



TEMPERATURE DEPENDENCE DIELECTRIC, FERROELECTRIC, SPONTANEOUS POLARIZATION CHARACTERISTICS AND TRANSITION TEMPERATURE OF BaTiO_3 FERROELECTRICS

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ABSTRACT

The dielectric and ferroelectric behaviour of BaTiO_3 is compressed in pellet form has been studied using capacity measuring unit. Its dielectric constant temperature dependence above the Curie point ($T > T_C$) in ferroelectric crystal and it must be obey curie Weiss law its Curie temperature is 125°C . BaTiO_3 is third group of ferroelectric viz. the so called oxygen octahedron group. Its chemical formula is ABO_3 where A is di or monovalent metal and B is tetra or pentavalent metal. In cooling cycle its derivative constant approximately follow same changes as in heating cycle. In 1st order transition $T_0 < T_C$ while for 2nd order transition. $T_0 = T_C$ T_0 is the Curie temperature and T_c is actual Barium titanate has upper transition temperature of 125°C above this temperature sample becomes non-ferroelectric and has cubic structure.

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INTRODUCTION

Dielectric behaviour of some material is in many aspects analogous to the magnetic behaviour of ferromagnetic materials. So these materials are called ferroelectric. A ferroelectric spontaneously polarized i.e. it is polarized in the absence of an external field; the direction of the spontaneous polarization may be altered under influence of an applied electric field. In general the direction of spontaneous polarization is not the same throughout macroscopic crystal rather than the crystal consist of a number of domains within each domain the polarization has a specified direction but this direction varies from one domain to another domain. It has become customary to call ferroelectric the phenomenon exhibited by these crystal and ferroelectric the crystal themselves. The reasons for this denomination are historical and due a formal similarity of the ferroelectric Phenomenon with that of ferromagnetism.

The similarity is mainly Phenomenological. Just as ferromagnetic materials exhibit a spontaneous magnetization and hysteresis effects in the relationship between dielectric displacement and electric field. This behaviour is mostly observed in certain temperature regions deli united by transition points above the crystals are no longer ferroelectric and show normal dielectric behaviour. Reviews of these properties and the problems involved in the field of ferro electricity are already avlable in the articles of Kanzing Forbergh, kumar et al., Prashad et al. and in the books of Megaw, Jona and shirane, Scaife, These author follow

different approaches in order accomplish the task both kanzing and forsbergh treat the problem of ferroelectricity in the properties which characterize the phenomenon Megaw on the other hand, presents her description of ferro electricity in terms of compounds, rather than properties and is particularly concerned with the crystallographic aspect of the problem. Our own approach in the present treatment of the same problem is to describe the properties of the various ferroelectric crystals individually and to emphasize the dielectric character of the ferroelectric phenomenon as judged from the view point of the solid state physics. Wainer and Saloman in 1942 observed a number of anomalus dielectric properties of BaTiO_3 . It was recognized in this country as ferroelectric material Van Hippel and coworkers, and indpently, by investigations in England, Holland and Switzerland. It is third group of ferroelectric, viz. so called oxygen octahedron group.

Experimental Details

The chemical were purchased from Fluka AG Switzerland. The compound sample was prepared by grinding mechanically into fine powder and it has been procured from Fluka Switzerland, about 99.9% puris form sample is avoiding from direct sun light and preferably the most of the sample preparation work has done at night. The powder was heated up to 1073 K for 16hrs then cooled to room temperature and grinded mechanically again for an hr to achieve fine powder the pellets were prepared with the compression machine testing machine CAT No. AIM-313 S. No 91070AIMIL. Associated, India has pressure range 0-10 ton wt/cm^3 . A suitable die was used having rectangular

