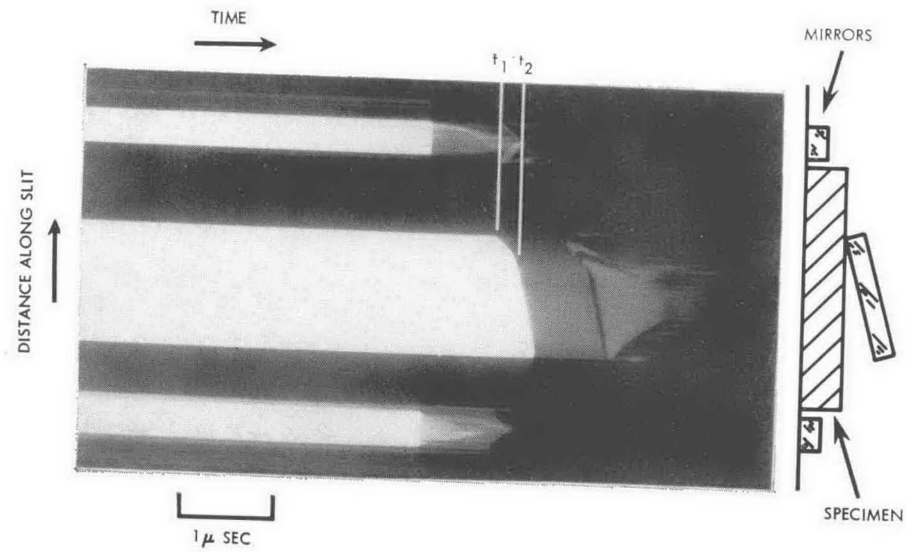

Fig. 9. Streak camera photograph of two shocks in $BaTiO_3$ (arrival times T_1 and T_2) affords both shock and free-surface velocities by measurement of the slope of successive light traces.

discharge recorded, the time at which the shock-accelerated surface reached that position is known. If several pins are used on a single specimen, an (x, t) plot of its motion can be made and its velocity obtained by differentiation. Such a pin record from a raster oscilloscope is shown in Figure 10.

But none of these data-taking methods is ideal; all are relatively delicate to arrange; and all involve rather complex subsequent reduction of the data.

PRESSURE TRANSDUCERS

There are a number of variations to the techniques described above for measuring shock parameters (Deal, 1962), all being suited for some particular material or application. A different approach is to use a transducer to record pressure or stress directly. Two philosophies are used in the use of transducers: one is to imbed a sensing element in the material, minimize the perturbation it causes, and ignore it. This approach is commonly used in sound field measurements. The other is to let the perturbation be as big as it need be, but calculate it. The latter approach has been successfully used in shock measurements. The transducer is made as large as the specimen with its flat face in contact with the specimen face. Reflection of the shock occurs at the specimen-transducer interface, and the change in shock amplitude is calculated by the procedure indicated in Figure 7. Two such transducers have been successfully used: the single-crystal quartz

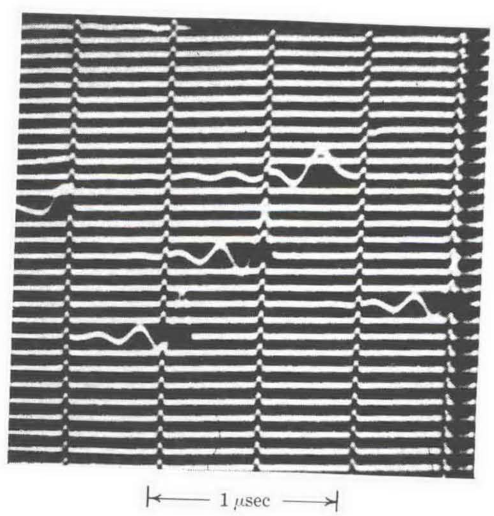

Fig. 10. Pin method for measuring shock and free-surface velocities in specimen uses motion of its shocked surface to close a gap and strike a pin, short-circuiting an R–C network which discharges through a raster oscilloscope to yield record.

