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Title : *Electrical Conductivity and dielectric properties of Silicon Nitride Ceramics*
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ABSTRACT

This thesis reports explorative research concerning the electrical properties of oxides and chalcogens doped silicon-nitride based materials. The focus is on searching for improved or unconventional properties in existing materials. Finally, the invention of new silicon-nitride based materials and understanding of the relationship between electrical properties and structure/composition are also challenging parts of the work described in this thesis from an application and scientific point of view, respectively. Here, it is noted that no attempt has been made to give a detailed electrical study and dielectric behaviour in audio frequency range (100 Hz to 1 MHz), which is an interesting subject of subsequent studies.

This thesis can divide into eight chapters. ***Chapter one*** is of introduction of ceramics specially nitride type ceramics. A brief review of work done by various workers on AlN, BN, GaN and Si_3N_4 and different type of ceramics materials and results reported by them has also been discussed in this chapter. The literature survey regarding different ceramics based composites is also discussed in detail. The details of aim of thesis are given in this chapter. And in the last of this chapter we have discussed the outline of the thesis.

In ***chapter two*** we have discussed the literature based on Silicon Nitride Ceramics (Si_3N_4). The structure and physical properties of Si_3N_4 have discussed in details. The work by various workers on electrical behaviours and mechanical properties on high temperature prepared by chemical vapour deposition, spark plasma sintering and sputtering technique has also been reported. The effects of microstructure or grain size on electrical and dielectric properties are also discussed in this chapter. The processing techniques used for fabrication of Si_3N_4 such as (RBSN), (RSSN), (HPSN), and (HIPSN) has been discussed in detail. The physical, electrical, thermal and mechanical properties of Si_3N_4 are summarized by a table. At the end of this chapter we have discussed a wide range of applications of Si_3N_4 based ceramics.

In ***chapter three*** we have discussed the theoretical description of dielectric dispersion and conduction mechanisms in ceramics. The electrical polarization takes place through four different mechanisms i.e. electronic, ionic; orientation and space charge polarization have been discussed in details. For interfacial polarization we have discussed the Maxwell-Wagner two layer model. The dependence of frequency on polarization and dielectric relaxation phenomena (Debye relaxation and non-Debye model) has been discussed in details. Ac conduction mechanism and quantum mechanical tunnelling with different hopping conductivity discussed. We have also discussed different type of dc conduction like ionic, electronic electrical transport mechanism and bulk limited electrical conduction. At the end of this chapter we have discussed the type of dielectric losses with negative capacitance.

Chapter four deals with the experimental details of the work including the synthesis and characterization of the sintered Si_3N_4 based samples prepared by hydraulic press. The samples are sintered in a high temperature furnace upto an optimized temperature. For structural characterization with confirmation of compositions, we used SEM and XRD. To understand the conduction mechanism and

dielectric phenomena we use picoammeter and LCZ meters. The details of the instruments with specifications are also given in this chapter.

In ***chapter five*** the electrical conduction phenomena, dielectric response and microstructure have been discussed in sintered silicon nitride ceramics at different temperature and frequencies. We have discussed microstructure and phase of the sintered samples was investigated by Scanning Electron Microscope (SEM) and X-ray diffractometer (XRD).The electrical conductivity, dielectric constant and dielectric loss increases exponentially with temperature greater than 600 K. The dielectric constant and loss have been measured in the frequency range 100 Hz to 1 MHz. The a.c. conduction studies in the audio frequency range 500 Hz to 1 MHz indicates that the conduction may be due to the electronic hopping mechanism. Silicon Nitride ceramics became dense after high temperature sintering. The effect of grain size and role of phase on electrical and dielectric properties have been also discussed in this chapter.

In the first part of ***chapter six*** we have studied the structure and electrical properties of $(Si_3N_4)_x(M)_{100-x}$ (M = V_2O_5 and ZnO) ceramics samples. The XRD shows the crystalline nature and SEM shows the morphology of these samples discussed in detail. At the end of this chapter, the inertial conductivity, Maxwellian dielectric relaxation time (τ_m) and average dielectric relaxation time (τ) have been measured and found that τ_m is less than τ.

In second part of this chapter we discussed the effect of composition of Silicon Nitride/yttrium oxide with Magnesium oxide on the electrical and dielectric properties of sintered ceramics. A constant amount of MgO was added to different concentrations of Si_3N_4 and Y_2O_3. It is found that the dc conductivity is thermal activated process in the high temperature range and the activation energy is composition dependent. The variation of dc conductivity with the concentration of Si_3N_4/Y_2O_3 is explained. Microstructure, compositional porosity and morphology were also investigated by Scanning Electron Microscope (SEM) and X-rd. As the Si_3N_4/Y_2O_3 concentrations increases the sintered ceramics based composite becomes denser.

The effects of chalcogens (Te and Se) additives on electrical conductivity, dielectric constant and structural properties of Sintered Silicon Nitride Ceramics have been studied in ***chapter seven***. Different amounts of Te (10 % & 20%) and Se (5%, 10%, 15% and 20%) were added as sintering additives to Silicon Nitride Ceramic powders and sintering was performed. Microstructure and composition were investigated by Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD).The electrical conductivity and dielectric constant (ε') increases exponentially with temperature greater than 800 K. The electrical conductivity and dielectric constant increase but activation energy decreases.

Chapter eight deals with the conclusion of the present thesis and discussed the future plan of our research work.