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cross-section of the piston about 2.33 cm². The pellets so obtained were covered with the remaining powder and heated again at 1073 K for 16 hrs. The pellets were polished to obtain smooth parallel surface and colloidal silver paint was used to form the electrodes the sample was annealed at 2/3 of its melting point in a furnace for about 8-10 hrs. The capacitance of the sample was measured by the capacity measuring unit Zenith M-92A. The dielectric constant and bulk ac conductivity of the sample were calculated by using following expressions –

$$\text{Dielectric constant (real)} \quad \varepsilon = 1 + \frac{\Delta C}{C_0}$$

$$\text{Where } \Delta C = C'' - C'$$

C'' and C' are the capacitance of sample holder with specimen and the capacitance of sample holder without specimen. C₀ is the geometrical capacitance.

$$C_0 = \frac{0.68854A}{d} \quad (\text{in p.f})$$

Where A is the area of pellet, d is the thickness of pellet in cm. The sample holder is directly fastened to the capacity measuring unit Zenith M92A). of pyro electric coefficient is p_e, change in temperature is then spontaneous polarization is calculated as

$$P_s = p_e \Delta T$$

RESULT AND DISCUSSION

The compound has chemical formula BaTiO₃. In heating cycle dielectric constant becomes maximum about 125°C. Its dielectric constant and spontaneous polarization (P_s) is the function of temperature. Thus BaTiO₃ has three ferroelectric phases. As the spontaneous polarization sets in at 125°C. The crystal expands in the direction of polarization and become perpendicular about 125°C. Its 1st phase transition temperature is about 198K, i.e. 75°C, have structure rhombohedral, and dielectric polarization is 2nd transition temperature is 290K(17°C) and have structure orthorhombic and direction of polarization is 011 but its last and third transition temperature is about 125°C i.e. 398 K. Here dielectric constant is maximum and becomes non ferroelectric in this temperature structure is tetragonal and direction of polarization is 001. The cooling cycle also shows high value of dielectric constant at 125°C. Such cycle also shows hysteresis and obey Curie Weiss law cooling cycle shows several peaks in dielectric constant plot which suggest the anomaly originated from the structural phase transition. It shows lowest Curie point about (-75°C) and higher Curie point for compound is about 125°C. The sample dielectric constant is not a constant but it depends on the field strength at which it is measured and it shows non-linear relationship between P_s and E. Its spontaneous polarization is the function of temperature. It is called pyroelectric effect because all pyroelectric crystals are spontaneously polarized when temperature of the sample becomes altered, the polarization changes and this change can be discussed pyroelectricity. Above the transition temperature, dielectric constant obeys Curie Weiss law.

$$\varepsilon = \frac{C'}{T - \theta} + C_0$$

Where C' is a constant

θ is a characteristics temperature.

C₀ is a constant contributed by electronic polarization

Below the Curie temperature, the dielectric constant nature of ferroelectricity, spontaneous polarization and crystal structure vary in the following way-

Transition temperature (°C)	Dielectric constant	Nature	Direction of polarization	Structure
75°C	3790	ferroelectric	111	Rhombohedral
17°C	6480	Ferroelectric	011	Orthorhombic
125°C	9753	Ferroelectric	001	Tetragonal
125°C	9890	Non-ferroelectric	001	Simple cubic structure

The spontaneous polarization was measured along the 001 direction, so that actually the values obtained from 30°C to 125°C when temperature of the sample is increases then spontaneous polarization is decreases. The polarization becomes zero when temperature of sample becomes greater than Curie point i.e. 125°C.

