PZT 75/25 + 1% Nb_2O_5										
Bauer [77B1]	___; 0.34	1.4 to 2.2	No	Yes, Q	—	—	—	Axial	—
PZT 85/15 + 1% Nb_2O_5									
Bauer [77B1]	___; 0.38	1.4 to 2.2	No	Yes, Q	—	—	—	Axial	—
PZT 95/5 + 1% Nb_2O_5									
Halpin [66H1]	7720; 0.34	0.4 to 3.3	No	Yes, I	No	Yes	No	Axial	Normally sintered
Halpin [66H1]	7990; 0.37	0.4 to 2.6	No	Yes, I	No	Yes	No	Axial	Hot pressed
Linde [67L1]	7760; 0.34	0.65 to 1.1	No	No	No	No	No	Axial	Polarization on shocked and recovered samples
Doran [68D3]	7740–7890; ___	0.2 to 14	Yes, $d(t)$	No	—	—	—	Axial	—
Halpin [68H1]	7720; 0.34	—	—	—	Yes	—	—	Axial	Resistivity, data from [66H1]
Halpin [68H1]	7990; 0.34	—	—	—	Yes	—	—	Axial	Resistivity, data from [66H1]
Lysne and Percival [75L5]	7550; 0.29	0.5 to 2.4	No	Yes, I	Yes	Yes	No	Normal	
Lysne and Percival [76L2]	___; ___	—	No	Yes, I	Yes	Yes	Yes	Norm. and Ax.	
Lysne [77L5]	___; 0.29	0.6 to 3.2	No	Yes, I	Yes	Yes		Normal	Depoled stress > 1.6 GPa
Dick and Vorthman [78D1]	7290–7370; 0.3	—	Yes, $V(t)$	Yes, I	No	No	No	Normal	Elect.-Mech. coupling
Mock and Holt [78M5]	7470; 0.3	1.4 to 2.9	No	Yes, I	Yes	No	No	Normal	—
Lysne [79L1]	___; ___	—	—	—	Yes	Yes	Yes	Normal	Interpretation of [77L5] Dielectric relaxation
PZT 95/5 + 0.8% WO_3									
Bauer et al. [76B3]	___; ___	—	No	Yes, Q	Yes	No	No	Axial	—
Bauer [77B1]	___; ___	—	No	Yes, Q	Yes	No	No	Axial	—
Bauer and Vollrath [76B2]	___; ___	1.5 to 2.0	No	Yes, Q	Yes	No	No	Axial	Charge versus resistance
PZT 96.5/3.5 + 1% Nb_2O_5									
Bauer et al. [76B3]	___; ___	0.2 to 1.1	No	Yes, Q	Yes	No	No	Axial	
Bauer [77B1]	___; 0.33	0.2 to 1.7	Yes	Yes, Q	Yes	No	No	Axial	Also study of recovered samples Phase transition at 0.2 GPa
Bauer and Vollrath [76B1]	___; 0.38	0.2 to 8.0	No	Yes, Q	Yes	No	No	Axial	Maximum charge at 1.7 GPa
PSZT 68/7 ($Pb_{0.99}Nb_{0.02}(Zr_{0.68}Ti_{0.07}Sn_{0.25})_{0.98}O_3$)									
Halpin [66H1]	___; ___		No	Yes, I	—	—	—	Axial	
Halpin [68H1]	___; ___		No	Yes, I	—	—	—	Axial	
PSZT 70/30-6 ($Pb_{0.99}Nb_{0.02}[(Zr_{0.70}Sn_{0.30})_{0.94}Ti_{0.06}]_{0.98}O_3$)									
Lysne [75L3]	___; 0.05	0.24 to 0.74	No	Yes, I	Yes	No	Yes	Axial	Reverberating wave; poss. trans., see also [76L2]
($(Pb_{0.715}Ba_{0.285})_{0.991}(Zr_{0.707}Ti_{0.293})_{0.981}Bi_{0.019}O_3$)									
Lysne [78L5]	7340; 0	0.24 to 0.88	No	Yes, I	No	Yes	Yes	Axial	Pen or "slim loop" ferroelectric

