4.7. Dielectric relaxation

In the various electrical response models discussed in the foregoing section of this review, permittivities have been regarded as stress, strain or electric field dependent but not subject to relaxation. Dielectric relaxation or "AC conductivity" is a well-known phenomenon at atmospheric pressure (see, e.g., Daniel [67D1]). Lysne has recently developed models for dielectric relaxation in the thick sample configuration for piezoelectrics [78L3, 78L4, 78L7], ferroelectrics [79L1], and normal dielectrics [78L3, 78L4, 78L7], subjected to dynamic loads [78L7]. These models demonstrate that if dielectric relaxation times are greater than 10^{-9} s and less than 10^{-5} s and if relaxed and instantaneous permittivities differ by more than a few per cent, dielectric relaxation may play a significant role in determining observed electrical response, and may easily be confused with shock-induced conduction. Lysne's work suggests the need for a major reexamination of the interpretation of relaxation effects – polarization, dielectric and conduction – in shock-loaded dielectrics.

Prior considerations of dielectric relaxation are reported by Hauver [70H2] in a private communication from M.H. Rice and on samples in a thin-sample configuration by Yakushev [78Y1].

In Lysne's theories the dielectric polarization is modeled by a Debye relaxation function, which implies an exponential relaxation between the instantaneous permittivity, ε_∞, and the relaxed permittivity, ε, when the field is held constant. The dielectric relaxation time, τ, is a critical parameter characteristic of the material. Lysne's expressions for current pulses require numerical evaluation.

Even though a phenomenological theory of dielectric relaxation may be applied to shock-compression problems, it is not readily apparent what physical effects give rise to significant differences between instantaneous and relaxed permittivities and relaxation times of the order of 10^{-7} s. Most of the solids under consideration do not exhibit relaxation effects in the times appropriate for a shock experiment and on the basis of our atmospheric-pressure or static-high-pressure experience would not be expected to show such effects. Nevertheless, prior sections of this review have demonstrated that shock-compressed solids are subject to localized mechanical and thermal heterogeneities, to phase transitions in which multiple phases may coexist, to local electrical conduction, and to local defect complexes. All of these features of the shock-deformed state evolve on approximately the time scale necessary to explain the observed relaxations. Based on the work of Sillars [37S1], which gives dielectric relaxation parameters for localized dielectric and conductive regions in a dielectric host, Lysne has shown [78L6] that significant relaxation effects are possible. According to Sillars' theory, the effects are highly dependent on shape of the defect.

The possibility of dielectric relaxation phenomena in shock-loaded dielectrics greatly complicates interpretation of electrical responses. Because localized shock-induced defects are known not to be in thermodynamic equilibrium (e.g., see the effects shown in section 4.5), relaxations may be controlled by thermal relaxation of local defects. Questions concerning statistical methods to relate the localized behavior to the continuum level are significant. In composites, viscoelastic and viscoplastic materials, observations such as those on PMMA and alumina-loaded epoxy [78L4], may be the result of mechanical relaxations. Although it will not be easy to interpret real or apparent dielectric relaxations, it is apparent that such relaxations must be considered and since the relaxations are dependent on defects, measurements of dielectric relaxation may provide a new means of investigating these defects.

4.8. Shock demagnetization

Just as the terms *shock-induced polarization* and *shock-induced conduction* describe a number of different physical effects, "shock demagnetization" is a general term that describes changes in ferromagnetic or ferrimagnetic states of shock-loaded samples due to a variety of physical effects. Unlike many conduction and shock-induced polarization effects that are unique to shock loading, dominant effects in shock demagnetization appear to be well described by physical mechanisms encountered in more conventional environments, viz.: (1) second-order pressure-induced phase transitions, (2) first-order polymorphic phase transitions, and (3) stress-induced magnetic anisotropy.

Much of the literature on this subject was reviewed by Royce [71R3] and first- and second-order transitions involving magnetization changes were reviewed by Duvall and Graham [77D6]. This review adds previously unpublished data on several materials.

The first work in this area was carried out by Neilson and coworkers [57A1, 58K1], and was interpreted with the assumption that the pressure and temperature in the shock-compressed material was sufficient to induce a Curie-point transition. Such an interpretation has not provided an explanation for many subsequent observations, however, and persistent studies have been necessary to identify the physical mechanisms and to measure appropriate material properties.

The ideal magnetic sample configuration is not compatible with planar shock loading and this incompatibility severely restricts shock-loading studies. When metallic materials are to be studied, they must be laminated with insulating films to form a sample in which eddy currents are not significant. The composite nature of such a sample introduces uncertainties into the determination of its thermomechanical state under shock compression. As shown in fig. 4.7, four experimental

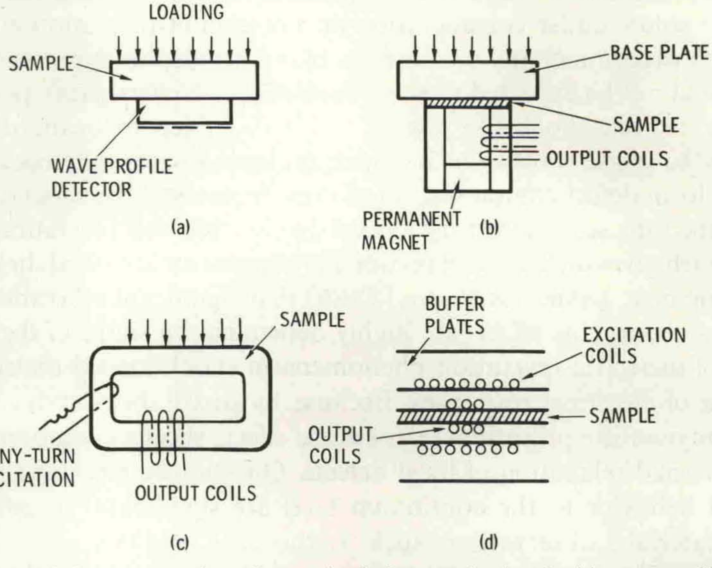

Fig. 4.7. A variety of different techniques are used to observe shock demagnetization. In (a), wave profile measurements are used to determine stress-volume relations in pressure-sensitive ferromagnetic solids [61C1, 66G1]. In (b), a uniaxial, thin-sample configuration is used for absolute demagnetization measurements. If the sample is conductive, the thickness is minimized and it is placed between Al_2O_3 plates to minimize eddy currents [71R3]. In (c), a thick-sample, two-dimensional configuration is obtained by using conventional tapewound magnetic "cores" to minimize eddy currents. This configuration does not give absolute measurements [58K1, 68G3]. In (d), the sample is enclosed by both excitation and pick-up coils. Since the coils are subjected to the loading, the technique is principally useful at low stresses [72G1].