CHAPTER - 3
AIM AND SCOPE OF THE PRESENT INVESTIGATION

Materials having high dielectric permittivity, high breakdown strength, low loss and fast response will be essential for the next-generation electrical and electronic applications such as telecommunication, magnetic data storage and power capacitors. Magnetic materials have been greatly investigated for these applications because of their high resistivity, low-dielectric loss, mechanical hardness, high Curie temperature and chemical stability [1]. It is known that the size distribution and the interaction between the magnetic NPs can greatly influence the dielectric performance of this material. The NPs are prone to conglomerate into the secondary particles due to large specific surface energy and strong cohesion. Therefore, a lot of methods focusing on surface modification of the magnetic NPs have been carried out to prevent agglomeration and improve the uniform size and the dielectric properties of the corresponding materials [2, 3]. One way to solve this problem is to cover the magnetic materials with a non-magnetic coating to create the core-shell nanostructure.

Core-shell NPs with magnetic components have attracted much interest in both fundamental and applied point of view. In magnetic CSNPs, the novel properties of magnetic components can be combined with those of another active component to make bifunctional or even multifunctional NPs. The properties of the magnetic/dielectric heterostructures have been analysed over the several decades due to the combination of their magnetic and electrical properties [4]. The coating with a dielectric shell on the surface of magnetic core of the NP leads to a high permeability independent of the frequency, even in the gigahertz range. Such materials are typically suitable for various applications such as telecommunication, magnetic data storage and human tumour therapy [5]. The encapsulation of magnetic material within

a proper dielectric shell would have showed the excellent electrical property because of their proper electromagnetic matching between the dielectric and magnetic losses [4, 6]. On the other hand, the ability to control the magnetic interactions is an important consequence of coating magnetic particles. The thickness of the coating materials controls the inter-particle interactions [7]. As a result, the surface modification of NPs can help to prevent agglomeration of the magnetic NPs and reduce the dielectric loss. Li *et al.* [8] analysed the dielectric properties of CSNPs dispersed in the polymer matrix. In this inorganic CSNP and polymer composite, moderate dielectric permittivity shell material reduces the large differences of dielectric constants between the inorganic core and polymer matrix. The buffer shell layer greatly suppresses the leakage currents and dielectric loss of the composites. Increasing the buffer shell layer thickness, suppresses the leakage current.

Gadolinium oxide (Gd_2O_3) is a well-known material, used in different form like monocrystal, thin film and powder form. It has been developed for various applications such as in magnetic [9, 10], catalysts [11], nuclear [12], phosphor and wave guiding applications [13]. For the magnetic resonance imaging (MRI) application, Gd_2O_3 NP has been demonstrated as a strong positive contrast agent. It is due to the large number of Gd^{3+} atoms presents in it, compared to the currently used gadolinium (III) chelates [14]. Because of the 4f-3d coupling, Gd^{3+} doped $NiFe_2O_4$ NPs have showed the lowest loss in the microwave frequency region compared to the bare $NiFe_2O_4$ NPs. This is an important factor for the application of magnetic materials with non-magnetic compound being used as a transformer core in the microwave region [15]. The NPs developed with the combination of non-magnetic/magnetic material as a core/shell nanostructure that non-magnetic material modifies the properties of the magnetic material. Particularly, interfacial exchange

coupling between the core and shell region plays a key role in the overall magnetic properties of these CSNPs [16].

The aim of the present work is to develop magnetic CSNPs suitable for the dielectric and magnetic applications. For the dielectric relaxation studies, magnetic NPs (Fe_2O_3 and $NiFe_2O_4$) have been encapsulated by non-magnetic material (Gd_2O_3). By coating of non-magnetic shell over the magnetic core, agglomeration and the inter particle interaction of magnetic particles can be prevented and reduce the dielectric loss. In the case of magnetic studies, CSNPs have been designed like magnetic shell ($NiFe_2O_4$ and NiO) with non-magnetic core (Gd_2O_3). The effect of Gd_2O_3 core on the properties of magnetic shell material and the role of roughened interface between the core and shell region which gives rise to a net interfacial moment at the nanoscale have been analysed. In addition to this, it has been investigated the thermal stability of magnetic core encapsulated by non-magnetic shell as a core-shell nanostructure at 650 °C heat treated sample.

➢ The present work is to explore, how the shell material and core-shell interface modulate the dielectric properties of core-shell nanosystem of Gd_2O_3 dielectric material coated iron oxide and nickel ferrite NPs. The dielectric relaxation of the materials will be studied by alternating current impedance spectroscopy.

➢ Our interest is to determine, how the EPR spectroscopy and magnetic characterisation results reconciled the core-shell nanostructured magnetic materials compared to the uncoated bare one.

➢ To prepare the phase pure and nanoscale core-shell particles, polyol and co-precipitation synthetic methods will have been carried out.

➢ It is also proposed to characterise the prepared CSNPs by TGA, XRD, TEM, Raman spectrometer, Vibrating sample magnetometer and Mossbauer analysis.

References

1. P. I. Slick, in Ferromagnetic Materials, edited by E. P. Wohlforth, North-Holland, Amsterdam, The Netherlands, (1980), Vol. 2, p. 189.

2. C. Yang, Y. Lin and C. W. Nan, Carbon 47 (2009) 1096.

3. A. Qureshi, A. Mergen and B. Aktas, J. Phys.: Conf. Ser. 153 (2009) 12061.

4. Z. D. Zhang, J. Mater. Sci. Technol. 23 (2007) 1.

5. X. F. Zhang, X. L. Dong, H. Huang, Y. Y. Liu, W. N. Wang, X. G. Zhu, B. Lv, J. P. Lei and C. G. Lee, Appl. Phys. Lett. 89 (2006) 053115.

6. F. Mazaleyrat and L. K. Varga, J. Magn. Magn. Mater. 215 (2000) 253.

7. J. Neamtu, J. Magn.Magn.Mater. 158 (1996) 461.

8. Z. Li, L. A. Fredin, P. Tewari, S. A. DiBenedetto, M. T. Lanagan, M. A. Ratner and T. J. Marks, Chem. Mater. 22 (2010) 5154.

9. J. B. Gruber, W. F. Krupte and J. M. Poindexter, J. Chem. Phys. 41 (1964) 3363.

10. N. T. McDevitt and A. D. Davison, J. Opt. Soc. Am. 56 (636) 1966.

11. J. M. Deboy, R. F. Hicks, Ind. Eng. Chem. Res. 27 (1988) 1577.

12. A. G. Murilo, C. L. Luyer, C. Dujardin, T. Martin, C. Garapon, C. Pedrini and J. Mugnier, Nucl. Instrum. Methods Phys. Res. A. 486 (2002) 181.

13. D. Balestrieri, Y. Philipponneau, G. M. Decroix, Y. Jorand and G. Hantozzi, J. Eur. Ceram. Soc. 18 (1998) 1073.

14. M. Ahren, L. Selegard, A. Klasson, F. Soderlind, N. Abrikossova, C. Skoglund, T. Bengtsson, M. Engstrom, P. O. Kall and K. Uvdal, Langmuir, 26 (2010) 5753.

15. S. C. Byeon, K. S. Hong, I. T. Kim, J. Appl. Phys. 83 (1998) 11.

16. R. F. L. Evans, D. Bate and R. W. Chantrell, Phys. Rev. B. 84 (2011) 092404.