

A Study on the Insulation Property of Electro Porcelain

S. GUNASEKARAN† and P. ABITHA*

Department of Physics, Anna Adarsh College for Women, Chennai-600 034, India

The FTIR spectral measurements and the dielectric studies have been carried out for three grades of electro porcelain and for their raw materials. A comparative study of the porcelain samples is carried out with the vibration band assignments and also with dielectric constants in X and K-band frequency ranges. Variation in the absorption of IR radiation and dielectric constant is observed and it may be due to the variation of the percentage of fire clay, which is one of the raw materials used in the preparation of electrical porcelain.

Key Words: FTIR, Electro porcelain, Dielectric constant, Fire clay.

INTRODUCTION

There is increasing interest nowadays in the use of ceramic materials in our everyday life. This interest is a result of the advantageous properties of these ceramics, especially their high refractoriness, binding speed, great resistance to chemicals, high insulation and strength development. Most ceramics are compounds of oxide elements in combination with other chemical elements. Ceramics are made into useful materials or products through high temperature processing. Ceramics include not only materials such as pottery, porcelain, refractory structural clay products, abrasives, porcelain enamel cements but also non-metallic magnetic materials, ferroelectrics and glass ceramics. The dielectric behaviour of Ni-Co ferrite ceramics reported recently¹ with its changes with temperature and frequency and the effect of calcination studied using IR spectra² with some ceramic materials lead to a similar investigation on an important ceramic application, electro porcelain. In addition to work on the development of bricks and concrete blocks³⁻⁵, glass ceramics, ceramic wares etc., a great deal of research has been done to develop high value products, electro porcelain, to use as insulators like fuse carrier. This electro porcelain is used in power transmission lines as a special support to avoid leakage of current. The raw materials, which are used in the preparation of this electro porcelain and also their final products are taken up in the present work to investigate their IR spectroscopic and dielectric properties.

†PG and Research Department of Physics, Pachaiyappa's College, Chennai-600 030, India.

EXPERIMENTAL

The starting materials used in the preparation of electro porcelain, silica sand, feldspar, ball clay, china clay, talc and fire clay, were obtained from a leading ceramic industry. These materials, which are involved in body preparation, are hard and soft in nature. Hard materials like feldspar are first crushed into small pieces in a jaw crusher and then to fine powder in pan oller mill and then sieved. This powder is mixed with soft clay to form a homogeneous mixture before charging it into the ball mill with water for grinding for about 10 h. Finally, the slip is passed through the magnetic separator to remove the iron particles, pressed into cakes and then dried in sunlight. Then the dried body is powdered and mixed with 6% of water, 2% of oleic acid and kerosene mixture so as to get good binding between the particles. The mass is allowed to rest for a few hours to get uniform soaking before being taken for pressing to the press as fuse carrier. A transparent glaze is applied on it and fired to temperature 1250°C in a shuttle kiln. Three grades of electro porcelain E2T1, E2T2 and E2T3 are prepared by the same method with the difference in the percentage of raw materials used especially with fire clay. Table-1 gives the percentage of raw materials used in the three grades of porcelain. The FTIR spectra of E2T1, E2T2 and E2T3 bodies have been recorded in the region 4000–450 cm^{-1} using Bruker IFS 66 V spectrophotometer at SAIF, IIT, Chennai.

TABLE-1
PERCENTAGE OF RAW MATERIALS AND THEIR DIELECTRIC
CONSTANT IN PORCELAIN BODIES

Raw materials	E2T1	E2T2	E3T3	ϵ_r at K-band
Silica sand (%)	27	27	27	2.77
Feldspar (%)	23	23	23	2.30
Bhimodole ball clay (%)	13	—	—	3.47
Bluefill china clay (%)	14	16	16	3.16
Bhagespura china clay (%)	13	15	16	3.38
Talc (%)	5	5	5	2.78
Fire clay (%)	5	14	13	1.86

To confirm and compare the insulation property of these samples, microwave measurements have been carried out on K-band and X-band microwave test benches. The operating frequency range and the dimension of the rectangular waveguide differs in the type of band. The frequency ranges for the K-band and X-band are 18–26 GHz and 8–12 GHz, respectively. Initially, the samples of porcelain and their raw materials have been shaped to suit the dimension of the waveguide without any air gap. It has also been ensured that the thickness of the sample is less than one-fourth of the guide wavelength for wave propagation. A direct and accurate method of Roberts and Von-Hippel⁶ has been considered here. This method is based on the measurement of shift in a minimum of standing wave produced by a short circuit when a sample of dielectric is placed in front of the

short circuit. The measurements have been repeated for all the four phases of the shaped samples. The dielectric constant is calculated using the relation

$$\epsilon_r = (\lambda_0/\lambda'_g)^2 + (\lambda_0/\lambda_c)^2 \quad (1)$$

where λ_0 is the wavelength of microwaves in free spaces, λ_c is the cut-off wavelength, λ'_g is the wavelength of dielectric filled space.

