cracks into the HMX-based PBX 9501. Intra-crystalline cracks were created by subjecting HMX to forward and reverse solid-to-solid phase transformations prior to formulation. Inter-crystalline cracks were induced by compressing formulated samples of PBX 9501 at an average strain rate of $0.00285\ s^{-1}$. Both sets of pre-damaged explosives were then impact tested using the LANL Type 12 Drop Weight-Impact Machine and their sensitivities compared to non-damaged PBX 9501. Results of these tests clearly show significant differences in sensitivity between damaged and non-damaged PBX 9501.
**Keywords:** Explosives, damage, sensitivity.

## INTRODUCTION

Polymer Bonded explosives (PBX) are made by formulating a particulate crystalline explosive with a relatively small amount of a polymer binder. The binder holds the formulation together structurally and generally reduces the impact and friction sensitivity of the explosive.

Structural damage in PBXs plays a significant role in the probability of non-shock initiation events. Damage may occur in the form of voids or cracks either within crystals or in binder-rich regions between crystals. These voids and cracks can affect whether impact-induce hot spots, and their reaction products, have sufficient transport pathways to propagate the reaction without releasing sufficient pressure to quench the reaction.

To study the effect of damage on non-shock initiation of explosives, we have separately engineered intra-crystalline and inter-crystalline damage into PBX 9501. Both types of pre-damaged explosives have been impact tested and their sensitivities compared to pristine PBX 9501.

## EXPERIMENTAL PROCEDURE

PBX 9501 is formulated using 95% HMX (3:1 course/fine) with 5% binder (Estane 5703/BDNPA-F). Some degree of both inter-crystalline and intra-crystalline cracking is naturally present in PBX 9501 after formulation and pressing.

To determine the effect of increased damage on the sensitivity of PBX 9501, inter-crystalline and intra-crystalline damage were separately engineered into PBX 9501. The same lots of HMX, Estane 5703 and BDNPA/F were used to create the undamaged PBX 9501 and both type so damaged materials for this study.

To induce inter-crystalline damage, pellets of PBX 9501, with a diameter of 5mm and an initial length $l_0$= 1.4mm, were die pressed. These pellets were then individually compressed to slightly past the ultimate compressive strength of the pellet in an Instron testing machine. The Instron machine tends to create damage in binder rich areas of the pellet. The compression was done at a platen velocity of 0.01in./min for a nominal period of 40 seconds. The resulting change in sample length

due to compression was 0.17mm. The average final sample length for these damaged pellets was 1.23mm corresponding to a true strain of 0.13. The average strain rate over the t=40 second test period was:

$$\left\langle \dot{\varepsilon} \right\rangle = \frac{1}{t}\ln\left(1+\frac{V_{platen}\,t}{l_0}\right) = 0.00285\,s^{-1}. \qquad (1)$$

To induce intra-crystalline damage, prior to formulation, the HMX was subjected to forward and reverse solid-to-solid phase transformations, β →δ→β. Crossing a phase boundary induces a density change leading to the formation of cracks in the HMX crystals, compare Figures 1 and 2. β →δ→β HMX (β-reverted HMX) was then formulated into PBX 9501, and pressed into pellets of 5-mm diameters and 1.3-mm heights.

For comparison, non-damaged PBX 9501 pellets and PBX 9501 pellets containing both inter-crystalline and intra-crystalline damage were also formulated and pressed.

Each of these four types of PBX 9501 pellets were then impact tested using the LANL Type 12 Drop Weight-Impact Machine. Reaction probabilities were determined for different several drop heights. A linear fit was then applied to the reaction probabilities to give a reaction probability curve for each type of material. These linear probability curves for Type 12 impact (with grit) and Type 12b impact (without grit) are shown in Figure 4.

