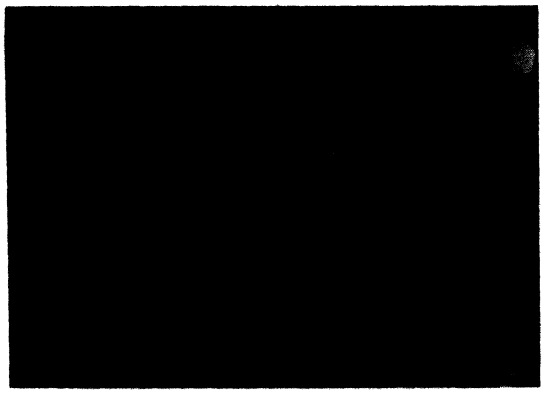

FIG. 2. Same conditions as in Fig. 1 with a temperature of about 90°C.

Figures 1 and 2 show the hysteresis loops which are so oriented that the charge or polarization axis is vertical, while the voltage or field-strength axis is horizontal.

Actual jumps in the polarization are shown as if a domain which contributes a charge ΔQ were aligned only after a finite voltage increases ΔV. In Fig. 2 apparently the whole crystal is acting as a single domain which snapped into alignment for practically the maximum field strength of 2570 volts/cm. Jumps of the order of magnitude as shown in Fig. 1 occur in about 10 percent of the frames, while a jump of the type shown in Fig. 2 was observed only once in about a thousand frames. Examination of the motion picture oscilloscope records and visual examination of the oscilloscope screen shows that the jumps in slope on the hysteresis loop occur in random phase.

Phenomenologically the Barkhausen effect in the case of ferromagnetic materials is analogous to the above effect for ferro-electrics. The domains for the ferro-electric case are much larger, however.

[1] C. B. Sawyer and C. H. Tower, Phys. Rev. **35**, 269–273 (1930). A. de Bretteville, J. Am. Ceramic Society **29** (11), 303 (1946); Phys. Rev. **69**, 687 (1946).

A Possible New Type of Spin-Spin Interaction

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February 11, 1948

IN view of the hyperfine structure difficulties brought to light by the experiments of Nafe, Nelson, Rabi[1] and others, I would like to advance a theory that might possibly have a bearing on these questions. Instead of introducing a new interaction between the electron and the electromagnetic field as Breit[2] has tried, we bring in an interaction between the electron and a new type of field. While the sources of the Maxwell field are the charges and the current densities, the sources of the new field are the spin densities. Thus the interaction between elementary particles, instead of being described by the usual charges and magnetic moments: coulomb, magnetic moment—orbit and magnetic moment—magnetic moment interaction (we avoid the term spin to keep it for the new field) contains now another term of pure spin-spin interaction. For non-relativistic velocities, spin density and density of magnetic moment are parallel, and thus the effect of the new field is to change the usual spin-spin interaction by an arbitrary factor that experiment alone can determine.

The non-relativistic equations for the new field (it has vectorial components Q and R) are

$$\begin{aligned} \text{curl}Q &= q\,\text{curl}S, & \text{div}Q &= 0, \\ \text{div}R &= -p\,\text{div}S, & \text{curl}R &= 0, \end{aligned}$$

where S is the spin density and q an arbitrary coupling factor. They can be compared with Maxwell's equations for B and E;

$$\begin{aligned} \text{curl}B &= J + \text{curl}M, & \text{div}B &= 0, \\ \text{div}E &= \rho - \text{div}P, & \text{curl}E &= 0, \end{aligned}$$

and the symmetry is at once obvious except for non-existence of a convection charge current in the spin field.

I had arrived previously at this conception from the point of view of general relativity when applied to Dirac particles. Generalized relativity has, so far, only utilized space curvature, omitting a possible torsion of space. The reason for that is that a classical particle has its four momentum parallel to its four velocity, or in other words, its transported momentum is in the direction of transport. A Dirac particle, on the other hand, behaves differently because the momentum vector is different in direction from the velocity vector (and the consequence of this is that one talks about spin). Torsion of space as a field acts differently from curvature of space (gravitation) only if the direction of transport is different from the transported vector. The Q and R field introduced above is the field of this torsion of space.

[1] Nafe, Nelson, and Rabi, Phys. Rev. **71**, 914 (1947).
[2] G. Breit, Phys. Rev. **72**, 984 (1947).

The Growth of Barium Titanate Crystals

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February 19, 1948

DURING the past year, the interest in the ferroelectric barium titanate has increased and this laboratory has received a number of inquiries concerning the growth of single crystals.

Bourgeois[1] describes a process by which he obtained microscopic crystals similar to perovskite with a stoichiometrical composition supposedly $2BaO \cdot 3TiO_2$. He used an excess of $BaCl_2$ as flux and equimolar parts of $BaCO_3$ and TiO_2 to form the compound. On repeating this process no well defined crystals resulted.

By adding an appreciable excess of $BaCO_3$, Blattner, Matthias, and Merz[2] were able to obtain well formed crystals which corresponded (except for their optical behavior) to what had to be anticipated from the polycrystalline $BaTiO_3$.