for the smectic diethyl 4, 4′-azoxydibenzoate:

$$A_0=\rho[v(90°)]^2=1.03(1.35\times10^5)^2$$
$$=1.88\times10^{10}\ \text{dyn/cm}^2,$$
$$A_0+B_0+2C_0=\rho[v(0°)]^2=1.03(1.42\times10^5)^2$$
$$=2.08\times10^{10}\ \text{dyn/cm}^2.$$

More of the constants can be obtained from optical measurements.[10]

In summary, it seems that two important points can be made: (1) The ultrasonic attenuation in an aligned smectic liquid crystal is extremely anisotropic, much more so than in the nematic case. No theory is available to explain this as yet. (2) Using the present ultrasonic results, reasonable estimates can be made of certain elastic constants in de Gennes's theory of the smectic state. There appear to be no previous results concerning any of these constants.

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[11] It is difficult to reconcile the somewhat garbled echo sequences for φ values other than 0° and 90° with Eq. (5). Modulated decay patterns would be expected, but not garbled ones. Other factors must be coming into play.

First X-Ray Diffraction Evidence for a Phase Transition during Shock-Wave Compression*

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(Received 29 September 1972)

The x-ray diffraction pattern of a shock-compressed material which is in the process of undergoing a crystal structure transformation has been observed for the first time. Pyrolytic BN, explosively shocked to 245 kbar, exhibits a diffraction pattern which indicates that the crystal structure *during* compression is like that of wurtzite.

The destructive nature of an explosive shock tempts one to suspect that the shock wave process is characterized by chaos at the atomic level. This *Götterdämmerung* view is unreconcilable, however, with the thesis that shock waves can transform crystal structures. Starting with the shock-induced phase transformation study by Minshall,[1] ample proof has been accumulated to establish the orderly nature of the shock-wave process. Resistivity[2] and shock-wave Hugoniot[3] measurements have established as a virtual certainty that shock pressures can induce crystal structure transformations within 10^{-7} sec. Until now, however, it has not been possible to inspect the actual crystal structure existing under dynamic conditions. Using the flash x-ray diffraction technique[5-7] we have for the first time been able to obtain an x-ray diffraction pattern of shock transformed material *at the instant of transformation.*

The problem of investigating a phase transformation on the Hugoniot is made difficult if transformation rates are too slow. Unless an appreciable amount of the new phase is formed during the time of our x-ray pulse, it will not be possible to obtain diffraction information concerning it. A simple way out of this difficulty is to use a semitransparent anvil to maintain pressure for a longer period of time. This, unfortunately, leads to very undesirable complications. X-ray-transparent anvils necessarily have lower shock impedance than any material we would wish to investigate. The result of this is that a partial-release wave travels through the sample and brings it to an off-Hugoniot point. Since the greatest interest is in obtaining information con-

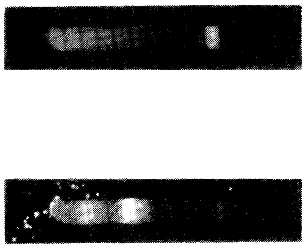

FIG. 1. Flash x-ray diffraction records of BN. The top record was obtained before shock-wave compression, and exhibits only the 004 Cu $K\beta$ line. The bottom record was taken at the instant the shock wave emerged from the front of the sample.

cerning material on the Hugoniot, we chose to do the more difficult experiment of looking directly at a transformation on the Hugoniot.

For this experiment we subjected compression-annealed pyrolytic BN[8] to a shock pressure of approximately 245 kbar. This material is highly oriented and gives exceptionally strong diffraction signals. The crystal structure is similar to graphite; Pease[9] has shown that there is a simple stacking difference. At a shock pressure of about 120 kbar[10-12] it transforms to a new structure which, from recovery experiments,[10,12,13] is thought to be similar to wurtzite.

A 1.3-cm × 1.3-cm × 0.1-cm piece was oriented so that the shock vector was parallel to the c axis of this pseudo single crystal. The top record of Fig. 1 shows the diffraction record of the unaltered material for the range $33° \leq 2\theta \leq 50°$. This particular range was selected so that we would have a fiducial mark on our film; the 004 $K\beta$ line of unaltered material is visible at the end of the record. For this record we used a high-intensity pulsed x-ray unit with unfiltered Cu radiation.

The bottom record was obtained during shock compression of our sample. The timing of our 40–50-nsec x-ray pulse was such that maximum intensity occurred at the instant the shock wave reached the front surface of the sample. The small spots on this film are shock-induced artifacts. The prominent and important feature to note on this record is that new lines appear.

