to magnetic domain boundaries the width of which has been computed to have a value of between 30 to 100 atomic diameters.[7]

[1] T. S. Kê, Phys. Rev. **71**, 533 (1947).
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[3] T. S. Kê, J. App. Phys. (in the press).
[4] T. S. Kê, communicated to Trans. A.I.M.E.
[5] C. E. Birchenall and R. F. Mehl, Mining and Metallurgy (November 1947).
[6] F. Seitz and T. A. Read, J. App. Phys. **12**, 538 (1941).
[7] F. Bloch, Zeits. f. Physik **74**, 293 (1932); also R. Becker and W. Dorng, *Ferromagnetismus* (Verlag Julius Springer, Berlin, 1939), p. 189.

Erratum: Interaction of Neutrons with Electrons

[Phys. Rev. **72**, 1254 (1947)]

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IN a recent letter to the editor[1] we erroneously estimated the expected scattering cross section of neutrons on electrons due to the polarization of the meson cloud in the field of an electron. While this effect no doubt exists theoretically it is much less important than the effect due to the spreading of the meson charge over a finite region in the nucleus as shown in the recent paper by Fermi and Marshall.[2] The conclusion at the end of the letter must therefore be withdrawn.

[1] J. M. Jauch and K. Watson, Phys. Rev. **72**, 1254 (1947).
[2] E. Fermi and L. Marshall, Phys. Rev. **72**, 1139 (1947).

Structure, Electrical, and Optical Properties of Barium Titanate*

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SEVERAL letters to the editor have appeared recently in this journal[1,2] and in Nature[3,4] dealing with observations on $BaTiO_3$. Since some of the statements made are somewhat misleading, and others present results anticipated by publications from this Laboratory,[5] a short account concerning the properties of barium titanate as they appear today on the basis of our recent investigations may be in order.

N. J. Field, A. P. DeBretteville, and H. D. Williams reported[1] two kinds of barium titanate crystals with different infra-red absorption, distinguishable by their bluish and yellowish colors. This coloration is due to dissolved platinum, and we can add to the color scale crystals from light green to deep red by varying the method of growing the material in Pt crucibles. The pure crystals without oxygen defect are colorless and may, for instance, be grown with the proper precautions in carbon crucibles.

A microscopic investigation reveals that, regardless of color, the crystals are subdivided into ferroelectric domains. The faces of these domains parallel to the polar axis are, in general, covered with a system of stripes oriented at 45° to the cube edges and apparently represent slip bands. In the direction of the polar axis the crystals appear clear and sometimes intersected by stripes parallel to the cube edges. In polarized light the structure of the domains is enhanced by various stress colors, and black boundary lines mark the regions in which the opposing stresses of several domains balance.

By the application of an electric field, the domain boundaries may be seen to shift some domains growing at the expense of others, and, finally, the polar axes change orientation in sudden jumps by 90° or 180°. Increase of the temperature to the Curie point makes first the 45° stripes and then the domains themselves disappear; they reappear on cooling in various arrangements, depending on the thermal history. By cooling in an electric field from above the Curie point, the whole crystal may be forced more or less into a single domain, but such a state breaks down later into several domains forming arrangements of lower energy. The domain structure can also be influenced by pressure; in short, all the domain phenomena derived by indirect evidence in the case of ferromagnetics can be made visible in these ferroelectric crystals.

$BaTiO_3$ crystals are generally biaxial because of the stresses set up by their domains, but we have succeeded in producing single crystals of such large domain areas that they appear nearly tetragonal in polarized light. According to our present evidence, the c axis represents the polar axis, and can be turned in electric fields; x-ray back-reflection photographs of these large domains are being made to decide the question.

At low field strength, the dielectric constant parallel to the polar axis is relatively small ($\cong 600$ at 25°C) and, perpendicular to it, is high ($\cong 2000$ at 25°C); they are nearly alike in the two latter directions. The crystals are piezoelectric, and their resonance vibrations disappear as the dielectric constant begins to increase towards its maximum. The vibrations of titania ceramics, discovered by Roberts in this Laboratory, should, therefore, not be treated as an electrostrictive phenomenon as done by Mason,[2] because a normal electrostrictive effect increases with dielectric constant.[6] The mechanical deformation of $BaTiO_3$ single crystals appears as the superposition of a linear and a quadratic piezo effect.

In addition to the cubic modification of $BaTiO_3$, there exists, among others, an hexagonal form[7] which is not ferroelectric.

A more extensive paper on titania single crystals and their interaction in ceramics is in preparation. Photographs of the domain effects will be shown at the annual meeting of the American Physical Society in New York.

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