Effect of Thermal Neutron Irradiation of $CoLa_xFe_{2-x}O_4$ Nanoferrites: XRD, FTIR, UV, VSM, and ESR Spectroscopy

By

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Introduction

Over the years, spinel ferrites have attracted considerable research interest due to their wide range of applications in many areas of the technological and medical industries.

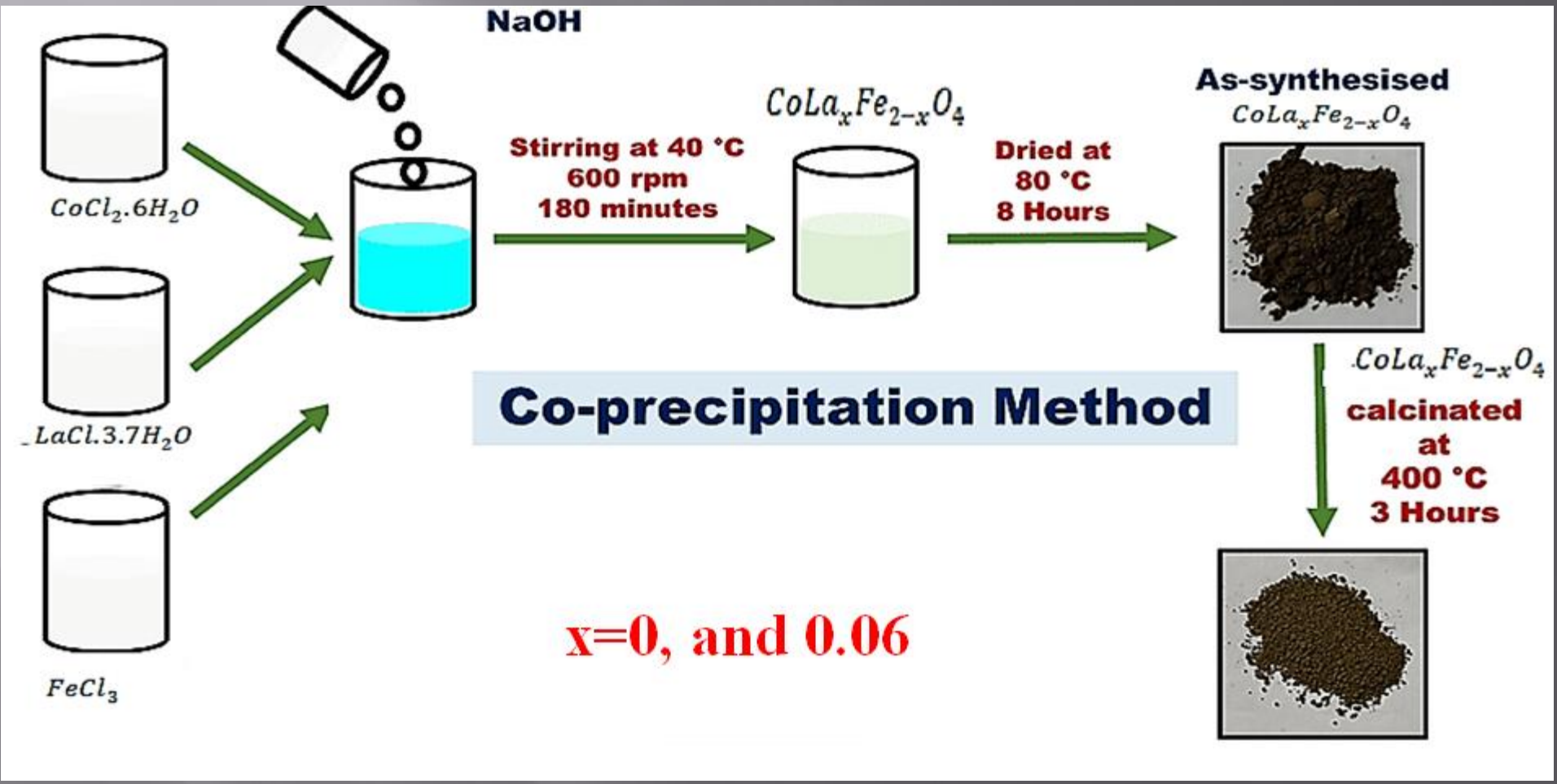
Among the spinel ferrite, cobalt ferrite is hard magnetic material, which has a cubic spinel structure with excellent magnetic, electrical property and chemical stability, has been extensively used for various technological application.

