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DIELECTRIC MEASUREMENTS ON PILE IRRADIATED BaTiO₃ SINGLE CRYSTALS

Abstract. — When irradiated with rapid neutrons, the tetragonal structure of Baryum Titanate becomes cubic and ferroelectricity disappears [1], [2]. We performed systematic measurements in order to check the ferroelectric properties: dielectric constant and spontaneous polarization, along with structural properties by using the anomalous X ray scattering for samples irradiated with doses between $1 \times 10^{18}$ n/cm² and $10^{20}$ n/cm².

For normal samples, X ray scattering patterns [3] show some local order in the paraelectric phase, that is chain correlations along linear rows. The para-ferroelectric transition can be interpreted as an order-disorder one in which the elementary dipole is the whole chain of correlated lattice cells. Such a model provides an explanation of the high value of the Curie Weiss constant. In fact, the Curie Weiss constant as computed from Landau’s theory is:

$$C = \frac{1}{2} \frac{P_s^2}{N k \log 2}$$

$k$ being the Boltzman constant, $P_s$ the saturated spontaneous polarization in the ferroelectric phase, $N$ the number of chains per unit volume. As the chains become longer, $N$ decreases and $C$ increases. The above equation is well verified for correlation of 10 or 12 cells in one chain which is in good agreement with the width of the X ray scattering.

There are three types of measured dielectric properties depending on the ranges of irradiation (see Fig.).

For low doses ($\leq 2 \times 10^{18}$ n/cm²) a neat peak is observed. In the paraelectric phase, the dielectric constant follows a Curie Weiss law. The transition temperature (with thermal hysteresis) shifts down somewhat, conversely the Curie temperature shifts up, so that the maximum value of the dielectric constant increases. The spontaneous polarization and Curie Constant increase slightly but the correlation length seems to remain unchanged.

For intermediate doses (between 2 and $8 \times 10^{18}$ n per cm²), the dielectric maximum is smoothed and widely broadened so that the value of the dielectric constant remains high in a large temperature range and no longer follows a Curie Weiss law. In addition the spontaneous polarization cannot be determined from the observed distorted hysteresis loop. On the other hand, the correlation length definitely decreases.

For large doses ($\geq 10^{19}$ n/cm²) the dielectric constant value becomes low ($\sim 100$) and does not change with temperature. All ferroelectric characters and chain correlation have disappeared.

Those results show that ferroelectricity is strongly related to local order, i.e. to chain correlations in the crystal structure. Nevertheless a more accurate quantitative study seems difficult and in any case would be restricted to low doses of irradiation.

References


Dielectric constant versus temperature of BaTiO₃ single crystals irradiated with rapid neutrons.