

## Dielectric Properties of Sodium Silicate-An Investigation Report

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Available online at: [www.ijcseonline.org](http://www.ijcseonline.org)

**Abstract**— The dielectric properties of sodium silicate ( $\text{Na}_2\text{SiO}_3$ ) (SS) have been investigated in a wide range of frequency and temperatures. A strong dielectric dispersion is found to exist in low-frequency region. The frequency dependent dielectric properties of SS follow universal dynamic response. The measured dielectric data strongly depends on dielectric dispersion and controls the basic relaxation property. However, the parameters that control the dielectric properties such as coupling of ions are found to have frequency and temperature dependency.

**Keywords**— XRD, Dielectric loss, Dielectric constant (real & imaginary part)

### I. INTRODUCTION

Since from the development of science, a lot of research works have been done on silicate based ceramic materials which include synthesis, surface morphology, microstructure analysis, physical properties and applications [1-7]. SS belongs to an orthorhombic crystal class. Many researchers have reported different methodologies for the preparation of sodium silicate such as low-temperature heating, the sol-gel method, high-temperature solid state reaction and many more. Generally, sodium based ceramics contains  $\text{Na}^+$ -ions for conduction. Substitution of  $\text{Na}^+$ -ions by some other ions can cause noticeable change in microstructure, dielectric and electrical properties. This simply signifies that the physical and chemical properties of SS can be modified or improved by the substitution of  $\text{Na}^+$ -ions by some other ions. The high ionic conductivity associated with the presence of random  $\text{Na}^+$ -ions in the crystal sites [4]. The literature survey reveals that the existence of electrical conductivity in materials supports dielectric dispersion and space charge polarization [4]. But it is important to notice how SS behaves under the influence of its conductivity, with regard to its dielectric characteristics. The dielectric spectroscopy is one of the important tools which gives a clear idea about the behavior of ions or grains under the alternating field and signifies the effective coupling of ions in the contribution of dielectric polarization. The frequency dependent dielectric properties of the sample arise prominently from the grain polarization and supports dielectric relaxation. The frozen out state may arise in the frequency dependent dielectric characterization of a sample at a particular frequency or temperature indicating indifferent dielectric behavior at that particular frequency. This paper reflects the investigation report on the

dielectric properties of SS as a function of frequency (100 kHz-5 MHz) at various temperatures ( $50^\circ\text{C}$ - $450^\circ\text{C}$ ).

### II. EXPERIMENTAL

The crystalline sodium silicate was synthesized from a stoichiometric mixture of  $\text{Na}_2\text{CO}_3$  (sodium carbonate) and  $\text{SiO}_2$  (silicon dioxide), using a conventional solid state reaction route. The initial powders were ball-milled in pure acetone for 2 h. The mixtures were initially heated up to  $900^\circ\text{C}$  in the air for 8 h with intermediate grinding. The ceramic sample was obtained by mixing the sintered powder with a small amount of polyvinyl alcohol as binder and cold-processing the mixture into pellets. (Diameter:10mm and thickness:1mm). Subsequently, these pellets were sintered at  $900^\circ\text{C}$  for 8 h. After sintering, the pellets were polished and silver painted on the flat surface for dielectric studies.

### III. RESULTS AND DISCUSSIONS

#### A STRUCTURAL ANALYSIS

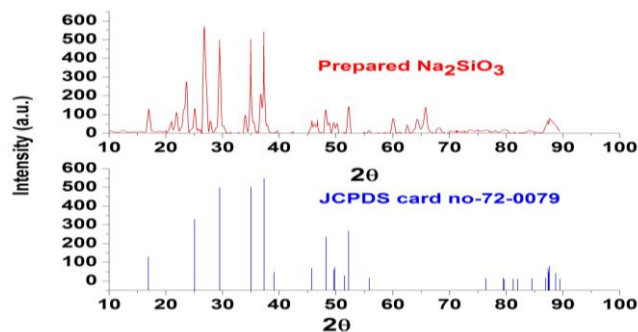


Figure-1: Room temperature XRD pattern of Sodium silicate

The XRD pattern of the sintered Sodium silicate (SS) sample is shown in Figure-1. For powder X-ray diffraction a 2-circle Goniometer, working in Bragg-Brentano geometry, was used with a rotating anode X-ray generator. Figure-1 shows the XRD picture ( $\text{CuK}\alpha$  line, wavelength =  $1.5406 \text{ \AA}$ ) of sintered SS. The diffraction peaks are little sharper and symmetric but different from those of precursor materials. The peaks are successfully indexed. A preliminary structural analysis indicates that the system under investigation has an orthorhombic structure with lattice constants  $a = 10.43 \text{ \AA}$ ,  $b = 6.02 \text{ \AA}$  and  $c = 4.81 \text{ \AA}$ , which is in good agreement with JCPDS card number 72-0079. This shows the completion of sintering [1-5].