Neutron irradiation can be a powerful tool to increase crystallographic defects to modify the structural, electrical, and magnetic properties.

Aim of work

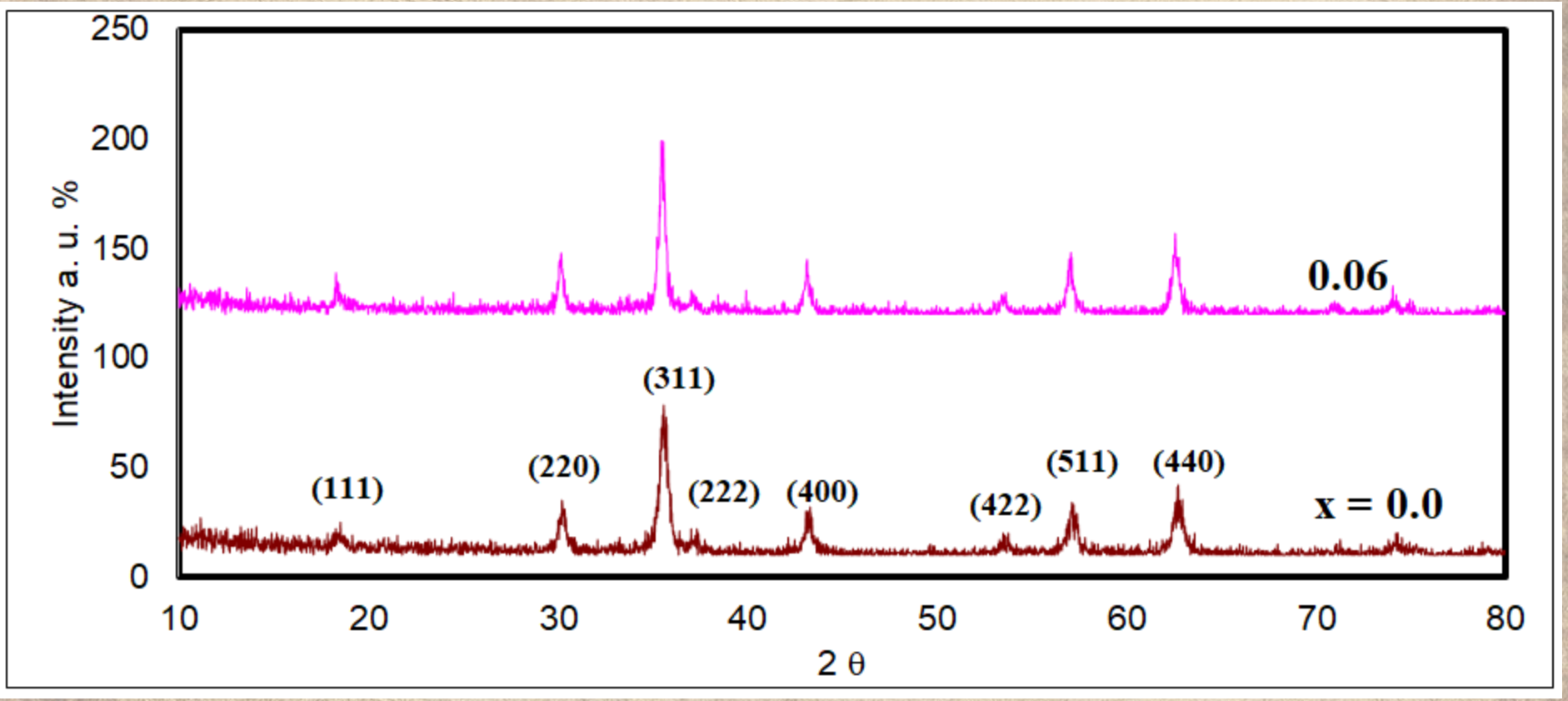
This work studies the effect of different doses of thermal neutron on $CoLa_xFe_{2-x}O_4$ (x= 0, and 0.06) to increase crystallographic defects to modify the structural, and magnetic properties of ferrites.

