Deposition and magnetic property measurement of Mn-Ferrite thin film and dielectric measurement of $Mn_{1-X}Zn_XFe_2O_4$ bulk

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Introduction & Objective

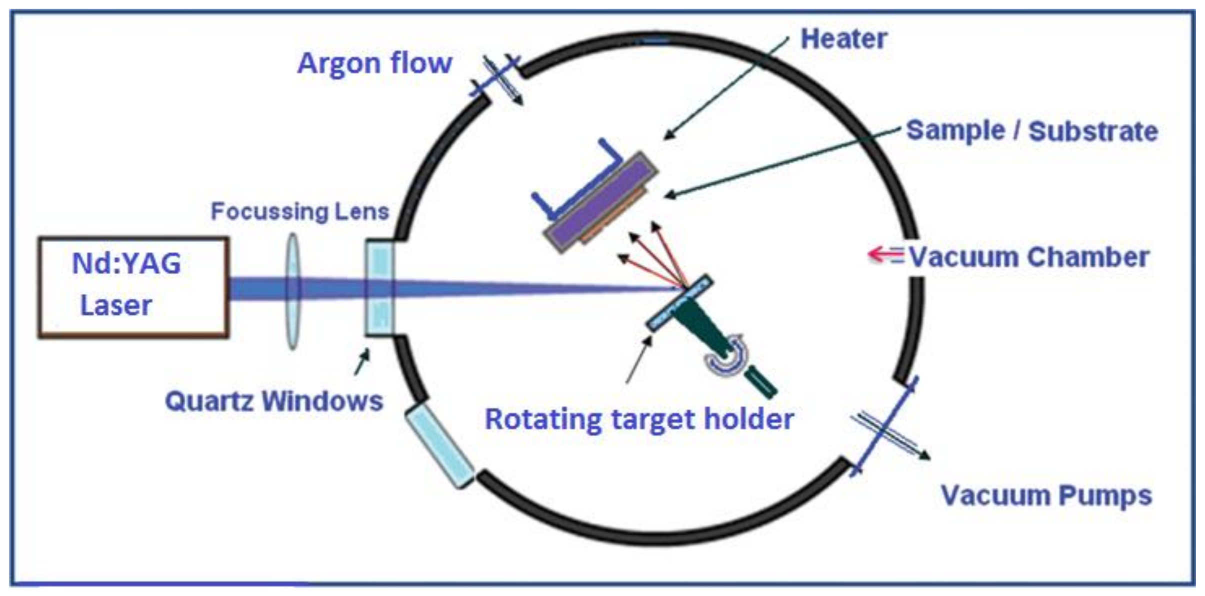
- The crystal structure of $MnFe_2O_4$ is 80% normal and 20% inverse spinel
- $MnFe_2O_4$ is used for computer memory chips, magnetic recording media, radio frequency coil fabrication, transformer cores, introduction of ferromagnetic or super paramagnetic particles into the tumor tissue
- Mn-Zn mixed ferrites are widely used as soft magnetic material for high frequency applications because of their high resistivity and high dielectric constant increases the skin depth
- Ferrites have high values of resistivity and low eddy current losses which make them ideal for high frequency applications

Objective:

- To deposition of $MnFe_2O_4$ ferrite thin films at room temperature and anneal at various temperatures (RT - 750 ˚C)
- Dielectric and DC conductivity measurements of Mn-Zn mixed ferrite

Thin Film Deposition

- Pulse laser deposition (PLD) is an physical vapor deposition (PVD) process to deposit ferrite thin films
- It has ability to deposit the film of same stoichiometry as that of same target material especially when there are several elements present in the target material
- The experimental setup of PLD system consists of a target holder and a substrate holder in a vacuum chamber