RESULTS AND DISCUSSION

The FTIR spectra of the three grades of electro porcelain are compared and given in Fig. 1. The observed fundamentals along with their vibrational

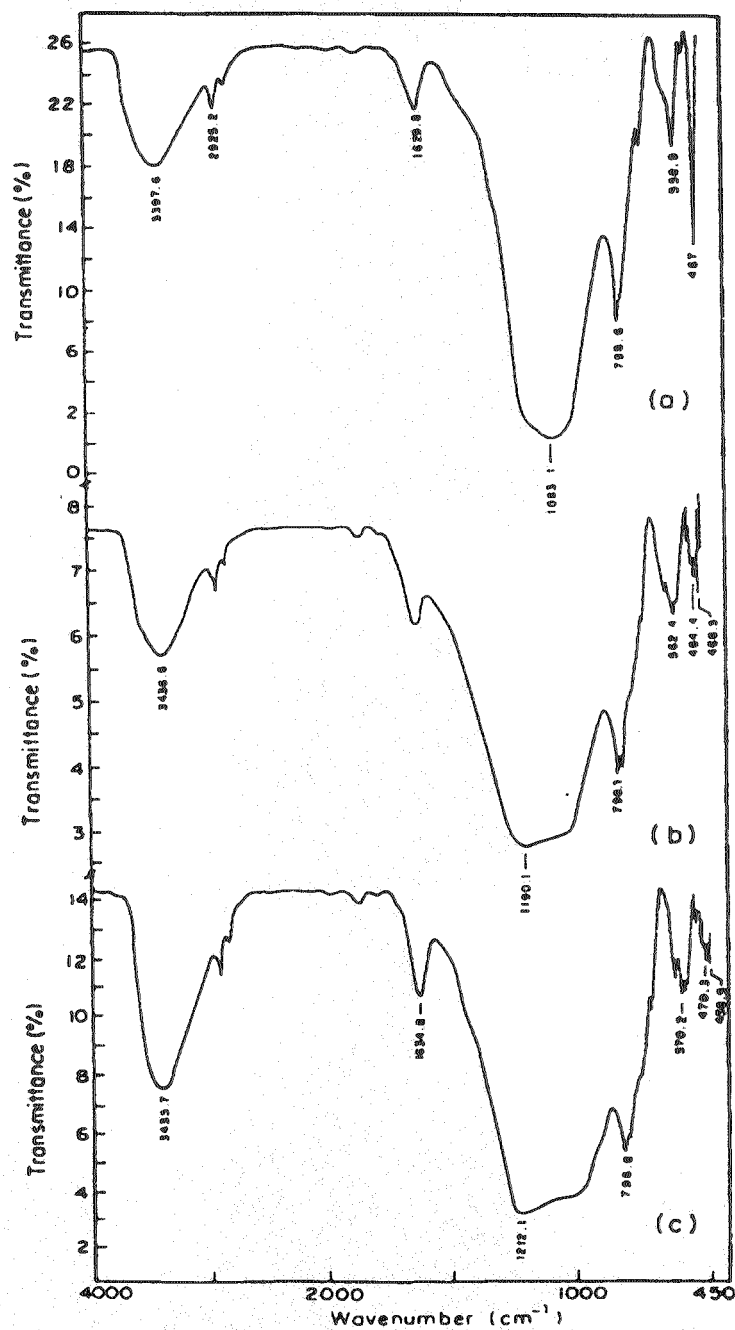


Fig. 1. The FTIR spectra of (a) E2T1, (b) E2T2 and (c) E2T3 porcelain bodies

assignments are tabulated in Table-2. Unassociated hydroxyl groups^{7,8} absorb strongly in the region 3670–3580 cm^{-1} . The relative intensity of the band due to hydroxyl stretching vibration decreases with an increase in concentration, with additional to broader bands appearing at lower frequencies 3580–3200 cm^{-1} . Here the bands at frequencies 3398, 3437 and 3436 cm^{-1} are assigned to O—H asymmetric stretching vibrations. The sharp bands at 2925, 2920 and 2921 cm^{-1} are assigned to O—H symmetric stretching vibrations.

