Impact of particle size on the magnetic properties of highly crystalline Yb^{3+} substituted Ni-Zn nanoferrites

PP-44

N. Jahan[1], M. N. I. Khan[2] and M. M. Uddin[1*]
[1]Chittagong University of Engineering and Technology, Chattogram-4349, Bangladesh
[2]Materials science Division, Atomic Energy Centre, Dhaka, Bangladesh
*Email: mohi@cuet.ac.bd

BPSC on Physics-2021
6-7 August, 2021
(Online platform)

Polycrystalline Yb substituted Ni-Zn nanoferrites with the compositions of $Ni_{0.5}Zn_{0.5}Yb_xFe_{2-x}O_4$ (x=0.00, 0.04, 0.08, 0.12, 0.16 and 0.20) have been synthesized by using sol gel auto combustion method. The magnetic characterization of the compositions has been performed by quantum design physical properties measurement system (PPMS). That ensured the formation of single phase cubic spinel structure. Saturation magnetization (M_s) and Bohr magnetic moment (μ_B) decrease while the coercivity increases with the increase in Yb^{3+} contents successfully explained by the Neel's collinear two sub-lattice model and critical size effect, respectively. Critical particle size has been estimated at 6.4 nm from the D_{XRD} vs. M_s, H_c plot, the transition point between single domain regime (below the critical size) and multi-domain regime (beyond the critical size). Curie temperature (T_c) reduces due to the weakening of A-O-B super exchange interaction and redistribution of cations, confirmed by the M-T graph. The compositions retain ferromagnetic ordered structure~~d~~ below T_c and above T_c, it becomes paramagnetic, making them plausible candidates for high temperature magnetic device applications. The relative quality factor (RQF) peak is obtained at a very high frequency (≥ 10^8 Hz), indicating the compositions could also be applicable for high frequency magnetic device applications.

Experimental Route

Nitrate of raw materials
↓
Weighting by different mole percentage
↓
Mixing with Ethanol
↓ pH maintained at 7 by Ammonia solution
Sol
↓ Heated at 80°C
Gel
↓
Dried Gel
↓ Calcined at 250°C for 5 Hrs
Ash
↓
Sample powder
→
Grinding and added PVA
↓
Pressing to desired shape
↓
Sintering
↓ Sintered at 700°C for 5 hrs
Final Product