Table 1. Heating cycle Variation of Dielectric constant with temperature

Temperature (°C)	DIELECTRIC CONSTANT		
	ε at 1KHz	ε at 10KHz	ε at 100KHz
-80	2112	2117	2217
-76	2328	2337	2339
-75	3790	3793	3799
-74	3530	3547	3548
-70	3510	3518	3522
-65	3025	3027	3029
-60	2832	2835	2838
-50	2833	2833	2836
-45	2710	2713	2716
-35	2625	2628	2631
-30	2620	2623	2626
-25	2610	2613	2616
-15	2600	2603	2606
-10	2590	2593	2596
0	2580	2583	2586
5	2500	2503	2506
10	2490	2493	2496
12	2430	2433	2438
14	2420	2427	2439
15	2400	2407	2017
17	6480	6488	6493
18	5200	5208	5210
20	5177	5179	5181
22	5170	5172	5176
28	5170	5174	5176
35	5160	5163	5166
40	5132	5135	5138
42	5127	5129	5132
50	5116	5119	5123
55	5111	5118	5124
60	5000	5007	5014
62	4800	4806	4810
66	4701	4711	4719
69	4701	4708	4709
73	4422	4428	4430
75	4402	4408	4414
78	4401	4406	4413
80	4107	4109	4111
82	4101	4103	4105
83	4093	4096	4098
89	4072	4075	4080
90	4066	4070	4075
95	4023	4025	4032
100	4011	4015	4018
105	4002	4000	4010
110	3910	3913	3916
112	3905	3907	3909
118	3812	3814	3817
119	3702	3712	3715
120	3512	3515	3518
121	3522	3527	3530
122	3407	3417	3427
123	3403	3413	3425
125	9890	9894	9893

Table 2. Variation of Dielectric constant with temperature at 1 KHz, 10KHz and 100KHz

Cooling cycle			
Temperature (°C)	DIELECTRI CONSTANT		
	ε at 1KHz	ε at 10KHz	ε at 100KHz
125	8793	8794	8799
123	2210	2212	2213
122	2190	2193	2197
121	2100	2103	2107
120	1800	1805	1808
119	1703	1706	1713
118	1700	1705	1704
112	1690	1693	1696
110	1689	1691	1696
105	1689	1691	1696
100	1670	1673	1676
95	1665	1668	1670
90	1662	1665	1668
89	1600	1607	1609
85	1597	1599	1602
82	1594	1599	1603
80	1590	1592	1598
78	1585	1587	1589
75	1577	1581	1583
73	1560	1565	1568
69	1553	1556	1558
66	1540	1546	1548
62	1537	1540	1543
60	1534	1537	1539
55	1530	1533	1538
50	1527	1530	1536
42	1524	1528	1529
40	1522	1523	1524
35	1518	1520	1521
28	1500	1507	1508
22	1490	1491	1493
20	1483	1487	1489
17	4021	4023	4028
16	1440	1446	1449
15	1438	1441	1444
14	1417	1420	1423
12	1411	1413	1415
10	1408	1409	1410
5	1400	1406	1407
0	1398	1402	1403
-10	1393	1396	1399
-15	1390	1393	1397
-25	1387	1390	1393
-30	1382	1384	1389
-35	1380	1387	1389
-40	1366	1368	1372
-45	1358	1360	1364
-50	1354	1358	1361
-55	1350	1355	1357
-60	1290	1295	1297
-65	1287	1289	1293
-70	1285	1287	1290
-75	2011	2012	2018
-76	1260	1265	1277
-78	1258	1260	1263
-80	1211	1213	1217

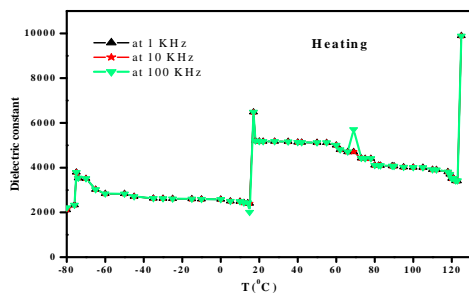


Fig.1: Dielectric constant Vs Temperature at 1 KHz, 10 KHz and 100 KHz

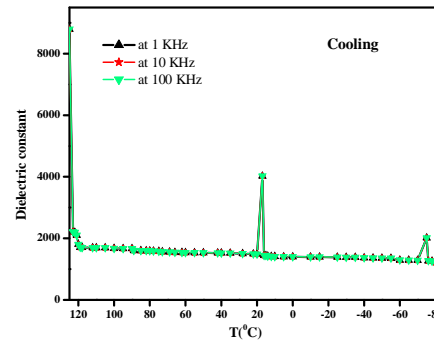


Fig. 2: Dielectric constant Vs Temperature at 1 KHz, 10 KHz and 100 KHz

Table 3. Variation of spontaneous Polarization vs. Temperature at 1 KHz, 10 KHz and 100KHz frequency