## B. DIELECTRIC STUDIES

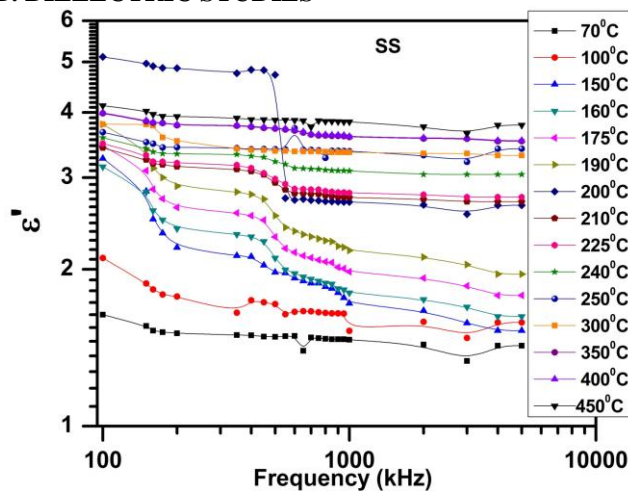


Figure-2: Variation of Real part of Dielectric constant ( $\epsilon'$ ) of Sodium silicate

The change in dielectric constant ( $\epsilon$ ) and dielectric loss ( $\tan \delta$ ) of Sodium Silicate with frequency (100 KHz-5MHz) at temperatures are shown in Figure-2, 3 & 4. The dielectric constant decreases with increasing frequency. At lower frequency the dielectric dispersion is large and it becomes independent of frequency above 1000 kHz. This is due to the fact that the dielectric material exhibits induced electric moment under the influence of electric field. At higher frequency, the polarization of the induced moments could not synchronize with the frequency of applied electric field. So, the dielectric attains a constant value above certain frequencies. At low frequencies, normally all types of polarizations exist. However, in Sodium Silicate, the ionic and electronic polarizations exist in the high-frequency range. It is observed that at higher frequencies these parameters become almost frequency-independent. The dielectric Constant has higher values at high frequencies and also at high temperature. For sodium silicate the dielectric constant also depends on temperature. With increase in temperature the dielectric constant increases. The

coupling between the charge carriers are very in the high temperature and increases prominent with temperature. At about  $200^\circ\text{C}$  and 600 kHz frequency an anomaly is observed in figure-2. This is due to frozen out condition. The dipoles are frozen to respond to the applied field at this frequency causing sharp fall of dielectric constant. But again the value of dielectric constant increases with increasing temperature showing the normal dielectric response to the applied field.

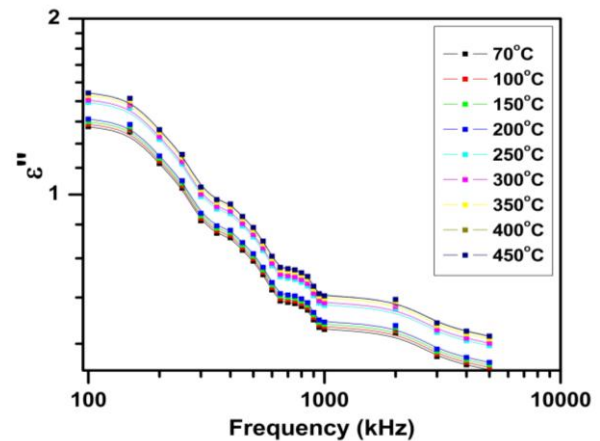


Figure-3: Variation of imaginary part of Dielectric constant ( $\epsilon''$ ) of Sodium silicate

## C DIELECTRIC LOSS

The dielectric loss in the low frequency region for all temperatures are very high and decreases with increasing frequency indicating a normal behavior of dielectric materials having mobile charge carriers of both types of both types (i.e., ions and electrons). The trend in  $\tan \delta$  versus frequency curve might be attributed to parallel conduction ( $\tan \delta = 1/\omega CR$ ), where  $\omega$  is the angular frequency,  $C$  the capacitance and  $R$  is the resistance), which is probably due to porosity. The loss tangent is a useful indicator of the potential of a material to extract energy from an electromagnetic field. The increase in permittivity and loss tangent, observed at room temperature as a function of frequency, decreases and can be ascribed to the mobility enhancement of the ionic charge carriers. But as we go on increasing the temperature the dielectric loss will also increase. The frozen out condition is observed in loss tangent graph also at 600 kHz also. This anomaly indicates the frequency independent dielectric response. The loss of energy due to the non-synchronize vibration of dipoles is responsible for dielectric loss. The phase lagging in dipole vibration with applied field increases with increase of temperature indicating increase of thermal noise or thermal vibration. The high thermal vibration causes high dielectric loss in high temperature. On the high dielectric dispersion in low frequency region can also cause high loss of energy. For this reason the dielectric loss is high in low frequency region [4-6].

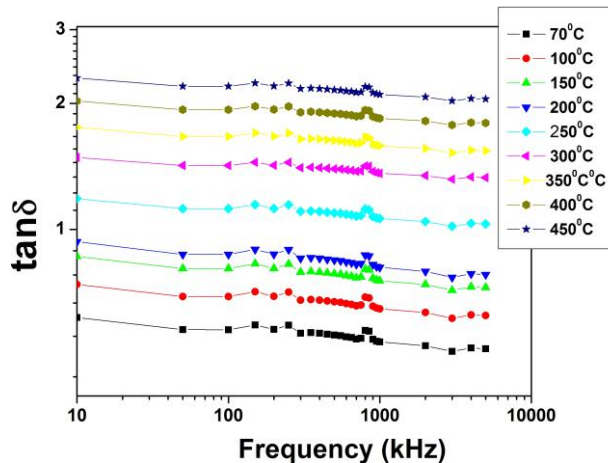


Figure-4: Variation of dielectric loss ( $\tan\delta$ ) of Sodium silicate

#### IV. CONCLUSION AND FUTURE SCOPE

The xrd study confirms the characterization of the sample. The effect of low-frequency dielectric dispersion is observed in the present dielectric study but different in magnitudes for real and imaginary dielectric constants. The anomaly in the dielectric response at 600 kHz frequency under study for all temperatures is a consequence of frozen out state. The thermo-active frequency dependent dielectric response is associated with energy loss termed as dielectric loss. The present study also highlights the effect of frequency and temperature on dielectric properties.

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