DEPENDENCE OF THE DIELECTRIC CONSTANT ON ELECTRIC FIELD IN SrTi(\(^{16}\)O\(_{1-x}\)\(^{18}\)O\(_x\)) AT OXYGEN SUBSTITUTION

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The theory of the dielectric properties of the oxygen-isotope-exchanged incipient quantum paraelectrics (SrTiO\(_3\), KTaO\(_3\) and CaTiO\(_3\)) is developed. The critical status of SrTiO\(_3\) as a virtual quantum ferroelectric is maintained by the dynamical electron-lattice hybridization (covalency) of 2p oxygen and 3d titanium states. This interaction leads to the ferroelectricity in BaTiO\(_3\), KNbO\(_3\), etc. Taking into account the electron-lattice p-d interaction and the coupling of TO and TA vibration, the expression of the soft mode frequency \(\Omega\) for the quantum paraelectric is obtained. The frequency \(\Omega\) is mass dependent including the dependence on mass of the oxygen atom. In SrTi(\(^{16}\)O\(_{1-x}\)\(^{18}\)O\(_x\)) the critical \(x = x_c\) value exists, at which zero-point motion of atoms (quantum fluctuations) is partially suppressed and the ferroelectric phase transition occurs at \(x > x_c\). The dependence of the ferroelectric transition temperature \(T_c\) on \(x\) is calculated. The mass-dependent modified Curie-Weiss laws for the \(T\)-dependence of the dielectric constant are derived. The theory is compared with the experiment, as it follows from our theory in KTaO\(_3\) and CaTiO\(_3\) the oxygen isotope substitution (\(^{18}\)O \(\rightarrow\) \(^{16}\)O) does not induce the ferroelectricity. In this case only \(\Omega\) depends on \(x\), but not in the critical manner. The dielectric constant (at \(x > x_c\)) can be written as

\[
\epsilon = \frac{C_0}{T^2 - T_c^2} \left[ 1 + 3 \beta \epsilon_0^3 E^2 \frac{C_0^3}{(T^2 - T_c^2)^3} \right], \quad T > T_c,
\]

where \(E\) is the strength of the electric field and \(C_0\); \(\beta\) the constants. The theory is compared with the experiment.