Chapter-VI

Summary and Future Scope

6.1 Summary of the thesis research work

The present thesis is focused on the two classes of anode materials viz. perovskite and double perovskite that are currently being used as potential anodes in solid oxide fuel cells (SOFC). Structural, microstructural and thermal properties of the investigated systems have been explored in correlation to electrical conductivity, which is one of the most desirable properties of the anodes. The conductivity and impedance spectroscopy techniques were employed to explain the electrical conductivity behaviour. The main outlines and summary of the present thesis are focused on following points

1. The conductivity of perovskite, lanthanum chromite ($LaCrO_3$) based systems, have been studied for Gd^{3+} doping on La site from 1 mol % to 10 mol % and conductivity spectra in the measured temperature range of this system was explained by conductivity Vs frequency plots. The temperature dependence of total conductivity was found to show Arrhenius behaviour in moderate temperature range. X-ray Rietveld analysis confirmed the orthorhombic perovskite structure phase formation for all the doped and undoped composition. The composition $La_{0.99}G0_{.01}CrO_3$ was found to exhibit maximum conductivity among the Gd^{3+} doped prepared compositions.

2. In double perovskite (Sr_2NiMoO_6) based systems, influence of Ni/Mo ratio on the electrical properties have been explored to develop anode material with enhanced electrical conductivity for SOFC. Rare earth (La^{3+}, Ce^{3+} and Sm^{3+}) doped Sr_2NiMoO_6 (SNM) systems (synthesized via sol-gel and citrate nitrate route) have been studied. In all doped and undoped SNM systems tetragonal phase was observed at room temperature along with minor secondary phases like $SrMoO_4$, NiO and Ce_2O_3. Porous surface morphology was found to observe for all the investigated systems. A doped few compositions were found to exhibit higher conductivity. At higher doping concentrations, decline in conductivity was observed due to extra secondary phases and might be also due to the formation of more oxygen vacancies. SNM systems enhance in conductivity due to presence of mixed valence charge carriers of Mo (Mo^{5+}/Mo^{6+}). The conductivity in reducing atmosphere was found to show considerably high conductivity in comparison to its value in air. Therefore, making it more suitable for anode material in SOFC application.

3. Electrical conductivity of a few promising compositions was measured in reducing atmosphere in the temperature range of 200-600 °C. Their conductivities are shown in Arrhenius fashion in Fig.6.1.