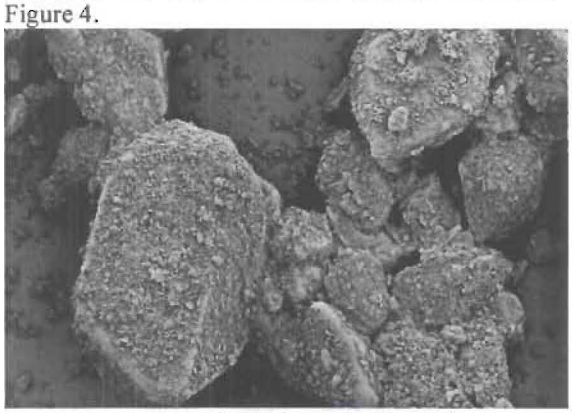

Figure 1. PLM image of β-HMX

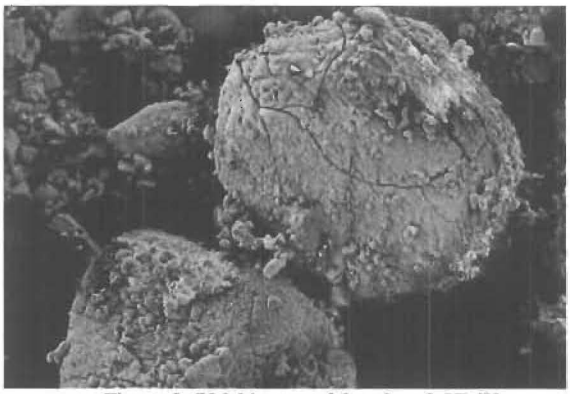

Figure 2. PLM image of β →δ →β-HMX

## RESULTS AND DISCUSSION

The sensitivities of these HE's turned out to be predictable with one notable exception. The results of the measurements for PBX 9501-beta and Instron damaged PBX 9501-beta are as predicted: the Instron damaged PBX 9501-beta resulted in greater sensitivity; refer to figure 3 and 4.

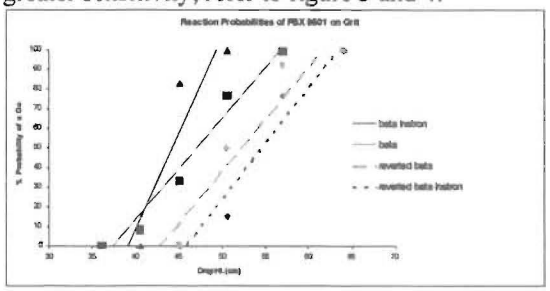


Figure 3.

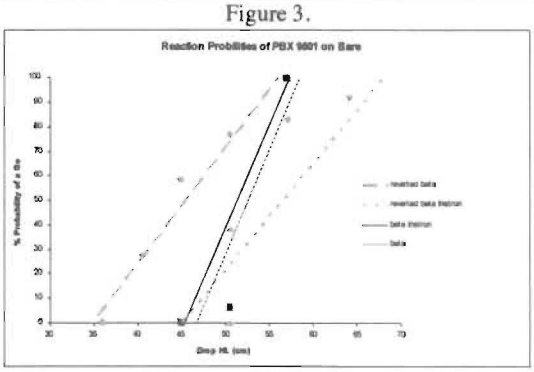


Figure 4.

The PBX 9501-beta reverted, however, had a lower sensitivity than the PBX 9501-beta. The results of the PBX 9501, beta reverted Instron damage, indicate very little change if any in sensitivity.

## CONCLUSIONS

The following conclusions can be drawn from the data:

- Impact Sensitivity with grit, as compared to pristine PBX 9501(β-HMX) –
  - Instron damaged PBX 9501(β-HMX) was the most sensitive to impact.
  - PBX 9501(β-reverted HMX) and Instron damaged PBX 9501(β-reverted HMX) are less sensitive to impact.
  - Instron damaged PBX 9501(β-reverted HMX) is the least sensitive.
  - The slope of the reaction probability plot is much steeper for the Instron damaged PBX 9501(β-HMX)

- Impact Sensitivity without grit, as compared to pristine PBX 9501(β-HMX) –
  - PBX 9501(β-reverted HMX) is the most sensitive. More sensitive even than PBX 9501(β-reverted HMX) on grit.
  - Instron damaged PBX 9501(β-reverted HMX) is still the least sensitive.
  - The slope of the reaction probability plot is much steeper for the Instron damaged PBX 9501(β-HMX).

## ACKNOWLEDGEMENTS

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