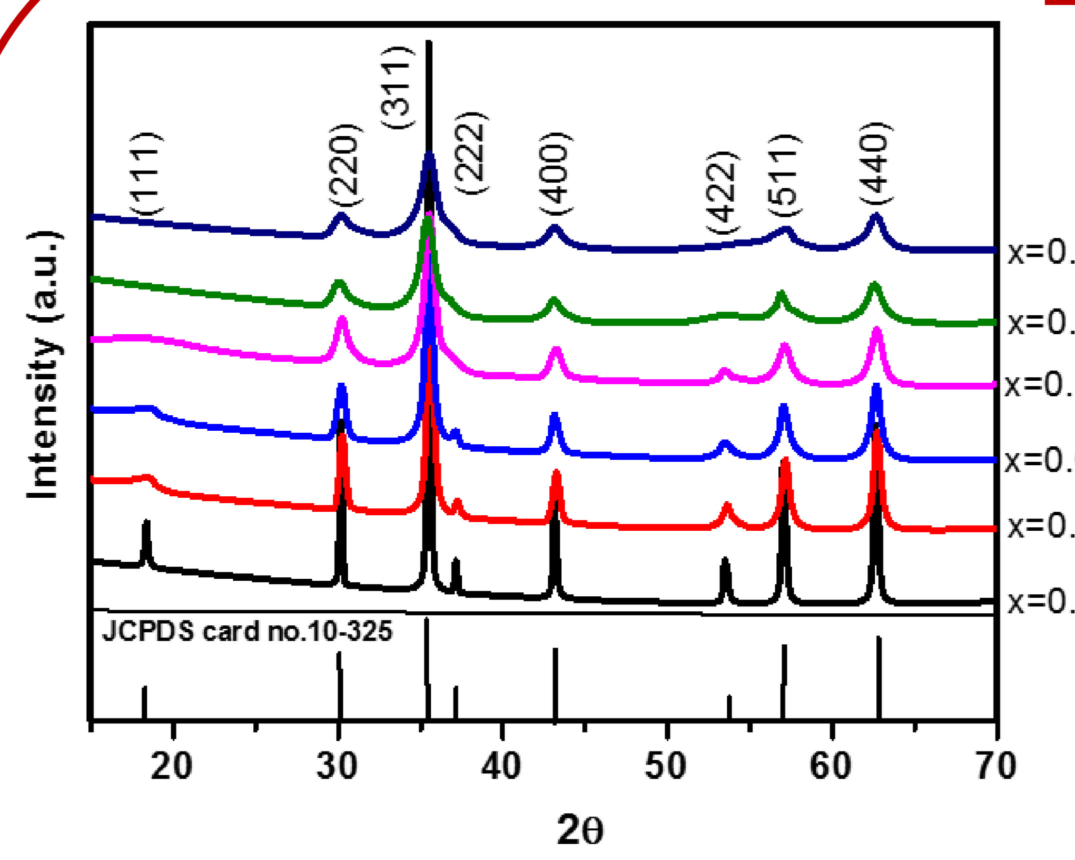
Sol-gel auto combustion technique

Analytical grade:
$Ni(NO_3)_2.6H_2O$(≥97.0%),
$Zn(NO_3)_2.6H_2O$ (≥98.0%),
$Yb(NO_3)3.5H_2O$ (≥99.99%)
$Fe(NO_3)_3.9H_2O$ (≥99.95)

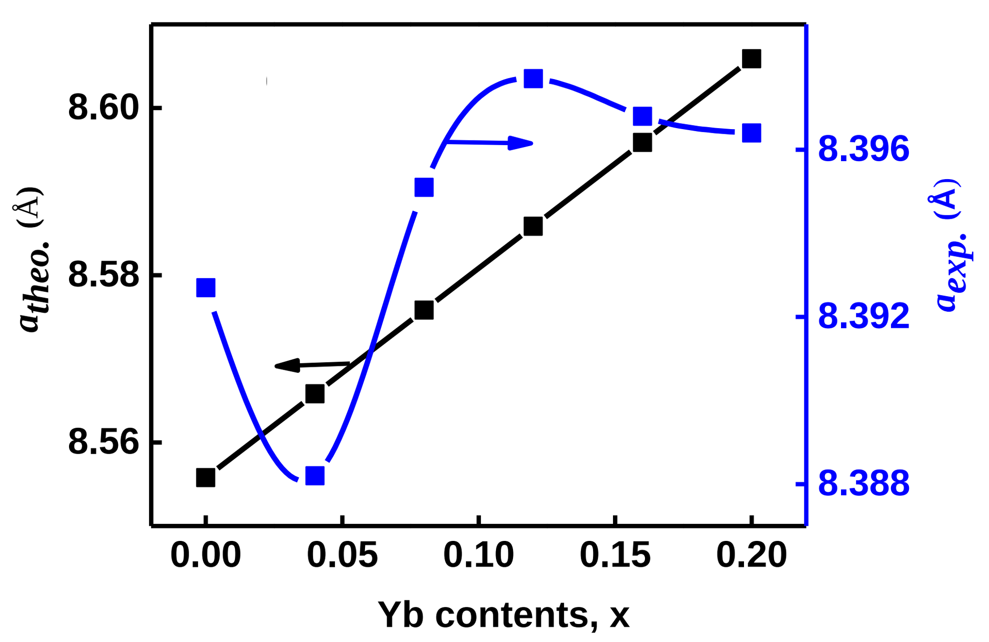
(Merck Germany)

(Wako, Japan)