Synthesis

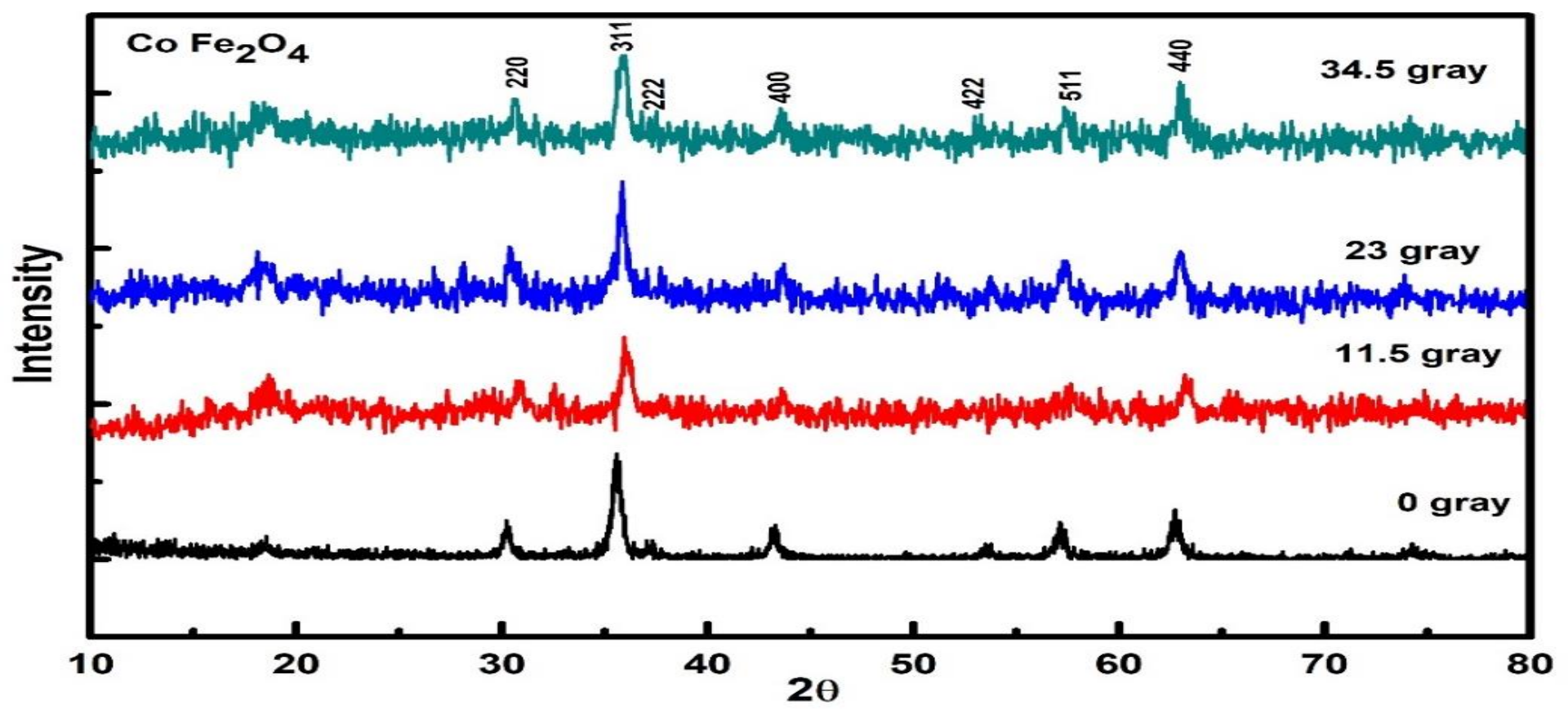

NaOH
$CoCl_2.6H_2O$
$LaCl.3.7H_2O$
$FeCl_3$
Stirring at 40 °C
600 rpm
180 minutes
$CoLa_xFe_{2-x}O_4$
Dried at
80 °C
8 Hours
As-synthesised
$CoLa_xFe_{2-x}O_4$
$CoLa_xFe_{2-x}O_4$
calcinated
at
400 °C
3 Hours
Co-precipitation Method
x=0, and 0.06

