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TITLE CRYSTAL ORIENTATION EFFECTS IN PETN EXPLOSIVE WITH 5 GPa SHOCKS

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CRYSTAL ORIENTATION EFFECTS IN PETN EXPLOSIVE WITH 4 GPa SHOCKS

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Shock initiation of detonation has been observed in PETN crystals of <110> orientation at the low shock strength of 4.25 GPa. This result explains some observations by other workers at Los Alamos National Laboratory that were considered anomalous. Chemiluminescent emission from the shock induced decomposition reactions has been observed using OMA spectrographs, photodiodes, and image intensifier cameras. The emission is not seen in the insensitive orientations, <100> and <101>; these orientations can deform using the primary slip plane, (110).

There have been indications of anomalous decomposition near 4 GPa in previous work at Los Alamos on <110> PETN crystals. Shock wave velocity measurements by S. P. Marsh recorded anomalously high velocities on some shots. P. M. Halleck and Jerry Wackerle observed a pressure excursion at the impact face about 0.3 μs after impact.[1] A wedge record obtained by B. G. Craig shows an unusual transition to an intermediate velocity. D. Vier found brightness temperatures from image intensifier camera (I^2C) photos of 3000 - 4000 K.

We decided to do a wedge experiment to verify Craig's result. Our crystal was thicker than his; results are shown in Fig 1. Our records show a transition to intermediate velocity followed by a transition to detonation. Results for run to detonation for all pressures are displayed in Fig. 2 including Craig's work.[2] It shows that the run at 4.26 GPa is the same as at 9.6 GPa and shorter than at 8.5 GPa, a very unusual double valued behavior. This behavior is believed to be due to plasticity effects that arise near 4 GPa because this is the shock stress at which maximum resolved shear stress is achieved.[3] The deviatoric stresses are believed to collapse above this stress level in this weak, brittle material.

In previous work we indicated that shock initiation at higher shock stresses crystals of <100> and <101> orientations appeared to be [illegible].[4] This was ascribed to their ability to slip on the primary (110) slip plane. [illegible] were done to check this difference in behavior among orientations near 4 GPa. Snapshots were taken with the shock 0.8 mm (0.2 μs) and 2 mm (0.5 μs) into the explosive. Substantial light from chemiluminescent emission was recorded from a <110> crystal but none from adjacent crystals of <100> and <101> orientations. Emission fluence from <110> crystals recorded on film with 10 ns exposures grew between the two snapshots in a manner consistent with the pressure record of Ref. 1; film density at 0.5 μs was six times greater than at 0.2 μs. No spatial structure to the emission was discernible. *Spatial structure associated with adiabatic shear might be expected in association with the high strain rate plastic flow to explain the initiation.* Spatial resolution was about 70 μm.

Emission and absorption UV/visible spectra have been obtained for both <110> and <001> orientations. Spectral data were taken beginning at 0.17 and 0.4 μs after shock entry for about 0.13 μs. Photodiode records of the total time resolved emission were also taken. Vier's I^2C photos indicated that <001> crystals emitted light but at lower levels than <110> at 2.2 GPa. Both orientations are in the sensitive category not having (110) planes available for slip, but <110> is more sensitive than <001> at higher pressures. Emission and absorption spectra were quite similar for both orientations. At 4.26 GPa there was a red shift of the absorption edge at 320 nm. There was extinction across the visible with intensity reduced by more than an order of magnitude at both early and late times. This extinction could be from

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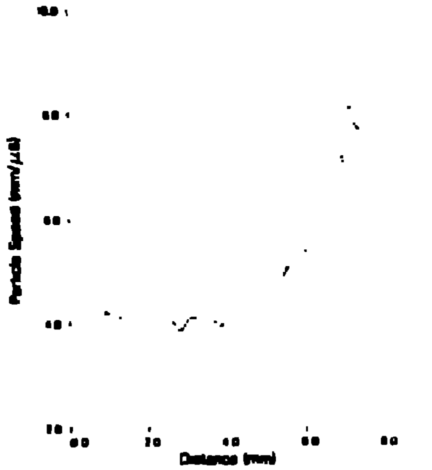

FIGURE 1
Wedge records for (110) PETN. Solid line is B. G. Craig's record at 4.0 GPa, dashed and dotted lines are our records at 4.26 GPa.

light scattering or molecular absorption. The source is not known, but it is similar to what we have seen in sapphire at 12.5 GPa. This is where plastic flow begins in sapphire, so it is possible that the light extinction in PETN is also related to plastic flow.

Emission spectra at 3.5 GPa were strong across the visible. Levels were low at early times in keeping with the PC and photodiode records (Fig. 3). After correction for spectrographic efficiencies the emission is strongest in the UV at 360 nm or shorter wavelengths. Data were taken with the shock part way through the crystal, so the emission was viewed through unshocked PETN which cut off emission at 320 nm. Emission radiance was slightly higher for (001) than (110). This is surprising since (110) is more sensitive at higher pressures. This is the first spectral information on shocked PETN. Using Wien['s l]aw these results would indicate a black body temperature of at least 8000 K. The calculated shock induced bulk temperature rise treating PETN as [illegible] is less than 200 °C. The 8000 K value is high even for detonation. [illegible] temperatures were based on no spectral information, only film density calibrated to black body source. We conclude that the

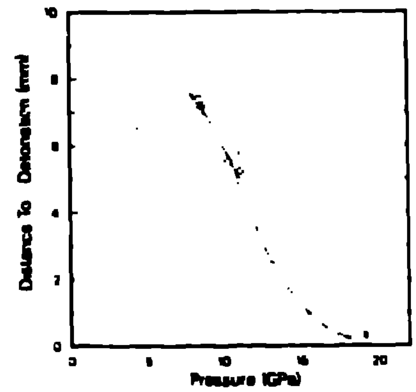

FIGURE 2
Run distance to detonation vs. shock stress for (110) PETN. Diamonds are data of Ref. 2.

emission is not that of a black or grey body. Rather, this is strong evidence that we are observing nonequilibrium chemiluminescence due to shock induced decomposition during the initiation process.

The photodiode record (Fig. 3) shows that at 4.26 GPa total emission reaches its maximum in about 0.9 μs. This is close to the classical induction time for thermal explosion at 4.26 GPa derived from shock and detonation velocities for PETN.

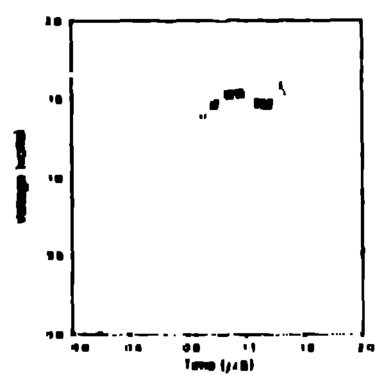

FIGURE 3
Photodiode record for total light emission from a [illegible] at 4.26 GPa

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