crystallographic orientations, the effects of impurities and radiation-induced defects have been investigated.

Although the observed current pulses are generally of complex shape, an "effective polarization", $Q_0 = i(0+)t_0/A = (1 - u/U)P_0/\alpha$, can be computed from the measured initial current and eq. (4.6). This parameter has been found to exhibit consistent behavior among the various ionic crystals. At low stress all the pure ionic crystals show a positive current indicative of a polarization oriented in the shock propagation direction. Although there may be considerable scatter, the effective polarization is observed to increase smoothly with increasing compression until a compression of about 30 per cent is achieved. Above this compression the polarization decreases and, with the exception of MgO and LiF, the sign of the effective polarization of pure ionic crystals is reversed when compressions of about 40 per cent are exceeded. At the highest pressures no polarization signals are detectable.

The collected data on maximum effective polarization for the various ionic crystals are shown in fig. 4.4. In this figure the polarizations are found to be well correlated with cation radius, dielectric constant and an electronic factor, $\gamma = \Delta\varepsilon/E_g a$, where $\Delta\varepsilon$ is the difference between low and high frequency dielectric constants, E_g is the energy gap and a is the lattice parameter. This electronic factor is thought to be a measure of dielectric breakdown strength in ionic crystals. The polarization data of fig. 4.4 indicate that the polarization is independent of anion and roughly the same for a given cation. With the exception of the cesium halides, the effective polarizations correlate well with the cation radius and as the cation size decreases, the polarization increases. The cesium halide crystals are in the CsCl structure while the other crystals are in the NaCl structure. If the more open CsCl structure is accounted for by multiplying the cation radii of the CsI and CsBr by the ratio of the hard-sphere-filled volumes for the sc and fcc structures, their polarization data are brought into agreement with the NaCl-structure crystals.

Based on the various observations, Mineev and his coworkers have concluded that the overall features of shock-induced polarization in ionic crystals below compressions of 30 per cent can be semiquantitatively described by cation-vacancy dipoles resulting from the shock-induced generation of large numbers of point defects and subsequent displacement of the cation over a distance of 1 to 10 lattice parameters in times of about 5×10^{-8} s. Transient defect levels of 10^{23} m^{-3} at compressions of 10 per cent, increasing by an order of magnitude for each subsequent 10 per cent compression, are found to be compatible with the polarization observations and other independent estimates. Relaxation of polarization follows the thermal equilibration of the shock-induced defect structure. The correlation with the electronic factor, γ, suggests that the maximum polarization may be limited by local internal dielectric breakdown.

Although there are still major unresolved questions, including the effects of polymorphic phase transitions in these materials, properties affecting the current pulse wave shapes and the reversal of the sign of the polarization at large compressions, the shock-induced cation-vacancy dipole model appears to be well descriptive of the observed polarization of ionic crystals. Graham [79G5] has recently summarized the data on shock-induced polarization in polymers, and has proposed that the effect arises from mechanically-induced bond scission. In the case of semiconductors, shock-induced generation of point defects is likely to be a dominant mechanism, but no detailed physical model has been proposed.

The difficulty in developing physical models for electrical responses of shock-loaded solids is well indicated by the present problem which required persistent efforts over a period of over ten years before credible physical processes could be identified. The cation displacement model
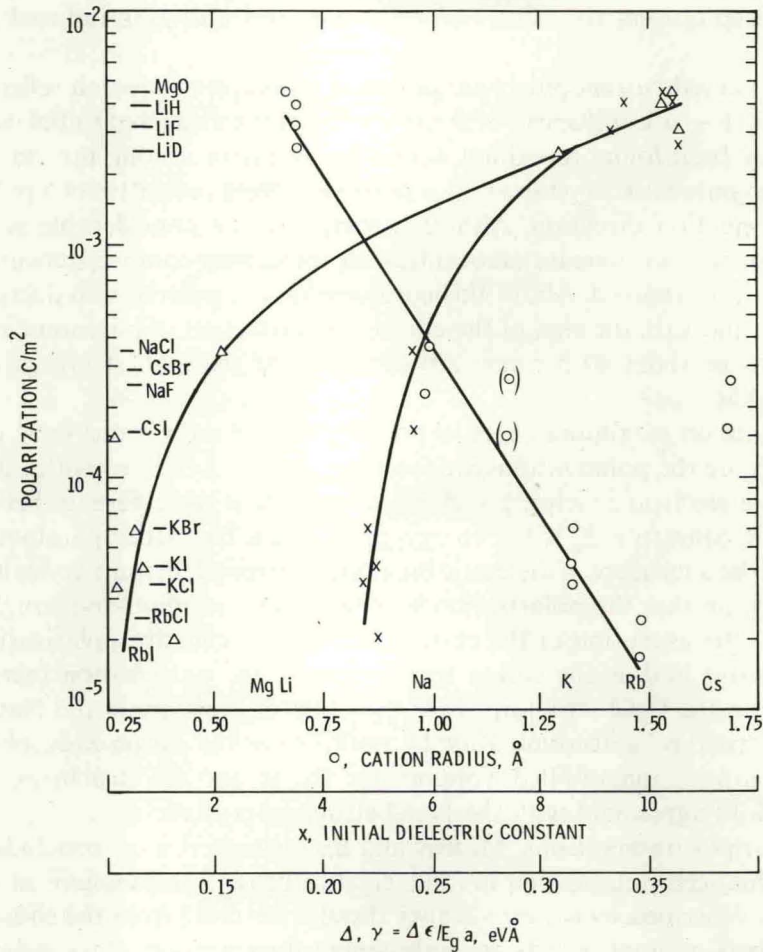
Fig. 4.4. The maximum effective shock-induced polarizations, Q_0, observed for ionic solids for the NaCl structure are observed to correlate well with cation radius, dielectric constant and an electronic factor, γ, which is thought to be a rough measure of dielectric strength. The maximum polarizations are found to be roughly the same for a given cation, independent of the anion. The polarizations observed for cesium halides, which are in the CsCl structure, do not correlate well with the cation radius. Nevertheless, if the cesium halide radii are multiplied by the ratio of hard sphere filled volumes for the sc and fcc structures, the data are as shown in parentheses and the observations are brought into agreement with the NaCl structure crystals. After Mineev and Ivanov [76M4] and Tyunyaev et al. [69T3].

emphasizes the importance of shock-induced defects and their non-equilibrium behavior. The observation of such processes as shock-induced polarization is overt evidence for nonequilibrium effects and should serve to alert us to the nonequilibrium nature of the shock process. It also suggests the use of electrical measurements to probe shock-induced defects.

4.6. Shock-induced conduction

The term "shock-induced conduction" denotes a class of phenomena in which the resistance of good insulators decreases markedly upon shock compression. Few comprehensive investigations