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The Influence of Hydrostatic Pressure on the Field-Induced Dielectric Constant Maxima of $SrTiO_3$

By

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The field induced maxima in the temperature dependence of the dielectric constants of $SrTiO_3$ are shifted down to the temperature range around $T = 20$ K by hydrostatic pressure. The connection between the temperature T_m of the maximum, the inducing field strength E, and the pressure p is nonlinear and corresponds to a relation deduced previously.

Die feldinduzierten Maxima in der Temperaturabhängigkeit der Dielektrizitätskonstanten von $SrTiO_3$ werden durch hydrostatischen Druck zu niedrigen Temperaturen im Bereich um $T = 20$ K verschoben. Die Verknüpfung zwischen der Temperatur T_m des Maximums, der induzierenden Feldstärke E und dem Druck p ist nichtlinear und entspricht einer früher abgeleiteten Beziehung.

1. Introduction

The dielectric constant of $SrTiO_3$ increases with decreasing temperature. Below the structural phase transition from cubic to tetragonal symmetry at $T_a \approx 105$ K the dielectric constant is always smaller than given by the Curie-Weiss law, which is valid above T_a [1], and at very low temperatures it reaches constant values of the order 10^4 [1 to 4], as recently investigated down to $T = 0{,}025$ K [5].

Below the structural phase transition at $T_a \approx 105$ K the dielectric properties are anisotropic. Usually regions with different orientations of the tetragonal axes with respect to the applied field are formed within the crystal lattice, the so-called paraelectric domains.

In dielectric measurements the contributions of the individual regions are averaged, thus blurring almost completely the structural phase transition at T_a and the resulting anisotropy in a polydomain crystal. In general the domain distribution and the corresponding dielectric constant values are hardly reproducible, as stated also by other authors [4, 6].

On the basis of lattice dynamical investigations [7], Pietrass and Hegenbarth [8] demonstrated by means of earlier measurements of several authors [4, 9] that the dielectric behaviour of $SrTiO_3$ within the temperature range 20 to 70 K may be favourably described using a quadratic temperature dependence in the thermodynamic potential. This is confirmed also by recent measurements [10] which are reported in this paper.

Without a dc field the $\varepsilon(T)$ dependence of $SrTiO_3$ shows no maximum. Applying an electric field, however, the dielectric constant at low temperatures decreases and with sufficiently strong fields maxima in the $\varepsilon(T)$ dependence

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occur [2, 4, 10 to 12]. Previous preliminary investigations [9] yielded that the maxima are influenced by pressure. In the present paper the $\varepsilon(T)$ dependence is investigated under the simultaneous influences of an electric field E and hydrostatic pressure p.

2. Experimental

For the pressure generation and as pressure transmitting medium helium gas was used. Thus strict hydrostatic conditions existed in all our measurements. The gas was thermically compressed to 1.5 kbar. Construction and manipulation of the device as well as the used measuring instruments have been already described in an earlier paper [9].

The temperature was determined inside the pressure vessel by means of a platinum-resistance thermometer. The influence of pressure on the resistance was corrected [10].

The investigations were carried out on a $SrTiO_3$ single crystal with the dimensions of 44.7 mm$^2 \times 0.39$ mm.

3. Results

The temperature dependence of the dielectric constant without pressure is represented in Fig. 1 for different field strengths. Already at field strengths $E \geqq 1.6$ kV/cm maxima can be induced at temperatures $T > 15$ K, having smaller absolute values with increasing field strength and lying at higher temperatures, as shown already by several authors [2, 5, 10 to 12].

The curve with $E = 0$ shows no dielectric constant maximum. By applying pressure the dielectric constant values decrease. The curves are flatter and do not show a maximum, as already seen in other papers [9, 13].

The influence of pressure on the field-induced maxima of Fig. 1 is represented for some curves in Fig. 2. Contrary to the field influence the maxima are shifted

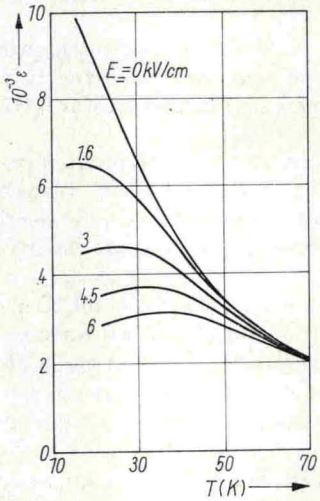

Fig. 1. The influence of an electric field on the $\varepsilon(T)$ dependence of a $SrTiO_3$ single crystal ($p = 0$)

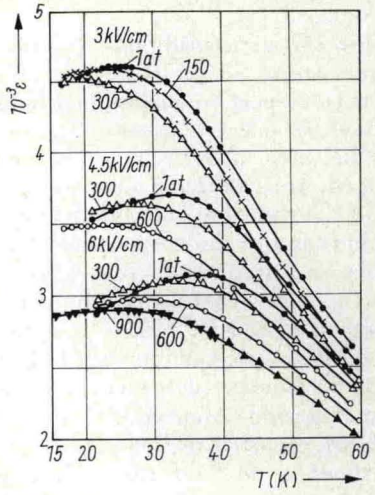

Fig. 2. The influence of the hydrostatic pressure on the $\varepsilon(T)$ dependence of $SrTiO_3$ with a simultaneously applied electric field (1 at = 0.981 bar)