Structural Analysis



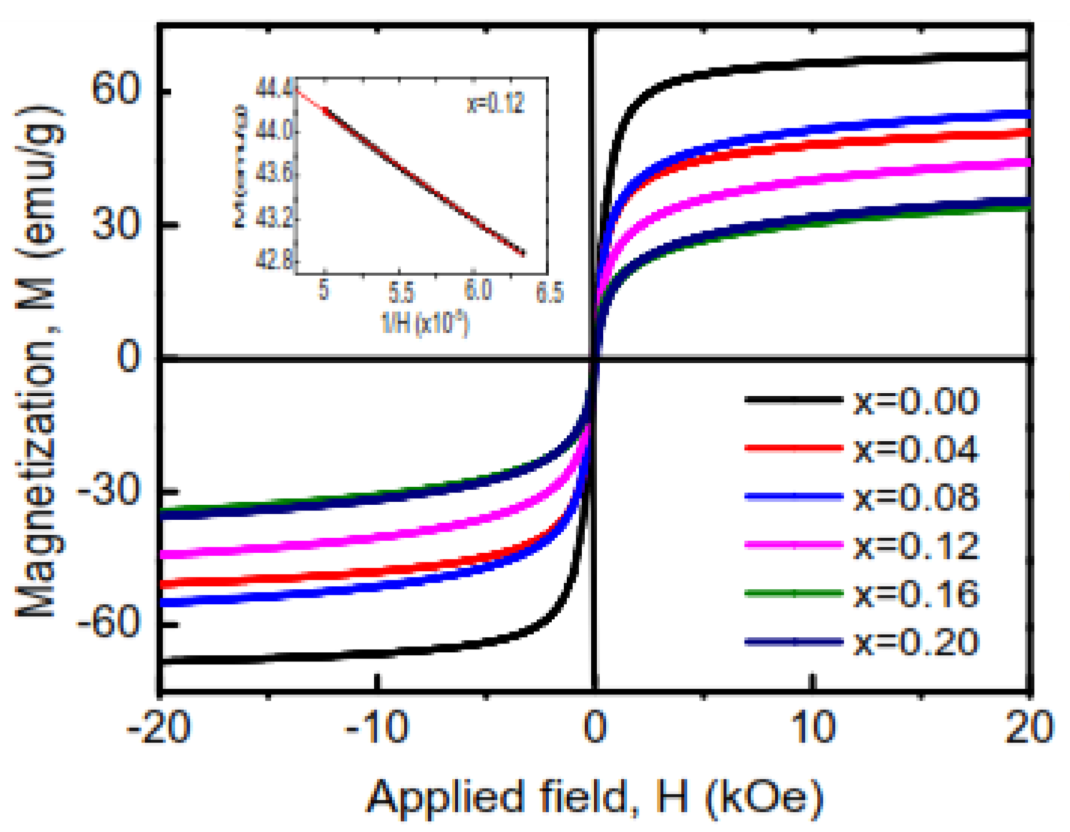
The XRD pattern of $Ni_{0.5}Zn_{0.5}Yb_xFe_{2-x}O_4$ (0≤ x ≤ 0.20) sintered at 700°C.

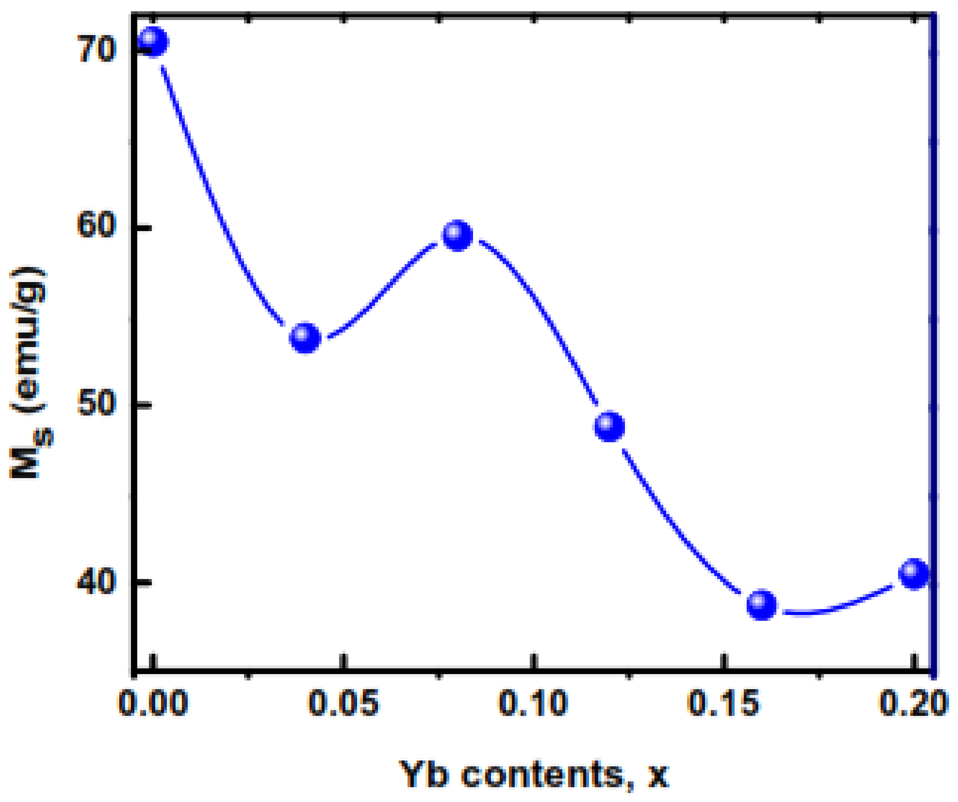


- Single phase cubic spinel structure has been confirmed by the XRD pattern.
- The crystallite size decreases from 23 to 5 nm.