Results and discussion

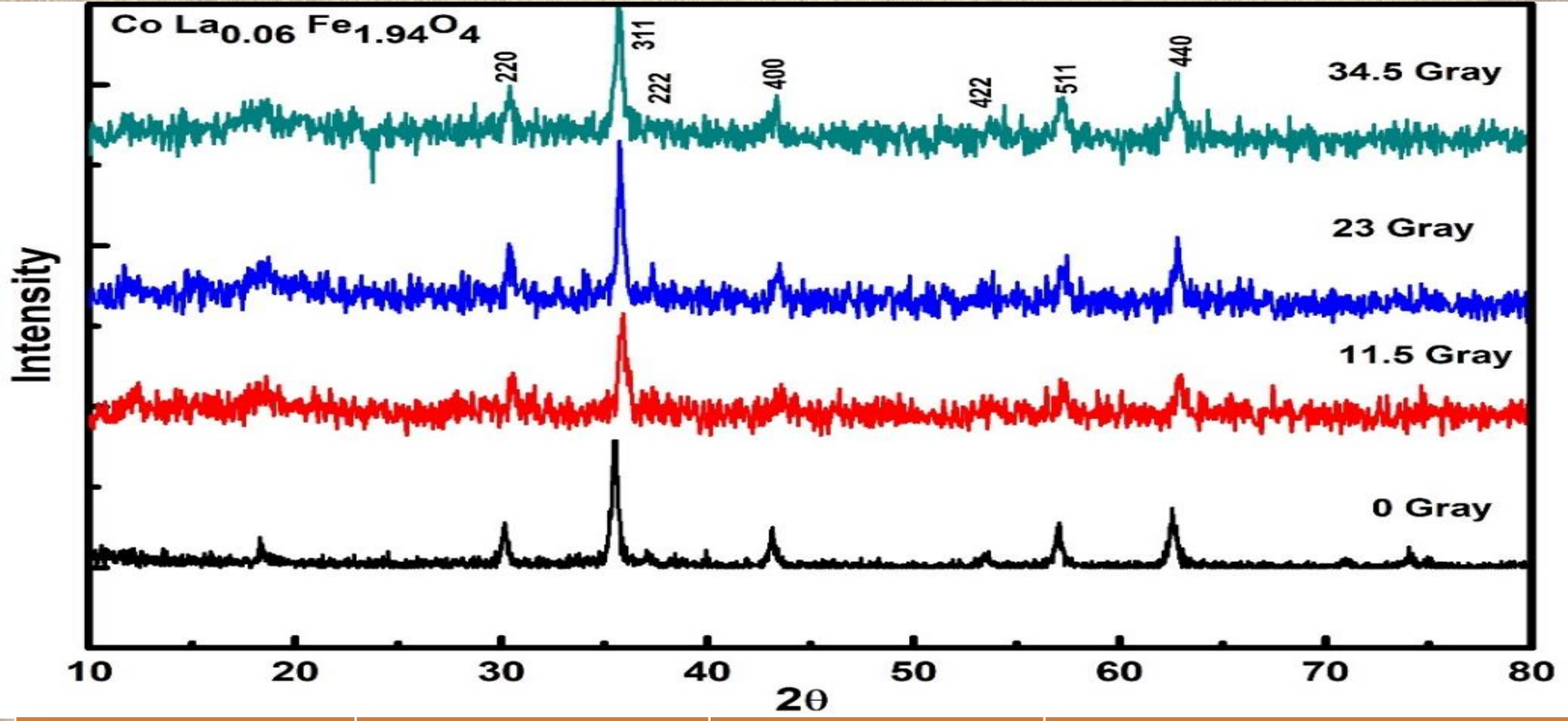
X-Ray Measurements



Sample	a(Å)	R(nm)	δ(nm^{-2})
0.0	8.35913	23.66	0.0019
0.06	8.38111	37.949	0.0014



Dose	a(Å)	R(nm)	$\delta(nm^{-2})$
0	8.35913	23.66	$1.876*10^{-3}$
11.5	8.35780	23.574	$1.799*10^{-3}$
23	8.33089	23.573	$1.799*10^{-3}$
34.5	8.31908	17.918	$3.115*10^{-3}$



Dose	a(Å)	R(nm)	δ(nm^{-2})
0	8.38111	37.949	$1.44*10^{-3}$