Additional experiments were conducted at pressures of approximately 145 and 205 kbar to verify that these lines came from the transformed material. For these lower-pressure experiments we observed entirely different patterns which indicated that the material had been compressed but had not yet transformed to any appreciable extent. We measured $c/c_0 = 0.84$ and 0.83, respectively, for the graphite phase at these pressures.

It is premature to attempt a full analysis of these results. Nonetheless, several conclusions appear obvious. First, it can now no longer be questioned that sufficient time exists for a phase transformation to occur at the shock front. This statement must be qualified somewhat since the transformation mechanism for BN is expected to be displacive[14,15] in nature. This type of transformation is more facile than a reconstructive one so these results should not necessarily be assumed to hold true for transformations requiring diffusion.

Second, we note that the intensity maxima for the new diffraction lines correspond to a d spacing of 2.20 ± 0.02 Å. (Since unfiltered Cu radiation was used, both the $K\alpha$ and $K\beta$ lines are present.) Within experimental error, this d spacing is the same as the 100 line of the wurtzite phase of BN prepared by static[16] and dynamic[10,13] synthesis. While this strongly suggests that wurtzite is the phase formed just behind the shock front in our experiment, these early results do not, of course, conclusively settle the issue.

Third, the level of intensity which we measure for the shock-compressed state is too great to be caused by diffraction from a randomly oriented powder. Instead, it is likely that some semblance of single crystallinity is maintained, which is consistent with earlier single-crystal experiments.[7] This observation, together with the observation that we did not observe the 002 wurtzite line, immediately suggests that it is possible to say something regarding the transformation mechanism. Since the c axis of the graphite phase (c_g^*) becomes the [110] direction of wurtzite ($c_g^* \rightarrow a_w^*$), the hexagons of graphite-line BN deform to the "boat" configuration rather than to the "chair" configuration ($c_g^* \rightarrow c_w^*$). This latter deformation might have been expected from symmetry considerations. Of course in the wurtzite structure both configurations exist, but we are looking here only at the deformation parallel to c_g^*.

Finally, we note that the diffraction line intensity and sharpness differ from that for recovered materials.[4,13,17] The line broadening encountered in recovered samples is indicative of very small crystallite size. Our experiment suggests that the decrease in crystallite size probably originates in the release process rather than in compression. In this connection, the lines of Fig. 1 show a distinct shoulder when scanned by a densitometer. The d spacing for this feature is about 2.14 ± 0.03 Å. In an experiment purposefully timed 200 nsec late, we observed only the 2.14 line and the 004 $K\beta$ line; the 2.20 line had disappeared. We have considered the possibility that sample motion for such a late experiment becomes important and could possibly account for these results. To guard against this error, we use the 004 $K\beta$ line as a fiducial, thereby largely eliminating this problem. Further work is in progress to determine the source of this line.

We have demonstrated that flash x-ray diffraction can be used to study phase transformations during shock-wave compression. The application of this technique is now expected to produce answers to many long-standing problems of very high-pressure polymorphism.

We thank L. Evans and A. Hughes for technical assistance.

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*Work performed under the auspices of the U. S. Atomic Energy Commission.

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In-Beam Measurements of the Nuclear Quadrupole Interaction in Cadmium Metal

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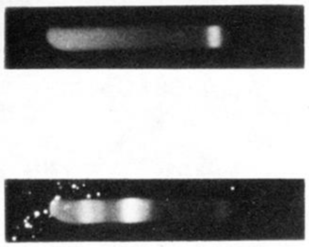
(Received 2 October 1972)

A time-differential perturbed angular distribution experiment on the 247-keV level of ^{111}Cd, excited by the (d,p) reaction in ^{110}Cd metal, shows a static quadrupole interaction at high temperatures and pronounced effects of radiation damage at lower temperatures.

During the last few years the study of the perturbed angular distribution of γ rays emitted after nuclear reactions has become a well-established technique for measuring the interaction of long-lived excited nuclear states with their surroundings. The relaxation effects observed with some solids have been explained by the action of fluctuating electric field gradients (EFG) due to lattice defects, which are introduced by the recoil of the excited nucleus itself.[1] When this work was first reported,[2] no in-beam observation of the static quadrupole interaction in metals had been published. It was attempted, therefore, to observe in a pulsed-beam [time-differential perturbed angular distribution (TDPAD)] experiment the static quadrupole interaction of the well-known 247-keV $\frac{5}{2}^+$ state of ^{111}Cd (mean life $\tau = 123$ nsec) in Cd metal. As the quadrupole interaction frequency of this system as a function of temperature is known from a time-differential perturbed γ-γ angular correlation experiment (TDPAC),[3] a detailed comparison is possible.

In our experiment we mounted a thin disk of polycrystalline ^{110}Cd metal on the finger of a cold trap filled with water or liquid nitrogen. The finger was heated electrically and the temperature



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