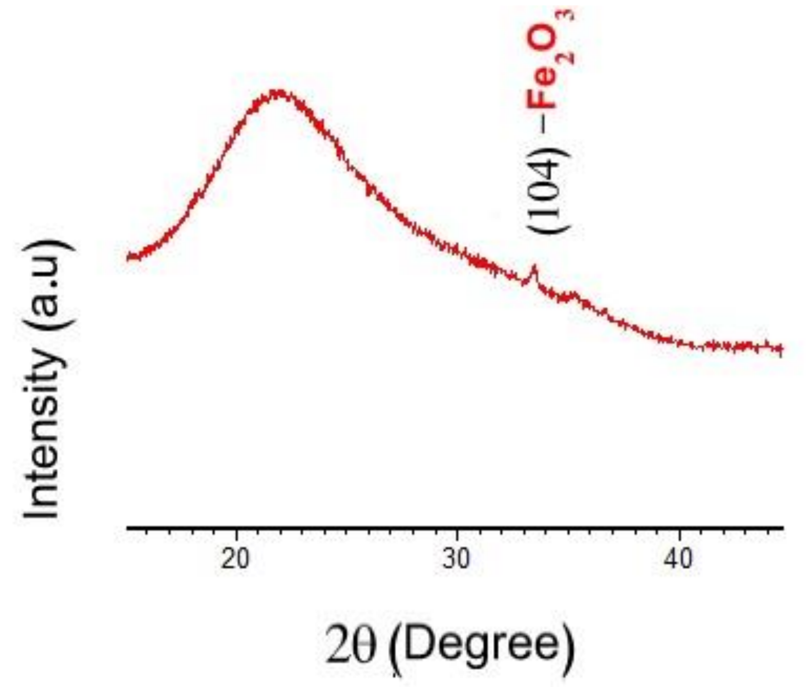


- Thin film pulse laser deposited on the amorphous quartz substrate at room temperature in the presence of argon partial pressure

Different parameters	Typical value
Target to substrate distance	4.5 cm
Base vacuum	7.4×10^{-6} mbar
Argon pressure	0.086 mbar
Energy density	2.5 J/cm^2
Wave length	355 nm
Pulse duration	5-6 ns
Repetition rate	10 Hz
Deposition time	30 min