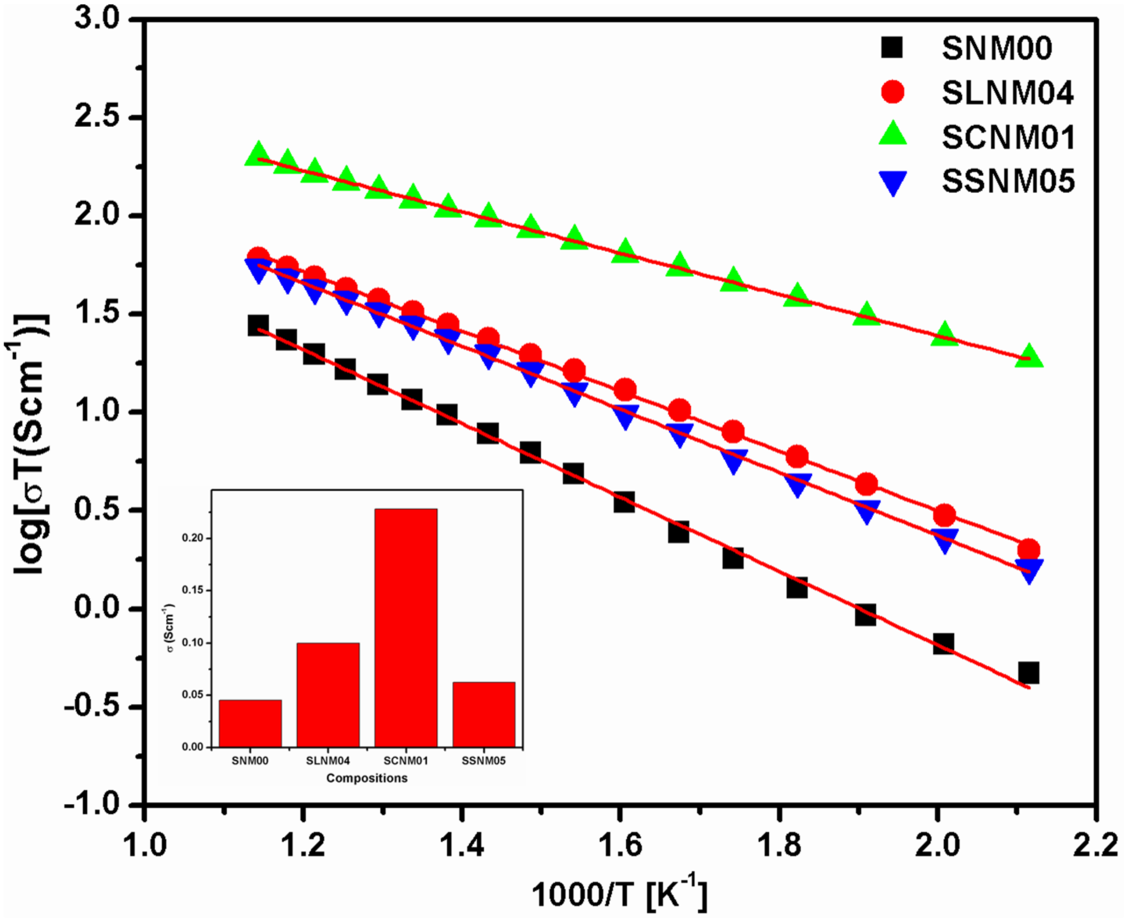

Fig.6.1. *Arrhenius plots of conductivity for the SNM, SLNM04, SCNM01 and SSNM05 samples in* H_2 *atmosphere. The inset depicts the variation of conductivity with composition at 600 °C.*

Figure 6.1 is clearly reveals that conductivity is enhanced to a high value with doping of rare earth elements (La^{3+}, Ce^{3+} and Sm^{3+}) in reducing atmosphere. The electrical conductivity in reducing atmosphere of composition SCNM01 was found to show highest value as compared to other doped systems. The inset of Figure 6.1 shows the bar diagram of conductivity versus different compositions (SNM, SLNM04, SCNM01, SSNM05) in reducing atmosphere (H_2) at 600 °C. It can be seen that for SCNM01 sample, conductivity is highest in reducing atmosphere among all samples. Hence, this composition may be proposed as one of the promising candidates for anode material.

6.2 Suggestions for Future Scope

The basic properties of anode materials like microstructure, density, thermal and electrical compability for SOFC depend on their synthesis route, dopants concentrations and microstructures. In sequence to acquire good conductivity and better performance of the materials, these parameters must be optimized. The microstructure is quite sensitive to the processing variables such as sintering temperature, atmosphere used during sintering, processing routes and also the amount of extra phase infiltration. So a detailed study on the effect of these processing parameters on the structural, microstructure, thermal and electrical properties of the investigated compositions is required. Moreover, the followings points may also be considered for future studies.

1. The conductivity behavior of the sample at different reducing atmosphere should be studied to know the stability of the materials.
2. The measurement of transference number is an important factor to confirm both electronic and ionic contribution of conductivity.
3. Thermal and chemical stability of the materials should be verified in reducing atmosphere for their applications as anode material.
4. Some of other cost-effective anode materials may be considered in perspective of improved electrical conductivity, performance, chemical and thermal stability and most importantly their operation at low or intermediate temperature range.
5. The performance of the optimized anodes may be checked their compatible with electrolytes and cathodes.
6. The investigations of materials should be focused on cheaper materials for intermediate/low temperature SOFC application.
7. The thermal expansion coefficient of all the prepared compositions can be measured to see their compatibility with the other components (cathode, electrolyte and interconnects) of the SOFC system.