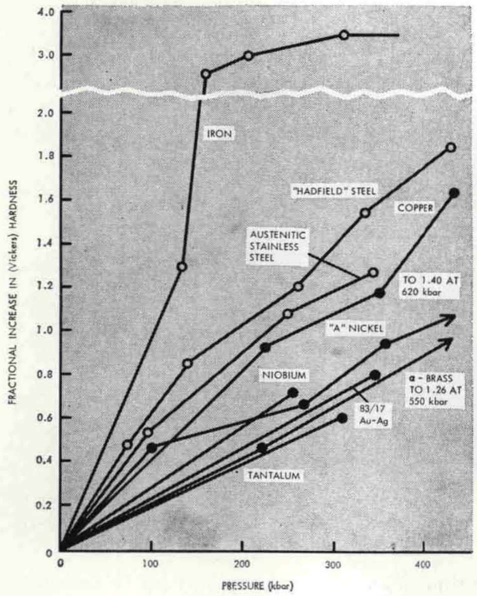

Fig. 11. Increase in hardness of shocked metals relative to their hardness in pre-shock, annealed condition is impressive. Curves cannot be extrapolated upwards indefinitely, however, because rapid rise in heat induced by shock would also have annealing effect. This would eventually surpass hardening effect, reversing slope of the curves.

transducer which produces a piezoelectric signal proportional to the difference in pressures at its two faces (Neilson *et al.*, 1962) and the manganin wire transducer which records pressure-induced changes in resistivity near the interface (Bernstein and Keough, 1964). Both these devices have their deficiencies, but both are useful under special circumstances. Contact pins of polar or ferroelectric materials, in which a thin wafer is compressed by the moving surface, thus generating a voltage, are also being used.

Work is in progress toward the development of a manganin gage which can be imbedded in the medium under study, but its successful development may be long in coming (Keough and Williams, 1967).

MORE APPLICATIONS AND SOME AFTERTHOUGHTS

At this point in our discussion, it will surprise nobody to hear that shock waves can alter the electrical and electronic properties of matter, often permanently. But studies of such effects have been less vigorously prosecuted than studies of mechanical effects.

Electrical effects which have been observed in shock include changes in electrical conductivity, polarization of insulators, depolarization of ferroelectrics, anomalous Peltier coefficients, and shifts of Curie temperatures (Doran and Linde, 1967). Most of the observed effects appear explicable on the basis of volume compression and deformation. The extent to which the rapid transient effects in the shock play a role is not yet known.

Shock-induced luminescence has been observed and usually appears to be due to compression of gases to high temperatures, to internal electric fields, or to triboluminescence. Here again the role of shock transients has not been delineated (Doran and Linde, 1967).

The most-used mechanical effect of shocks has been simple volume compression which provides basic data for high pressure equations of state (Kormer *et al.*, 1962). However, the stress produced in a plane shock wave is anisotropic. In consequence the shock is often preceded by an elastic precursor, whose amplitude is a measure of dynamic yield, and the shear stresses in either the precursor or the shock wave may produce material effects such as martensitic transformation, twinning, and dislocation multiplication. These effects are observed in microscopic exam-

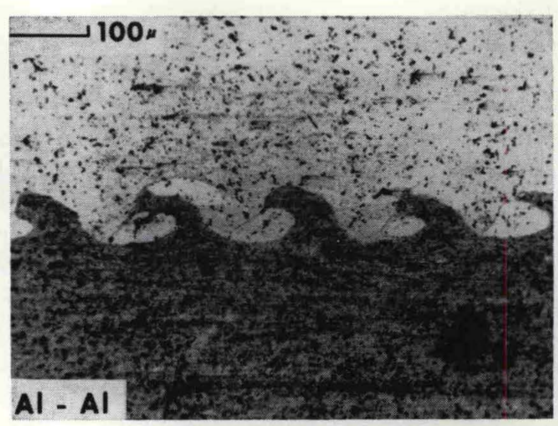

Fig. 12. Both size and shape of ripples at interface between explosively bonded aluminum alloys depend on velocity and impact angle in contact, aid diffusion of atoms across interface by straining surfaces at high rate, provide interlock.