INFLUENCE OF THE INTERNAL ELECTRIC FIELD IN $BaTiO_3$ ON THE LIFETIME OF ^{89}Zr

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In the internal electric field of $BaTiO_3$ a change in the lifetime of ^{89}Zr was investigated. The measured relative change of the decay constant is $\Delta\lambda/\lambda = (4.4 \pm 0.4) \times 10^{-4}$.

From an aqueous solution of 2 mCi carrier-free $^{89}ZrOCl_2$ (77% EC, $T_{\frac{1}{2}}$ = 78.4 h) [1] $ZiO(OH)_2$ was adsorbed by high purity $BaTiO_3$, from which two equivalent samples, A and B, were sintered.

Below the Curie temperature, $T_C = 120^oC$, the $BaTiO_3$ lattice is tetragonal and spontaneously polarized, which causes an electric field strength [2] of about 10^8 V/cm, at the place of the Ti (or substituted ^{89}Zr) ion. Above T_C the lattice is cubic and the spontaneous polarization vanishes.

This fact permits one to switch off the internal electric field by heating the sample above T_C. The idea of the experiment is to compare the lifetime of ^{89}Zr in these two lattice states of $BaTiO_3$. The activities N_A and N_B, respectively, of these samples were determined with two 7.5 × × 7.5 cm^2 NaI(Tl) scintillation counters. After a measuring period of Δt = 400 s the samples were mechanically interchanged and the activities automatically registered. This was done during a time of more then five half-lives.

For the evaluation of the relative change in the decay constant, the following ratio $F(t)$ of activities were calculated:

$$F(t) = \frac{N_A(t-\Delta t) + N_A(t+\Delta t)}{2N_B(t)} \sim \exp(-t\Delta\lambda) \approx 1 - t\Delta\lambda .$$

The function $F(t)$ is essentially insensitive to the electronic drift of the apparatus. If the difference in lifetimes is small, $F(t)$ will change linearly with time.

The experimental result shows a decrease of the decay constant λ of ^{89}Zr in the electric field of the $BaTiO_3$. This can be interpreted by the assumption that the electron density at the ^{89}Zr nucleus has been decreased by the electric field.

The increase of the ratio $F(t)$ on the left part of fig. 1 corresponds to the following change of the decay constant

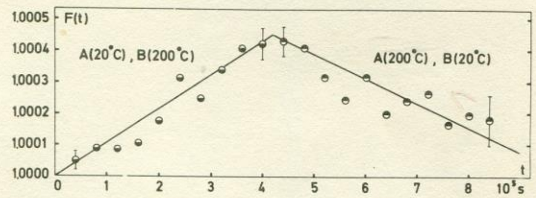

Fig. 1. Ratio of activities of the samples at different temperatures as a function of time. The half-life of ^{89}Zr is equal to 2.82×10^5 s. The figure shows the function $F(t)$. In the first time interval $(0 - 4.2 \times 10^5$ s) probe B, and in the second time interval $[(4.2 - 8.5) \times \times 10^5$ s] probe A is held at a temperature $T > T_C$.

$$\frac{\lambda_B(^{89}Zr, 200^oC) - \lambda_A(^{89}Zr, 20^oC)}{\lambda(^{89}Zr)} = (4.4 \pm 0.4) \times 10^{-4} .$$

On the right hand part of fig. 1, i.e. sample A at 200^oC and B at 20^oC, the decrease of $F(t)$ corresponds to a smaller change of λ:

$$\frac{\lambda_B(^{89}Zr, 20^oC) - \lambda_A(^{89}Zr, 200^oC)}{\lambda(^{89}Zr)} = -(3.2 \pm 0.6) \times 10^{-4} .$$

The difference of these results can be explained by the different amount of ^{89}Zr atoms substituted at the lattice-site of the Ti atoms in the ferroelectric samples. This has been confirmed by the measurement of $F(t)$, when both samples were at 20^oC, i.e. spontaneously polarized (fig. 2). The increase of $F(t)$ corresponds to

$$\frac{\lambda_B(^{89}Zr, 20^oC) - \lambda_A(^{89}Zr, 20^oC)}{\lambda(^{89}Zr)} = (1.3 \pm 0.6) \times 10^{-4} ,$$

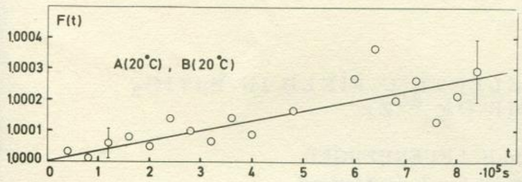

Fig. 2. Ratio of activities as a function of time. Both samples in the ferroelectric state.

which is exactly the difference of the measured results in fig. 1.

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