Yb contents (x)	Crystallite size, (nm)	Average grain size, (nm)	Lattice parameter (a_{expt}) (Å)	Porosity P (%)
0.00	23.1	52.06	8.393	55.15
0.04	10.9	24.29	8.388	66.60
0.08	9.5	24.12	8.395	69.11
0.12	6.4	18.97	8.398	70.18
0.16	4.8	17.97	8.397	71.34
0.20	5.6	17.50	8.396	72.48

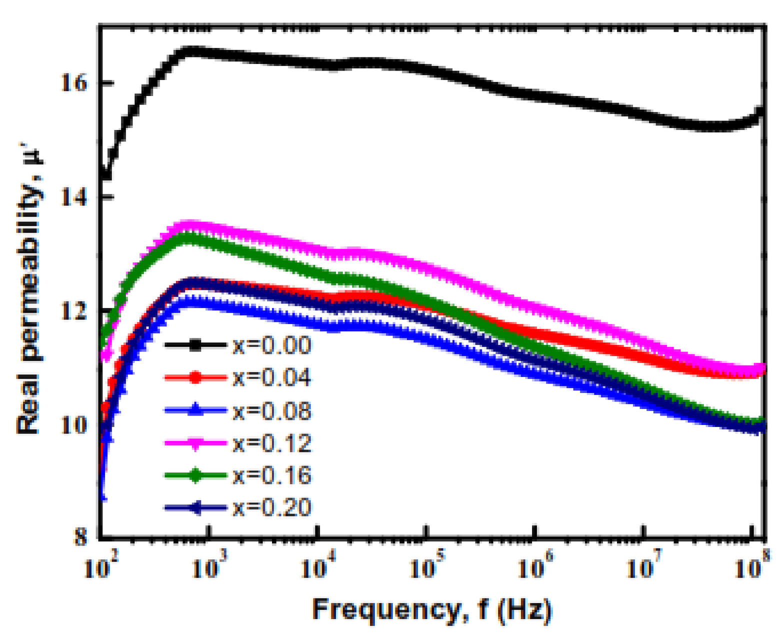
Magnetic Properties

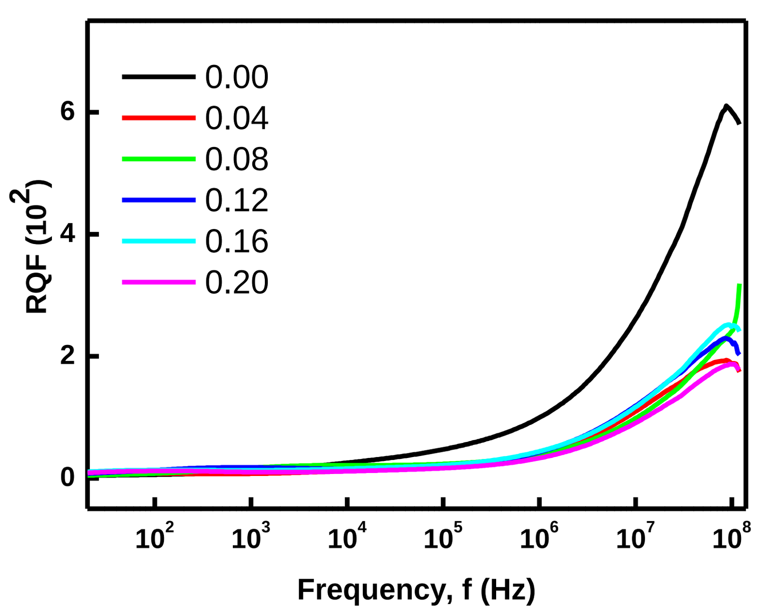




- Saturation magnetization (Ms) decreases from 70 to 38 emu/g and coercivity increases from 6 to 24 Oe with the increase in Yb^{3+} contents.

