Size of $BaTiO_3$ elements were $8 \times 8 \times 0.5$ (mm) for No. 1, No. 2 and $3 \times 5 \times 0.3$ (mm) for No. 3. In every case, they were operated very successfully. As in the case of tuning fork, fundamental vibration was excited when two elements are in the same phase, and if proper phase difference is given harmonic vibration was excited. Q value of vibrator was abowt 2000 — 5000, and in (B) type Q was greater than (A) type. Internal loss was about 20 db in every case.

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6. Study on High Dielectric Constant Ceramics. (XXI)

$BaTiO_3$ Ceramics as a Material of Dielectric Amplifier

Kiyoshi ABE and Tetsuro TANAKA

(Abe Laboratory)

It was known that dielectric amplification using ferroelectric property is possible according to the same principle as the magnetic amplifier using ferromagnetic property, and such amplifier has attracted much attention since $BaTiO_3$ ceramics were found out. However, few reports and data on dielectric amplifier, the production of materials or the application of amplifier, were published. Recently, the characteristics especially concerning amplification in dielectric properties of $BaTiO_3$ ceramics, were inspected and the experimental results were put in order mathematically in our laboratory.

As the permittivity is affected by d-c bias most sensitively near Curie temperature, it is desirable for the material of amplifier to have the Curie point at room temperature. Such materials are easily made by mixing titanate of Sr, Zr or Sn in $BaTiO_3$ because the Curie point decreases in proportion to the quantity of Sr, Zr or Sn. The materials having such characteristics that the permittivity is not largely influenced by the temperature, have been made already. The characteristics of permittivity to d-c bias were measured about the materials having sharp temperature characteristics (A-kind material) and flat temperature characteristics (B-kind material), and results were compared with theoretical ones.

Characteristics of permittivity to d-c bias:

The characteristics of permittivity to d-c bias will be mathematicaly represented by assuming the suitable equation to the saturation characteristics of ferroelectric materials. Many equations representing saturation characteristics have been presented, from which two equations suitable for $BaTiO_3$ ceramics were selected.

$$E = aD + bD^3 \qquad (1)$$

$$E = \alpha \sinh(\beta D) \qquad (2)$$

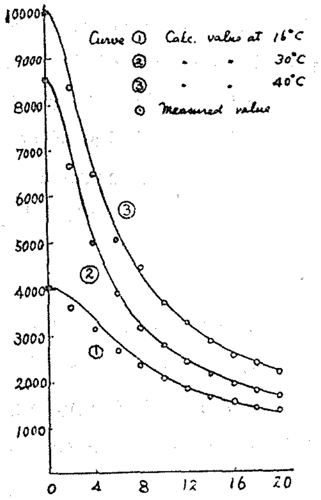
where a, b, α, β are material const. Which only depend on temperature. If we put ε_0 as initial permittivity (permittivity at weak electric field) and ε as reversible permittivity, ε is given by the inclination (dD/dE) of D-E curve and fundamental equations are deduced from equation (1) and (2).

$$E = \left(\frac{\varepsilon_0}{\varepsilon} - 1\right)^{\frac{1}{2}}\left(\frac{\varepsilon_0}{\varepsilon} + 2\right)\left(\frac{1}{3\varepsilon_0}\right)^{\frac{3}{2}}\left(\frac{1}{b}\right)^{\frac{1}{2}} \tag{3}$$

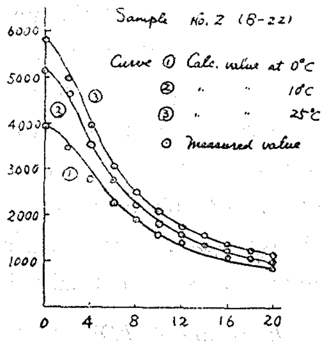
$$\frac{\varepsilon}{\varepsilon_0} = (1 + \beta^2\varepsilon_0{}^2E^2)^{-\frac{1}{2}} \tag{4}$$

$d\varepsilon/dE$, $(d\varepsilon/dE)_{max}$…………etc. are calculated from equation (3) and (4), the results of which are summerized in the Table.

