the very large precursor amplitude observed for the [111] crystal is a result of the fact that the primary slip system is unstressed and yielding must occur on a secondary system. Gupta [77G7] has recently reported analogous results for another alkali halide crystal, lithium fluoride. This effect of orientation is taken as strong evidence of the relevance of dislocation glide to dynamic yielding.

Members of the Shock Dynamics group at Washington State University, including G.E. Duvall, G.R. Fowles, J.R. Asay, and Y. Gupta, have investigated dynamic yielding in lithium fluoride crystals [72A2, 72A3, 72A4, 73G5, 75G7, 75G8, 75A4, 75F1, 76D2, 77G7, 78R1]. These studies are much more extensive than any other similar investigations and are distinguished by unusually thorough material characterization and attention to other details, both theoretical and experimental. This work has confirmed the assumption that (for this material) the explanation of dynamic yielding is to be found in the motion of dislocations on established glide systems, and has resolved a number of other basic questions. Specifically, the results are consistent with the hypothesis that the instantaneous response to impact is elastic, that there is a stress threshold below which wave attenuation does not occur, and that precursor attenuation is attributable to both stress relaxation and hydrodynamic attenuation (primarily the former). The accumulation of plastic strain permitting stress relaxation is attributable to both grown-in dislocations and dislocations nucleated heterogeneously at point defects (interstitial Mg^{++} ions and radiation-induced Frenkel defects). The concentration of these defects and their state of aggregation have been shown to have a profound influence on precursor attenuation, with the attenuation rate being increased by increasing defect concentration or decreasing clustering of the existing defects. This and other evidence supports the conclusion that the large dislocation density necessary to produce the observed attenuation rate is a consequence of heterogeneous nucleation of dislocations at the point defects. The investigations have shown that regenerative multiplication processes cannot account for the observed decay. Neither variations in surface damage produced during sample preparation nor variations in the density of subgrain boundaries influences observations significantly.

Taylor [68T1], Pope and Stevens [73P1], and Pope and Johnson [75P1] have studied dynamic yielding in beryllium single crystals (hcp). This crystal is especially interesting because dislocations can move on distinct primary $\langle 11\bar{2}0\rangle$ $\{0001\}$ (basal), secondary $\langle 11\bar{2}0\rangle$ $\{10\bar{1}0\}$ (first-order prism), and tertiary $\langle 11\bar{2}3\rangle$ $\{11\bar{2}2\}$ (second-order pyramidal) glide systems for which the resolved shear stress for static yield are in the approximate ratios 1:7:100. These differences are sufficient to permit the conduct of shock-compression experiments in which each glide system is activated separately. In experiments in which the shock propagated in the *a* direction (producing secondary slip) or the *c* direction (producing tertiary slip) precursor waves rise to sharp peaks in a few nanoseconds and relax within ~ 20 ns to minimum values which then increase with the arrival of the plastic wave (see fig. 3.3d). A difference in yield strength of the secondary and tertiary glide systems is quite apparent from the observations, but the complexity of the waveforms makes quantitative comparison of static and dynamic yield strengths uncertain. Investigation of basal slip presents an additional complexity in that the crystal must be impacted at an angle to the *c* axis if a shear stress is to be imposed on the basal plane. Such an impact does not produce a precursor in which the motion is strictly longitudinal but calculation shows that transverse motion effects are negligible in the elastic wave and the critical resolved shear stress for basal yield can be measured as though the material were elastically isotropic. Experiments conducted on crystals about 4-mm thick and cut at angles ranging from 23° to 61° to the *c* axis indicated that dynamic yield occurred at critical resolved shear stresses ranging from 0.06 to 0.19 GPa. This variation was attributed to a dependence on the normal stress applied to the glide plane (consistent with observations of ⟨111⟩ LiF by Rosenberg [78R1]), but we believe experiments conducted at other propagation distances would be required to confirm this interpretation.

In the foregoing discussion, the precursor wave has been assumed to rise instantaneously. In many cases this approximation is satisfactory, but a number of polycrystalline metals exhibit precursor risetimes so great as to suggest distinctly anomalous response. In the case of beryllium the observations have been explained by Stevens and Pope [73S5] in terms of differences in yield point among the grains arising from residual thermal microstresses. In the case of tantalum, Gillis et al. [71G2] have offered an explanation based on a similar gradual development of plastic flow associated with dislocation multiplication in the wavefront. In contrast to these materials in which observed risetimes exceed 50 ns, the precursor risetime in aluminum is of the order of 10 ns, a value comparable to the uncertainty in its measurement. Nevertheless, Arvidsson et al. [75A2] noted a systematic increase in risetime with propagation distance, and have shown that the observation is consistent with the effect of adding a small viscosity term to the elastic constitutive equation. Meyers [77M3] has recently reviewed a range of published waveforms and has shown that the explanation of certain of the observations lies with the effect of various scattering phenomena that occur as the wave propagates through the polycrystalline material.

3.3.4. Plastic wave profile

Analysis of an entire elastic-plastic waveform can provide information about deformation mechanisms beyond that obtainable from examination of precursor decay alone. The difficulty of this analysis is that many variables are changing simultaneously. It is only in the case of a steady wave that quantitative information can be obtained by direct analysis of the observed waveform. Johnson and Barker [69J1] (see also [73P2]) applied this analysis to the profile of the main plastic compression wave in aluminum alloy 6061-T6 on the assumption that it had fallen far behind the precursor wavefront and was propagating with unchanging form. With this approach both the stress dependence of dislocation velocity $V_d(\tau)$ and the way in which the number of mobile dislocations increased with accumulation of plastic strain were determined. The function $V_d(\tau)$ was found to depend more strongly on τ than had been indicated by quasi-static investigations, but dislocation multiplication was in good agreement with such results. The steady-wave technique offers the advantage of simplicity, but is subject to error if applied to evolving waveforms and is not applicable to analysis of the most interesting part of many waveforms, that of rapid relaxation immediately behind the front of a precursor wave. Usually it is necessary to study evolving waveforms. In this case the experiment must be simulated numerically using a computer code incorporating the theory of section 3.3.2. Various models of dislocation velocity, nucleation and/or multiplication, immobilization, etc., can be considered. Calculations are performed with varying models and/or parameter values until, by trial and error, acceptable agreement between calculation and observation is achieved. Calculation of the entire profile of waves governed by the viscoplasticity theory outlined was first undertaken by Johnson and Band [67J1], Wilkins [68W3], and Gilman [68G2]. These calculations successfully reproduced qualitative features of the waveforms but the results were compromised by the artificial viscosity method used. The waveform dispersion introduced into calculations by this method can be avoided by use of the method of characteristics, or of hybrid methods. Such calculations have been made by Herrmann et al. [71H2], Clifton [71C5], and, most recently, by Asay et al. [75A4]. This latter work bore on the analysis of waveforms in high purity [100] crystals of lithium fluoride, and showed the power of a