- After deposition one film is annealed in argon atmosphere for 2 hours

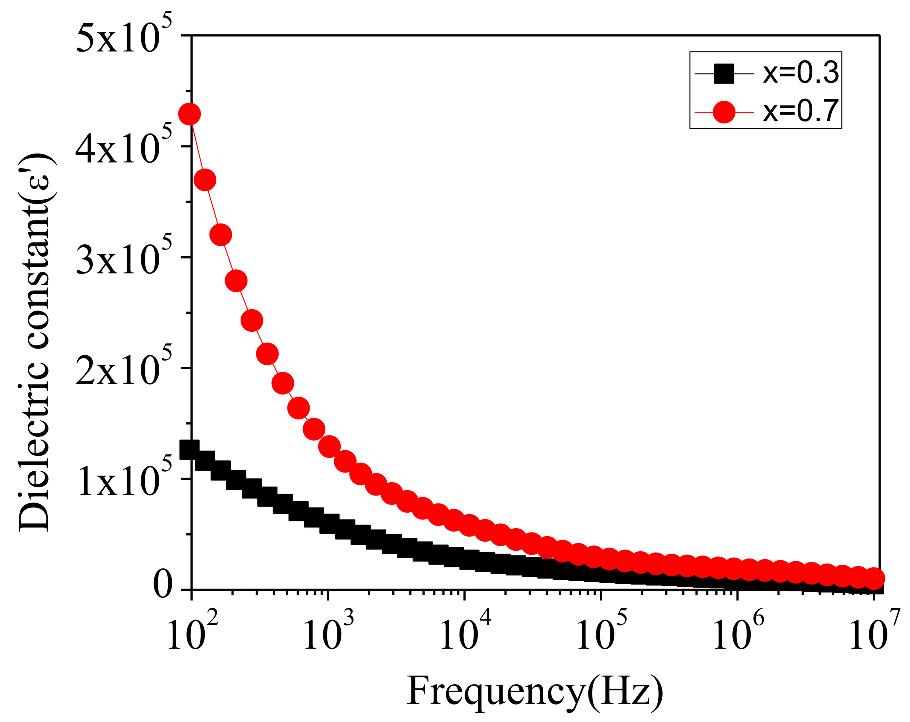
Thin Film XRD



- XRD pattern of $MnFe_2O_4$ film as deposited at RT and annealed at 750 ˚C in presence of argon for 2 hours
- Extra peak of Fe_2O_3 was observed

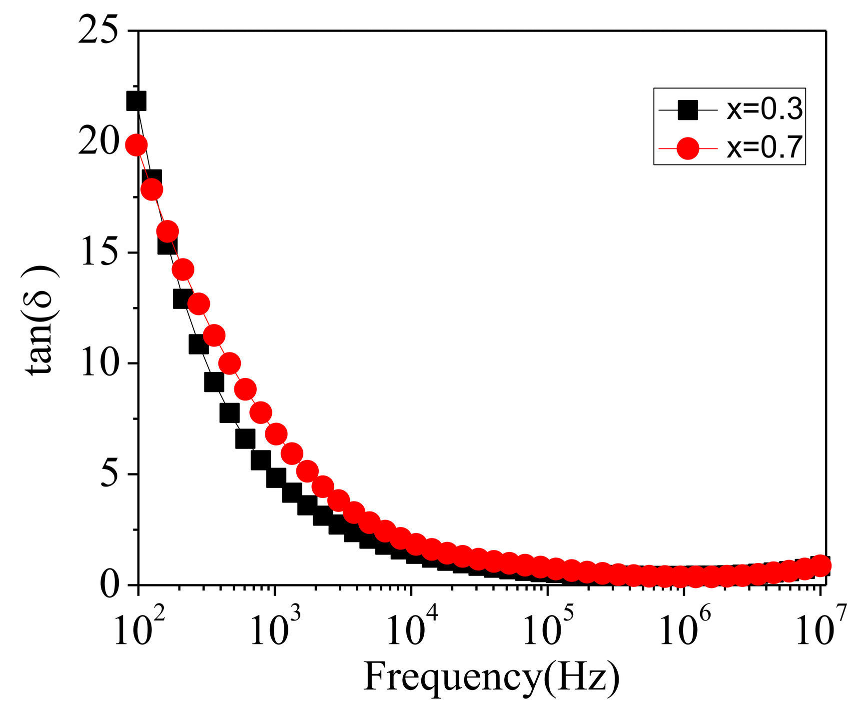
Dielectric Measurements of $Mn_{1-X}Zn_XFe_2O_4$ bulk

- A small pallet of Mn-Zn ferrite with diameter less than 10 mm and thickness less than 2 mm is silver coated and then heated at 120 ˚C for 30 mins
- The Broadband dielectric spectrometer was used for the dielectric measurement of the bulk sample