Temp. (°C)	Ps at 1KHz	Ps at 10KHz	Ps at 100KHz
30	24.9	24.0	23.50
35	24.9	24.0	24.50
40	24.8	23.9	23.40
45	24.78	23.83	23.37
46	24.73	23.81	23.30
47	24.7	24.80	24.25
48	24.0	23.13	23.0
50	23.9	23.10	22.98
55	23.9	23.10	22.96
59	23.9	23.10	22.96
SS60	23.8	23.08	22.30
65	23.8	23.08	22.29
70	23.7	23.0	22.28
75	23.3	23.9	22.21
78	23.0	22.8	22.11
85	22.9	22.0	21.87
88	22.8	22.0	21.87
90	22.8	22.0	21.00
95	22.4	21.8	20.7
100	22.3	21.5	20.53
105	22.0	21.43	21.50
110	20.0	19.90	19.70
115	16.5	15.95	15.86
118	16.4	15.83	15.80
120	16.3	15.52	15.75
122	16.0	15.73	15.70
124	16.0	15.70	15.40
125	0	0	0

Conclusion

In this study BaTiO₃, shows ferroelectric behaviour and three transition temperature about -75⁰, 17⁰C, and 125⁰C. Above temperature 125⁰C sample become non ferroelectric. Its spontaneous polarization is also depends upon temperature. When temperature is increases then spontaneous polarization decreases and at above 125⁰C, it becomes zero. The crystal structure is also change; first crystal is cooled from its paraelectric phase to the ferroelectric tetragonal, orthorhombic and rhombohedrum phases. Due to crystal structure changes, near the transition point thermodynamics properties, dielectric, elastic optical and thermal constant shows similar behaviour. Dielectric constant in heating and cooling both cycles is temperature dependence and above the Curie point it is governed by Curie Weiss Law. The spontaneous polarization has negative pyro electric coefficient because it is decreases with rising to temperature.

REFERENCE

1. A.F Devonshire, Phil. Mag. 40.1040 (1949).
2. A.F Devoshire; Theory of Ferro electrics Phil. Mes. Vol.3 April (1954) pp.85.

3. A.J Dekker; Solid state Phys. United Kingdom (1958) pp.190 and 191.
4. B.C Frazar, M Mckeown and R. Pepinsky, Phys. Rev 94, 1435 (1954).
5. B.T Mattias, Science, 113, 591 (1951); National Research Council, Wiley, New York, 1951.
6. C.J.F Bottcher; Theory of electric Polarization, Elsevier, New York, 1952 pp63.
7. D.F. Rushman and M.A Strivens, Trans. Faraday Soc. 42A, 231 (1946).
8. E.T Jayenes, Ferroelectricity, Princeton Univ. Press Princeton, 1953 chaps. 1,3.
9. G. Shirane, F.Jona and R. Pepinsky "Some Aspects of Ferro electricity" Proc. IRE, Dec. (1995) pp.1738.
10. G.Busch and P. Scherrer, Naturwiss, 23 737 (1935); G. Busch, Helv. Phys. Acta,11 269(1938).
11. G.H. Jonker and J.H Van Santen, Science,109,632 (1949).
12. Gupta R.N and Mishra, M (1981); Ind. J. Pure and App. Phys. Vol. 17 pp. 1151-53.
13. H.T Evans; ActaCryst. 4, 377 (1951).
14. J Valasek, Phys. Rev. 17, 475 (1921); 19,478 (1922); 20,644(1922); 24,560
15. J.H Van Saten and W. Oechow Ski. Physical 14,545 (1948).
16. Kumar. A; Prasad A, Choudhary, S.N and Choudhary, R.N.P (2004); Mat. Lett.
17. L. Onsager, J.Am. Chem. Soc. 58, 1486 (1936).
18. Scaif. B. K.P (1989); Principle of Dielectric (Clareden Press).
19. W.G Cady, Peizoelectricity, McGraw Hill, New York 1946.
20. W.P Mason, Phys. Rev. 73 854(1947).
21. W.P Mason; Peizo electric crystals and their applications Van Nostran New York (1950).
