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Experimental Verification of Pressure Enhancement by Encapsulation*

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In this note we report experimental results which verify the pressure enhancement by encapsulation previously suggested[1] on theoretical grounds. The experiments consisted of comparing the occurrence of a pressure-induced change of state in encapsulated and unencapsulated samples. The sample material chosen for this study was a ferroelectric ceramic,[2] which undergoes a pressure-induced transition from the ferroelectric state to the antiferroelectric state at approximately 40 000 psi.

Two spherical samples were ground from a single billet of the ceramic and electroded to form capacitors. One of the samples was encapsulated in an epoxy[3] sphere and the samples mounted in a hydrostatic pressure chamber for simultaneous testing. The samples were then poled in the ferroelectric state by the application of 1000-V dc, which placed a bound charge of approximately 1 μC on each sample. The fluid pressure in the chamber was then raised at about 800 psi/sec and the charge released by the pressure-induced transitions of the samples recorded on a dual-pen autograph. The horizontal axis of the autograph was driven by a transducer monitoring the pressure in the chamber.

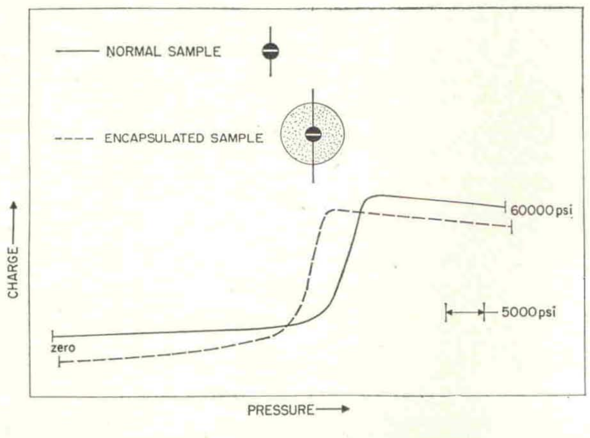

FIG. 1. Charge released from poled ferroelectric samples during the pressure-induced transition from the ferroelectric state to the antiferroelectric state. The encapsulated sample (dotted curve) depoled at a lower pressure due to the pressure-enhancing effect of the encapsulation.

Figure 1 is a reproduction of the data recorded by the autograph during a typical experiment and displays a pressure enhancement of approximately 15% due to the encapsulation. During the experiments, the zero points of the curves were arbitrarily displaced vertically for clarity and slightly displaced horizontally by the two-pen arrangement of the autograph. To verify that the effect observed was due to the encapsulation, several variations of this experiment were performed (including removing the epoxy from the encapsulated sample and encapsulating the other sample). In all cases, the encapsulated sample discharged at lower applied pressures than the unencapsulated sample.

Although a numerical comparison between theory and experiment is limited by the lack of accurate data concerning the elastic parameters of the materials, calculations with estimated values[4] predict the pressure enhancement should be between 10 and 20%. The Poisson's ratio of the encapsulating material is the controlling factor in the calculation of the expected enhancement [Ref. 1, Eq. (7)], and greater enhancement would have been encountered in these experiments if an encapsulating material with a low Poisson's ratio had been used. The fact that a pressure enhancement of approximately 15% was observed even with a high Poisson's ratio encapsulating material such as epoxy, emphasizes the potential importance of the effect to high-pressure experiments. Encapsulation effects are an inherent part of all experiments at very high pressures or low temperatures in which the pressure medium is a solid. Consideration of these effects should be included during the interpretation of the pressure-induced phenomena, as well as for an accurate pressure calibration in such experiments.

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[1] J. A. Corll and W. E. Warren, J. Appl. Phys. **36**, 3655 (1965).

[2] $Pb_{0.99}Nb_{0.02}[(Zr_{0.80}Sn_{0.20})_{0.94}Ti_{0.06}]_{0.98}O_3$.

[3] The epoxy used was a 100/20 mixture of Hysol 6020 resin and AX hardener, which cures at room temperature overnight.

[4] Using the notation of Ref. 1: $N=1$; $\xi=0.24$; $\eta\approx0.12$; and $0.40<\nu<0.46$. These values were estimated from rough measurements on the epoxy and assuming the compressibility of the ceramic to be 6.0×10^{-4}/kbar.