11.5	8.33988	16.397	$3.719*10^{-3}$
23	8.31617	19.111	$2.738*10^{-3}$
34.5	8.33955	15.225	$4.314*10^{-3}$

Bulk cobalt ferrite has perfect spinel structure with equal distribution of Fe^{3+} ions on both A-site (octahedral site) and B-site (tetrahedral site),

$$(Fe_1)[Co\ Fe]O_4$$

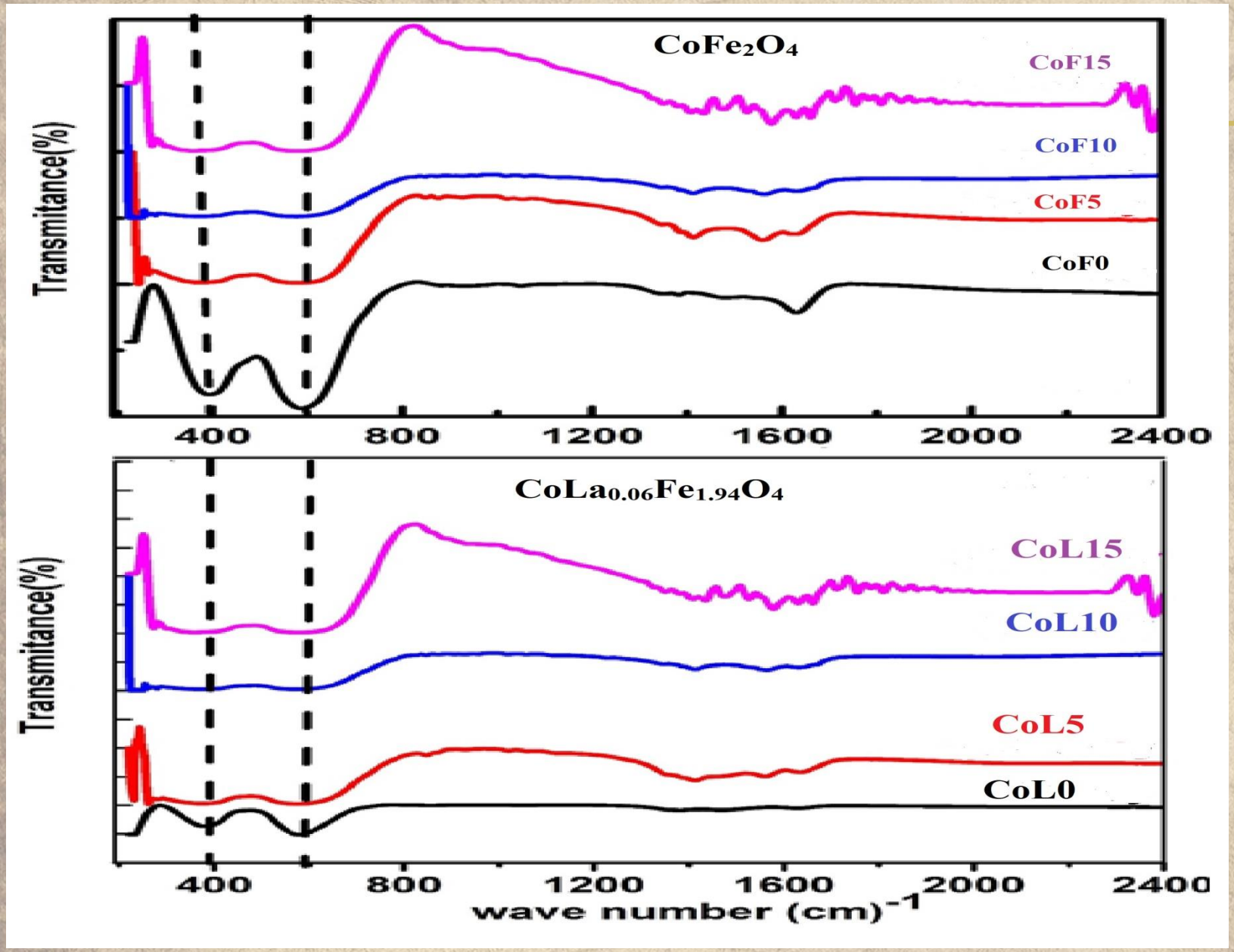
but in nanometer scale it is in mixed spinel state