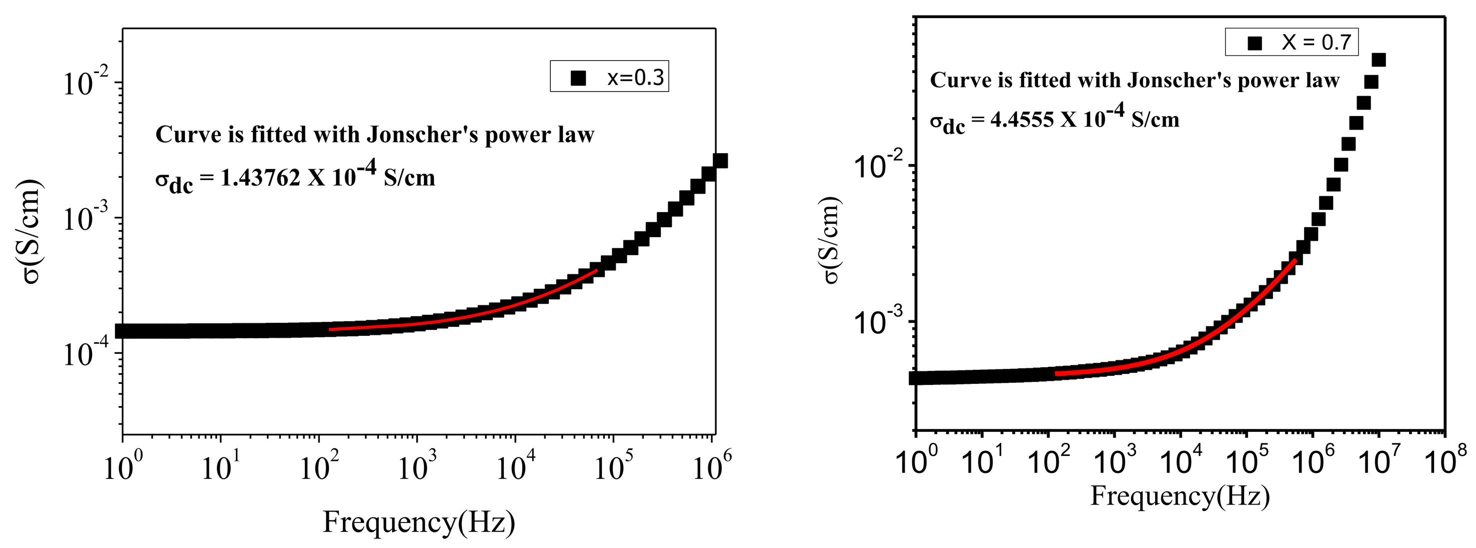
Dielectric constant vs. frequency for $Mn_{1-X}Zn_XFe_2O_4$(x = 0.3,0.7)

- The electron exchange between Fe^{2+} and Fe^{3+} ions and the hole exchange between Mn^{3+} and Mn^{2+} ions in octahedral sites results in an local displacement of charge carrier in the direction of the field which causes polarization
- Beyond a certain frequency the charge carriers exchange cannot follow the alternating field and hence dielectric constant reduces with increase in frequency
- The dielectric constant of $Mn_{0.3}Zn_{0.7}Fe_2O_4$ has maximum value because of the fact this it has maximum ferrous ions in octahedral site which involve in exchange interaction
- Dielectric constant is a function of sintering temperature and Zinc content



Dielectric loss tangent vs. frequency for $Mn_{1-X}Zn_XFe_2O_4$(x = 0.3,0.7)

- The dielectric loss is due to lag of polarization w.r.t applied field
- As pointed out by Iwauchi (1971), there is Strong correlation between conduction mechanism and the dielectric behavior. Maximum loss when hopping frequency equal to that of the externally applied frequency.
- The anomalous behavior is due to presence of both n- and p- type charge carrier



- This type of frequency dependent conductivity spectra in general can be explained by Jonscher's power law,

$$\sigma_{ac} = \sigma_{dc} + A(T)\omega^n \quad \text{-------------------- (1)}$$

- Here σ_{dc} is the dc conductivity (a frequency independent plateau in the low frequency region); $A(T)$, the temperature dependent frequency pre-exponential factor; and n, the power law exponent which generally varies between 0 and 1.
- The increase in conductivity with increase in zinc content suggest the presence of an increasing concentration of Fe^{2+} ions
- Conductivity also influenced by the microstructure factors such as grain size, porosity and grain boundary

Discussion

- The dielectric constant of Mn-Zn mixed ferrite and the loss factor decreases rapidly with an increase in frequency and then reach a constant value
- The redistribution of metal ions by varying the zinc content is responsible for the modification of ferrite properties

Acknowledgement

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