microscope, and their dielectric properties were studied.

For growing $BaTiO_3$ single crystal, $BaCl_2$ is usually employed as flux. But in our laboratory, $Na_2CO_3$ was used with the relative proportion of one mole $Na_2CO_3$ to 0.20~0.26 mole $BaCO_3$ and $TiO_2$. The crucible in which the growth take place, should preferably be of pure platinum. But for the sake of its cost, we were obliged to use nickel crucible. To avoid its oxidation at high temperature above 1000°C, it was heated in the reducing atmosphere, being covered with graphite.

Good results were obtained by cooling the molten substance from 1100°C down to approximately 850°C within more than ten hours. Dissolving $Na_2CO_3$ in water, crystals with linear dimension from 0.1 to 2.0 mm are rapidly separated. Crystals grow in the form of cube or flat plate, and yellowish or brownish colored.

Under microscope, crystal is devided into regions shaded by fine parallel lines, oriented at an angle of 45° or parallel to the cube edges. Observing the crystal between crossed Nicols, it shows parallel extinction.

To investigate the dielectric properties, silver electrode were fired on both parallel planes of cubic crystal. The dielectric constant at room temperature varied widely between individual crystals from about 800 to 2000. The temperature, at which the dielectric constant has maximum value and the shape of temperature characteristic curve also varied between individual crystals. This may be due to the impurity unexpectedly included into crystal. There was found generally a large hysteresis in the temperature curve between temperature ascending and decending, which will be perhaps due to internal strain.

The dielectric constant is much influenced from applied field and D. C. biasing field. But these characteristics also shows the existence of individuality according to crystals, and no uniform results were obtained.

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## 4. Study on High Dielectric Constant Ceramics. (IX)

Application of Piezoelectricity of $BaTiO_3$ Ceramics for Phonograph Pickup

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The electrostrictive and piezoelectric properties of $BaTiO_3$ ceramics have been experimentally studied by the writers in previous report (IV). $BaTiO_3$ cermic has permanent piezoelectricity below the Curie point, and its sensitivity shows neglegible change between-70°C and 70°C, independent of humidity effects. The possibility of firing the silver electrode on its surface, in combination with upper excellent properties, makes it an ideal material for use in phonograph pickups.

Practically $BaTiO_3$ ceramic is cut in narrow strips, the sides of which are covered with silver frit. Two such pieces are fastened by soldering to the opposite side of a thin metal armature, which increases the mechanical strength of the strip, and also this symmetrical construction contribute to the flatness of frevuency response. The thickness of the strip must be determined from a compromise between a thin strip, which is preferable for the purpose of high capacitance, high compliance and small mass, and a thick strip, which is desirable for the purpose of the easy handling, freedom from the dielectric breakdown during the polarizing treatment. From the above point of view, we found that 0.25–0.3 mm was the best values.

Polarization takes about one hour in the field of 15000 V/cm, the exact time of which depends on the applied field.

The treated units are then assembled in a plastic cartridge. A sapphire needle with a tip of 0.06 mm radious is jointed to the armature arm. Rubber pads on either side of the assembly support it and at the same time act as lateral damper.

The characteristics of pickups produced on trial are as follows.

(1) output : 0.3–0.5 volt at 1k. c, on a standard test record.
(2) frequency characteristics : ± 10db (60 c/s–10000 c/s)
high resonant frequency : about 5000 c/s.
(3) internal capacitance : about 1000 pF at 20°C.
(4) tracking weight : 20 gram.
(5) needle point lateral compliance : $0.5 \times 10^{-6}$cm/dyne.

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## 5. Study of Semi-conductors. (IV)

Electrical Resistivity of Spinel Type Semi-conductor

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Recently, semi-conductors having spinel type structure are attracted much attention from electrical engineers for the reasons of their thermally sensitive resistivity, physically and chemically stable properties. Practically interesting spinel type semi-conductors are mainly consist of Fe, Ni, Co, Mn and some other metal oxide, the methods of preparation and properties of these materials are somewhat systematically studied.

In the prerarations of specimens, much attention were taken to avoid impurities, which probably give a remarkable influence on the conductivity. To get uniform specimens, all matarials were mixed at the state of nitrate. Oxide powders, obtained after heating, are pressed to a disc form (about 2 mm thick and 10 mm diameter) and fired in a furnace. Each specimen has a optimum firing temperature to become a perfectly sinterd ceramic, which usually lies between 1100°C and 1500°C.