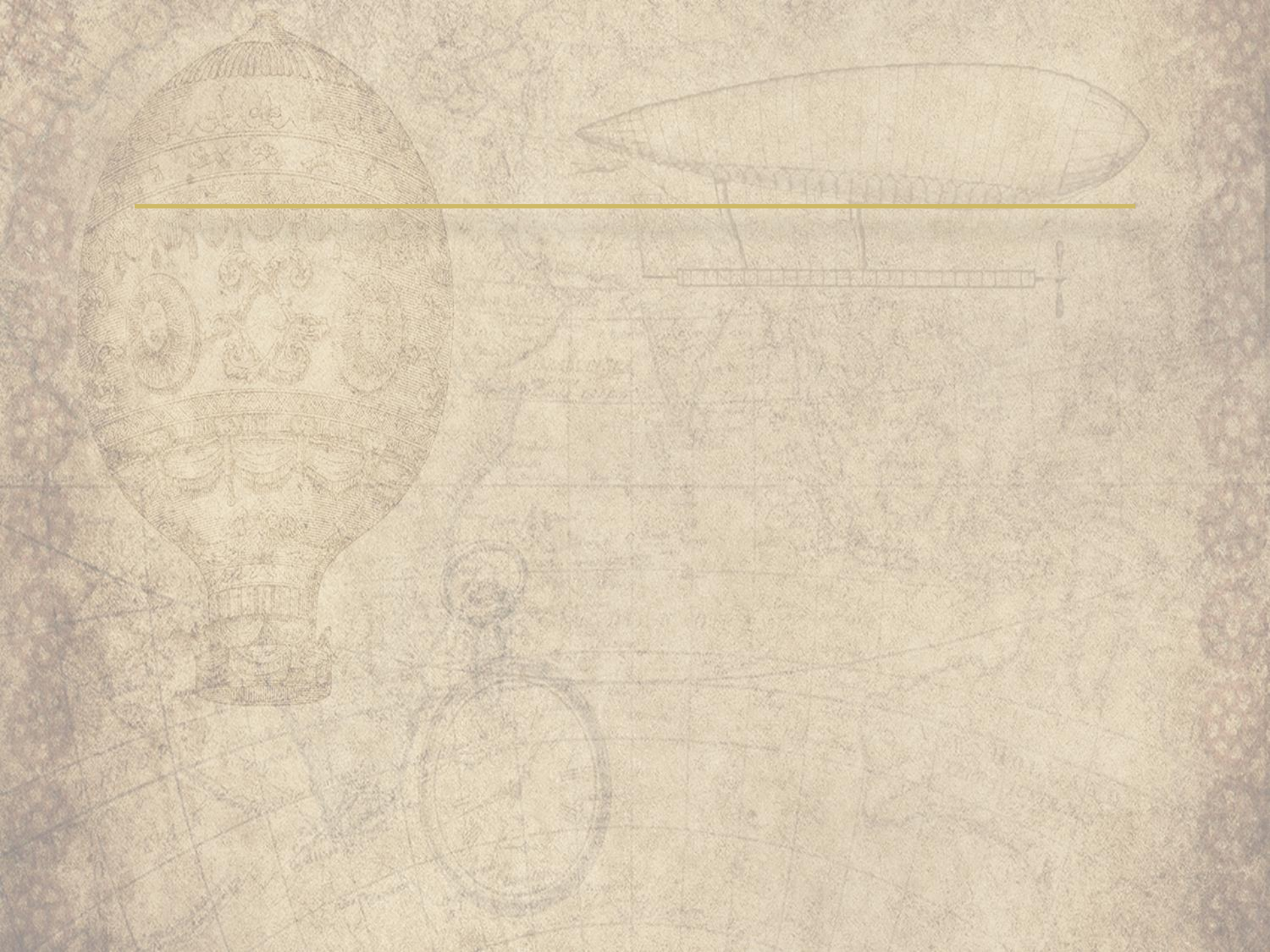
$$(Co_xFe_{1-x})[Co_{1-x}Fe_{1+x}]O_4$$

Co(II)	4-coordinate, tetrahedral	0.72
Co(II)	6-coordinate, octahedral	0.79
Co(II)	6-coordinate, octahedral, high spin	0.885
Co(III)	6-coordinate, octahedral	0.685
Co(III)	6-coordinate, octahedral, high spin	0.75
Fe(II)	6-coordinate, octahedral, low spin	0.61