	Eqs. from 1st assumtion	Eqs. from 2nd assumption
Eqs. of assumption	$E = aD + bD^3$	$E = \alpha\sinh(\beta D)$
Fundamental eqs.	$E = \left(\frac{\varepsilon_0}{\varepsilon} - 1\right)^{\frac{1}{2}}\left(\frac{\varepsilon_0}{\varepsilon} + 2\right)\left(\frac{1}{3\varepsilon_0}\right)^{\frac{3}{2}}\left(\frac{1}{b}\right)^{\frac{1}{2}}$	$\frac{\varepsilon}{\varepsilon_0} = (1 + \beta^2\varepsilon_0{}^2E^2)^{-\frac{1}{2}}$
$\frac{d\varepsilon}{dE}$	$-2\sqrt{3}\,b^{\frac{1}{2}}\varepsilon_0{}^{\frac{5}{2}}\left(\frac{\varepsilon}{\varepsilon_0}\right)^3\left(\frac{\varepsilon_0}{\varepsilon} - 1\right)^{\frac{1}{2}}$	$-\beta^2\varepsilon_0{}^3E(1 + \beta^2\varepsilon_0{}^2E^2)^{-\frac{3}{2}}$
$\left(\frac{d\varepsilon}{dE}\right)_{\max}$	$-0.897b^{\frac{1}{2}}\varepsilon_0{}^{\frac{5}{2}} = -0.69\frac{\varepsilon_0}{E_{\frac{1}{2}}}$	$-0.385\beta\varepsilon_0{}^2 = -0.667\frac{\varepsilon_0}{E_{\frac{1}{2}}}$
$\left(\frac{\varepsilon}{\varepsilon_0}\right)_{\frac{d\varepsilon}{dE}=\max}$	0.833	0.816
$(E)_{\frac{d\varepsilon}{dE}=\max}$	$0.2755\left(\frac{1}{b}\right)^{\frac{1}{2}}\left(\frac{1}{\varepsilon_0}\right)^{\frac{3}{2}} = 0.358E_{\frac{1}{2}}$	$\frac{1}{\sqrt{2}\beta\varepsilon_0} = 0.408E_{\frac{1}{2}}$
$E_{\frac{1}{2}}$	$4\left(\frac{1}{b}\right)^{\frac{1}{2}}\left(\frac{1}{3\varepsilon_0}\right)^{\frac{3}{2}}$	$\frac{\sqrt{3}}{\beta\varepsilon_0}$



DC Biasing Voltage kv/cm
Fig. 1.



DC Biasing Voltage kv/cm
Fig. 2.

The comparisons between the observed values and values calculated by equation (3) about sample No. 1 (A-kind material, Curie point at 38° C) are shown in Fig. 1, where the calculated values are represented by curves and the measured values by dots. For sample No. 2 (B-kind material, Curie point at 22° C), the comparison are shown by Fig. 2. In both figurs, the measured values coincide fairly well with the calculated ones. It can not be decided which of these equations is more approximate to the real state, because the difference of characteristics between equation (3) and (4) are very small.

Characteristics of Dielectric Amplifier:

In fundamental circuit shown in Fig. 3, if internal resistance in E_0 and E_m are

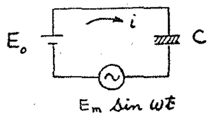


Fig. 3

neglected and $E_0 \gg E_m$ is assumed, the current flowing through C is

$$i = \omega C E_m \sin \omega t \qquad (5)$$

where $C = \kappa\varepsilon$. The value corresponding to g_m in vacuum tube (the change of current to small change of bias) is

$$g_0 = \omega\kappa E_m \left(\frac{d\varepsilon}{dE_0}\right) E_0 \,. \qquad (6)$$

As ω becomes large, g_0 becomes very large and it is understood that the degree of power amplification of 10^6 order can be easily attained.

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7. Construction of an X-Ray Counter Spectrometer for the Studies of Polymers

Yasuhiko NUKUSHINA

(Sakurada Laboratory)

Details of the construction and experimental techniques in the application of an X-ray counter spectrometer for the studies of amorphous and crystalline polymers have been given. As preliminary experiments cellulose fibers such as rayon and ramie, polyisobutylene and polyvinyl alcohol have been used.