* See also the recent summary by Novitskii et al. [79N3].

a) Indication of mechanical (Mech.) measurements are whether displacement versus time is measured, indicated $d(t)$ or whether velocity or stress versus time is measured, indicated $V(t)$. Indication of electrical (Elect.) measurements are whether integrated charge or peak voltage, indicated Q, or current or voltage waveform, indicated I, is measured.

b) Orientation of remanent polarization is either along the shock direction, called axial mode, or perpendicular to shock direction, called normal mode.

numerous variables on a few selected materials. In order to make a convincing case, variable electrical configurations (e.g., open and short circuit, axial- and normal-mode), variable electrical states (i.e., various initial remanent polarizations), and variable stresses and sample dimensions need to be employed. Time-resolved measurements of both electrical and mechanical waveforms are required. Temperature is an important, but neglected, variable. Compositional studies and the relation of properties under shock loading to those under static high pressure and uniaxial stress need to be carefully examined (see, e.g., Fritz [78F1] and Fritz and Keck [78F2]). Short pulse, multiply-reverberating and acceleration pulse loading will help to elucidate history-dependent electrical and mechanical behavior.

4.4. *Normal dielectrics*

Nonlinear properties of normal dielectrics can be studied in the elastic regime by the method of shock compression in much the same way nonlinear piezoelectric properties have been studied. In the analysis of section 4.2 it was shown that the shape of the current pulse delivered to a short circuit by a shock-compressed piezoelectric disk was influenced by strain-induced changes in permittivity. When a normal dielectric disk is biased by an electric field and is subjected to shock compression, a current pulse is also delivered into an external circuit. In the short-circuit approximation, the amplitude of this current pulse provides a direct measure of the shock-induced change in permittivity of the dielectric.

A normal dielectric may be characterized by eq. $(4.1)_2$ with the piezoelectric terms deleted. For an isotropic dielectric subject to uniaxial strain and a colinear electric field this equation takes the form

$$D_1 = (\varepsilon^{\eta}_{11} + \tfrac{1}{2}\varepsilon^{\eta}_{111}E_1 + \tfrac{1}{2}f_{111}\eta_1)E_1, \qquad D_2 = D_3 = 0. \tag{4.9}$$

Neglecting the small effect of electrostrictive coupling on mechanical behavior, we see from eq. $(4.1)_1$ that shock propagation is not influenced by electrical effects. Under this approximation, a steady shock propagated into the material will divide its thickness into two regions of uniform strain that can be analyzed in the same manner as for the piezoelectric response. In the absence of free charge, eqs. (4.3) and (4.4) applied to an elastic disk of thickness L having an electrode of area A and subject to a potential V yield the relation [68G5] (see also Allison [65A1] and Royce [68M3])

$$\frac{i(t)L^2}{AVU\varepsilon^+} = \left[\frac{u}{U} + \frac{\Delta\varepsilon}{\varepsilon^+}\left(1 + \frac{u}{U}\right) + \left(\frac{\Delta\varepsilon}{\varepsilon^+}\right)^2\right]\left[1 - \frac{ut}{L} + \frac{\Delta\varepsilon}{\varepsilon^+}\left(1 - \frac{t}{t_0}\right)\right]^{-2} \tag{4.10}$$

for the time interval $0 < t < t_0 = L/U$ after impact. In this relation ε^+ is the permittivity of the uncompressed material, i.e., the coefficient of E_1 in eq. $(4.1)_2$ evaluated at $\eta_1 = 0$, $E_1 = V/L$, and $\Delta\varepsilon$ is the change in this coefficient that occurs with passage of the wave. The change in permittivity, which is proportional to the electrostrictive constant f_{111}, is the quantity sought in an experimental measurement.

As with the piezoelectric case, material constants are most easily determined from the initial jump in current, $i(0+)$, which, from eq. (4.10), is

$$\frac{i(0+)t_0}{A} = \left(1 - \frac{1}{\alpha}\left(1 - \frac{u}{U}\right)\right)D_0 \tag{4.11}$$