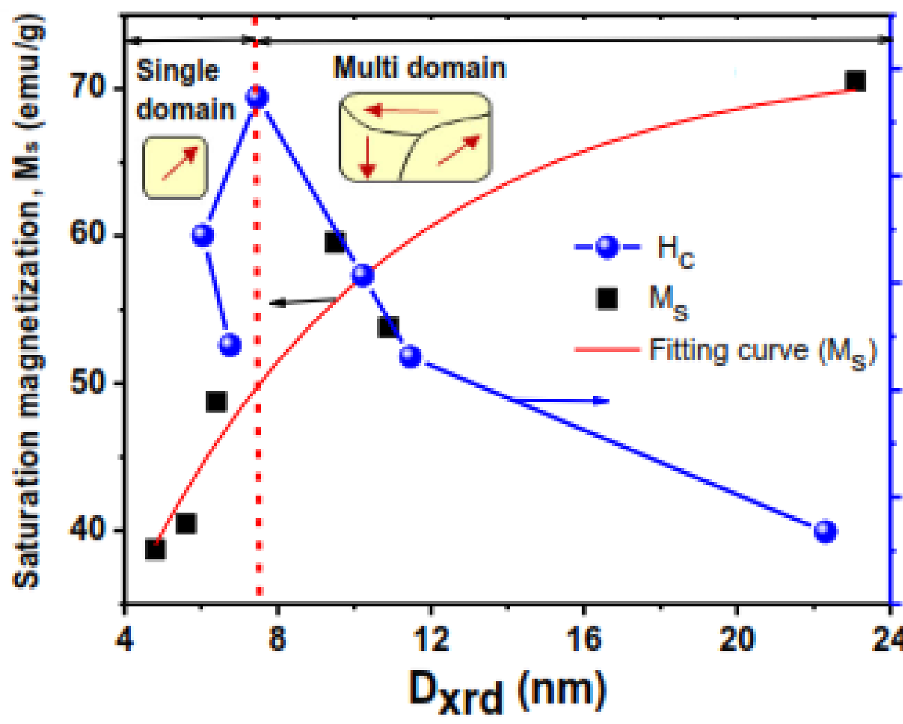
Permeability and RQF

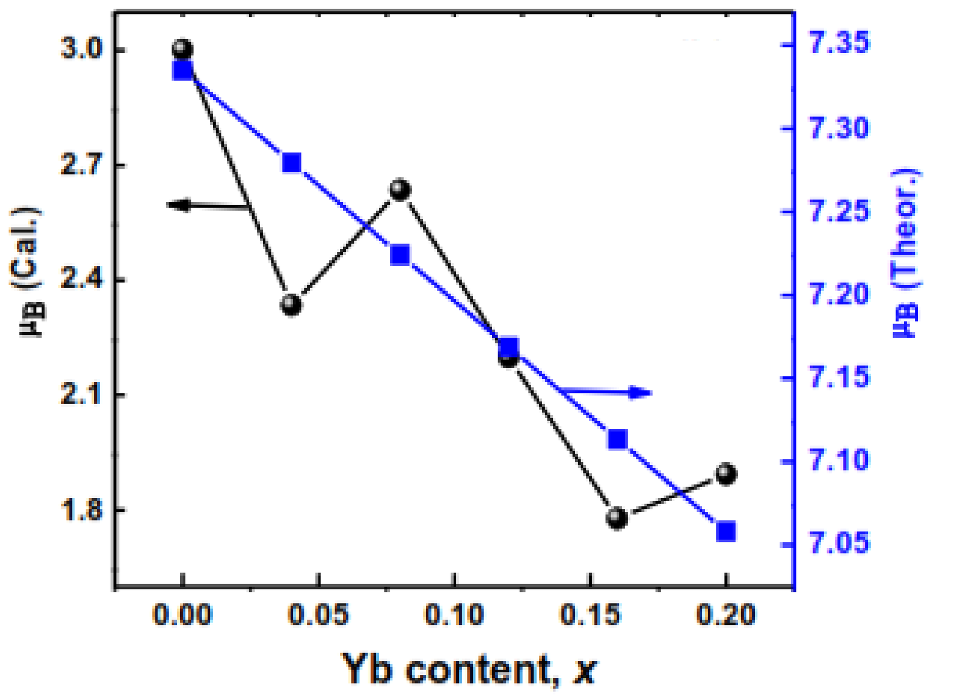




- The variation of μ' has been observed for all compositions and successfully explained by the established domain wall and spin rotation mechanism.

Size dependent M_s and H_c





- The M_s increases with increasing particle size/Yb^{3+} ions, showing the maximum value of H_c is of 47.3 Oe at D_{xrd} 6.4 nm indicating the critical particle size of the compositions which is the transition point of single domain regime and beyond it is transferred into multi domain regime.

Conclusions

- The composition remains the ferrimagnetic ordered structured up to T_c, indicating these materials are a plausible candidate to use at high temperature devices.
- High frequency peak of relative quality factor (10^8 Hz) indicating the compositions are suitable for high frequency applications.

Ref: N.Jahan, M. M. Uddin et al., ***J Mater Sci: Mater Electron*** 32:16528–16543 (2021)

This work Supported by CUET DRE (CUET/DRE/2016-2017/PHY/003)