it could be a proton with energy about 30 Mev. The direction of the zenith (assuming this star to be formed while the aircraft was in level flight) is marked in Fig. 1, and so there is a downward momentum component for the visible fragments. The kinetic energy of the initiating radiation, if a nucleon, must have been more than 200 Mev.

Another point of interest in this event is the long range of the ejected meson. The chance of such a track lying wholly in the emulsion, so that identification is possible, is small. In view of this, and although very few events of this type have been reported yet,[4] we might speculate that an appreciable number of the cosmic stars observed give mesons which leave the emulsion before they can be identified, or are somewhat too energetic to leave a visible record (>about 7 Mev).[8]

We are indebted to the British Overseas Airways Corporation for carrying our plates, to Misses Joan Young, Shirley Young, and Beverly Mear for searching, and to Dr. W. J. Henderson for his interest in the above work.

[1] The plates were exposed on consecutive flights totaling about 400 hours over periods of about six weeks before development. The ceiling was about 25,000 feet.
[2] A. Morrison and E. Pickup, Phys. Rev. **74**, 706 (1948).
[3] Two of these seven events occured in an additional 160 stars of two or more prongs in C2, bismuth loaded emulsions, and one in some C2, unloaded emulsion.
[4] G. P. S. Occhialini and C. F. Powell, Nature **162**, 168 (1948) for σ-mesons from stars; C. F. Franzinetti and R. M. Payne, Nature **161**, 735 (1948) for Li^8 fragments; C. M. G. Lattes *et al.*, Nature **160**, 486 (1947), Table V for π- and σ-mesons.
[5] E. O. Salant, J. Hornbostel, and E. M. Dollman, Phys. Rev. **74**, 694 (1948).
[6] See U. Camerini *et al.*, Nature **162**, 433 (1948).
[7] Using the range energy relation given by Lattes, Occhialini, and Powell, Proc. Phys. Soc. **61**, 173 (1948), p. 181.
[8] We were able to trace back the longest σ-meson we have found, 1100μ with certainty. This corresponds to an energy of 6.8 Mev (for mass 300 m).

The Dielectric Behavior of $BaTiO_3$ Single-Domain Crystals

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THE measurements of the dielectric constants of $BaTiO_3$ have up to now been made on sintered materials[1] and on multi-domain crystals.[2,3] Once having succeeded in growing single-domain crystals it was of great interest to establish the anisotropy of the dielectric constant by making measurements parallel (ϵ_c) and perpendicular (ϵ_a) to the polar axis. Such a measurement was made by Mason and Matthias[4] and gave the unexpected result that ϵ_a was about 500 times greater than ϵ_c not only in the Curie region but also above the Curie point in the cubic region, where the polar axis disappears.

We have, therefore, repeated these measurements on very thin single-domain crystals of area of the order of a few mm^2. The great majority of crystals have the polar axis perpendicular to the large faces (*c*-crystals), so that the measurements of ϵ_a could be made only on small

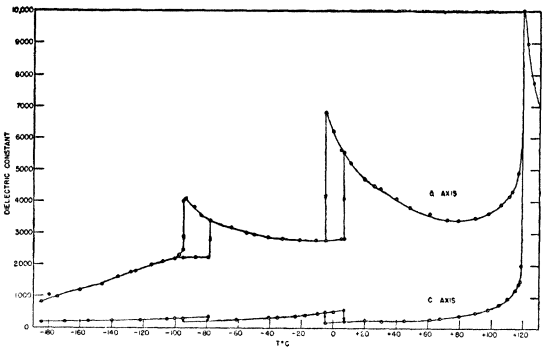

FIG. 1. Dielectric constant of $BaTiO_3$ single-domain crystals.

crystals. As a check, measurements of ϵ_a were also made on *c*-crystals and the results agreed satisfactorily.

It is seen (Fig. 1) that ϵ_a is greater than ϵ_c but in a more reasonable ratio of about 20:1 at room temperature, and that in particular $\epsilon_a = \epsilon_c$ at the Curie point as required by the transition to the cubic modification. The different behavior of ϵ_a and ϵ_c between the Curie point and the transition point at about 0°C can be explained, as confirmed by optical observations, by the fact that the Ti ion in the oxygen-octahedra has an increasing tendency to displace itself from the eccentric position [001] toward [011], until at the transition point the [011] position becomes suddenly the most stable one. An analogous behavior of the dielectric constant is observed between the transition points at about 0°C and −85°C. Here the stable position of the Ti ion in the oxygen octahedra seems to become the direction of the body diagonal [111]. It is significant that domain formation occurs at both transition points.

Above −5°C, that is, in the tetragonal temperature region, where there are no domains, the results for all the measured crystals are very reproducible. (In Fig. 1 are plotted the values of ϵ_a for the crystal which gave the highest values.) It is not clear whether one should expect theoretically $\epsilon_a \neq \epsilon_c$ below −95°C. However, below the transition point at about 0°C the single-domain crystals break up into several domains. This domain structure varies from sample to sample as shown by optical evidence, and the slight variation of the measured results. The appearance of a large thermal hysteresis would seem to substantiate this argument.

In contrast to the result of Mason and Matthias,[4] we have found at room temperature no drop in ϵ_a up to 40 Mc/sec. Furthermore, our hysteresis loops are quite symmetric and saturation is obtained with fields of only about 1000 volts/cm. This indicates that our crystals are more free of internal stresses (at least above −5°C) and contain less impurities than the crystals of Mason and Matthias (mostly Pt impurities).

[1] v. Hippel, Breckenridge, Chesley, and Tisza, Ind. Eng. Chem. **38**, 1097 (1946).
[2] Blattner, Matthias, Merz, and Scherrer, Experientia **3**, 148 (1947).
[3] Bernd T. Matthias, Nature **161**, 325 (1948).
[4] W. P. Mason and B. T. Matthias, Phys. Rev. **74**, 1622 (1948).