TABLE-2
FTIR SPECTRAL ANALYSIS OF DIFFERENT GRADES OF ELECTRO PORCELAIN

Wave number for E2T1 (cm^{-1})	Wave number for E2T2 (cm^{-1})	Wave number for E2T3 (cm^{-1})	Vibrational assignment
3398 (0.75)	3437 (1.24)	3436 (1.12)	O—H asym. str. vib.
2925 (0.67)	2920 (1.18)	2921 (0.04)	O—H sym. str. vib.
1630 (0.67)	1630 (1.21)	1635 (0.97)	O—H bend. vib.
1083 (2.50)	1190 (1.56)	1212 (1.49)	Si—O str. vib./Al—O str. vib.
799 (1.08)	798 (1.41)	799 (1.27)	Fe—O str. vib./Mg—O str. vib.
559 (0.72)	562 (1.91)	570 (0.96)	Si—O out-of-plane bending vib.
467 (0.90)	468 (1.16)	459 (0.87)	Si—O in-plane bend. vib.
690 (0.70)	690 (1.21)	690 (0.98)	Ca—O str. vib.

The band due to the asymmetric Si—O—Si stretching vibration⁹ is normally in the region 1100–1000 cm^{-1} and due to the greater ionic character of the Si—O group, this band is much more intense than the corresponding C—O band for ether. In porcelain this broad band is very strong and observed at 1083, 1190 and 1212 cm^{-1} . This may also be assigned to Al—O stretching vibration according to Nakamota¹⁰.

The medium strong peaks at 559, 562 and 570 cm^{-1} may be due to Si—O out of plane bending and the peaks at 467, 468 and 459 cm^{-1} may be due to Si—O in-plane bending¹¹. The strong sharp peaks at 799, 798 and 799 cm^{-1} with a shoulder appears due to Fe—O stretching vibration¹¹. Ca—O stretching vibration occurs at around 690 cm^{-1} in all three grades of porcelain as weak band¹⁰.

The absorbance values of these three grades of electro porcelain are compared with the particular type of vibration. The values given within parentheses in Table-2 refer to absorbance. The absorption values for E2T2 body are found to be more, when compared to other two types. This may be due to the increase in dipole moment leading to increase in the insulation property of this type of electro porcelain.

TABLE-3
DIELECTRIC CONSTANT FOR DIFFERENT GRADES OF ELECTRO PORCELAIN

Sample	Dielectric constant	
	K-band (18–26 GHz)	X-band (8–12 GHz)
E2T1	5.12	6.40
E2T2	2.21	3.50
E2T3	4.98	3.80

Dielectric constant for different grades of electro porcelain is listed in Table-3. The dielectric constant of electro porcelain at X-band lies between 3.5 and 6.4 and at K-band lies between 2.21 and 5.12. As the microwave frequency decreases, the dielectric constant increases. The dielectric constant of E2T2 is the lowest and this may be due to the high percentage of fire clay compared to the other two samples. The dielectric constants evaluated for the samples in the present investigation are strongly supported by the spectral data illustrated in Fig. 1. This has been possible because the relaxation frequencies of the ionic polarization are in the infrared range¹². This decreasing trend of dielectric constant in E2T2 may be due to the increase in dipole moment, which causes an increase in the absorbance of the infrared light.

REFERENCES

1. K.K. Patankar, S.L. Kadam, V.L. Mathe, C.M. Kanamadi, C.P. Kothawale and B.K. Chougule, *British Ceramic Transactions*, **102**, 19 (2003).
2. E. Salahi and G. Heinrich, *British Ceramic Transactions*, **102**, 79 (2003).
3. N.C.B. Nath and L. Misra, *Proc. Natl. Workshop on Utilization of Fly Ash*, Roorkee, India **87A** (1988).
4. T. Wandell, *Am. Ceram. Soc. Bull.*, **75**, 79 (1996).
5. S.S. Amritphale and M. Patel, *Silic. Ind.*, **52**, 314 (1987).
6. V. Roberts and A. Von Hippel, *J. Appl. Phys.*, **7**, 17 (1956).
7. I. Motoyama and C.H. Jarboe, *J. Phys. Chem.*, **70**, 326 (1966).
8. J.H. Vander Maas and E.T.G. Lutz, *Spectrochim. Acta*, **30A**, 2005 (1974).
9. G. Socrates, *Infrared Characteristic Group Frequencies*, John Wiley & Sons, New York, p. 126 (1980).
10. K. Nakamoto, *Infrared and Raman Spectra of Inorganic and Coordination Compounds*, John Wiley & Sons, New York, p. 107 (1974).
11. A.Y.M. Mollah, T.R. Hess and D.L. Cocke, *Cem. Conc. Res.*, **24**, 109 (1994).
12. W.O. George and P.S. McIntyre, *Infrared Spectroscopy*, John Wiley & Sons, New York (1987).