	6-coordinate, octahedral, high spin	0.78
	8-coordinate, octahedral, high spin	0.92
Fe(III)	6-coordinate, octahedral, low spin	0.55

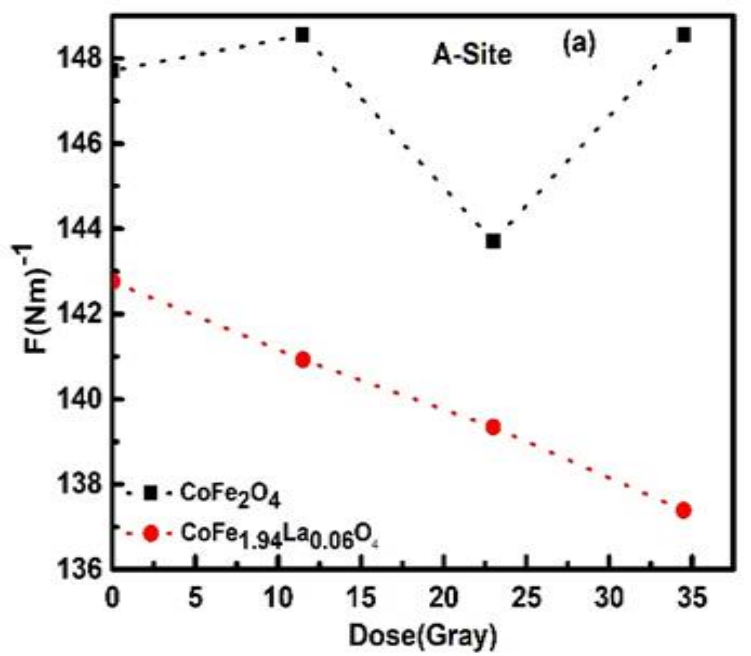
So, the effect of radiation on the compound $CoLa_xFe_{2-x}O_4$ (x= 0, and 0.06) is the shrinkage of the unit cell, as a result of the cobalt ion changing valence from di- to tri-.

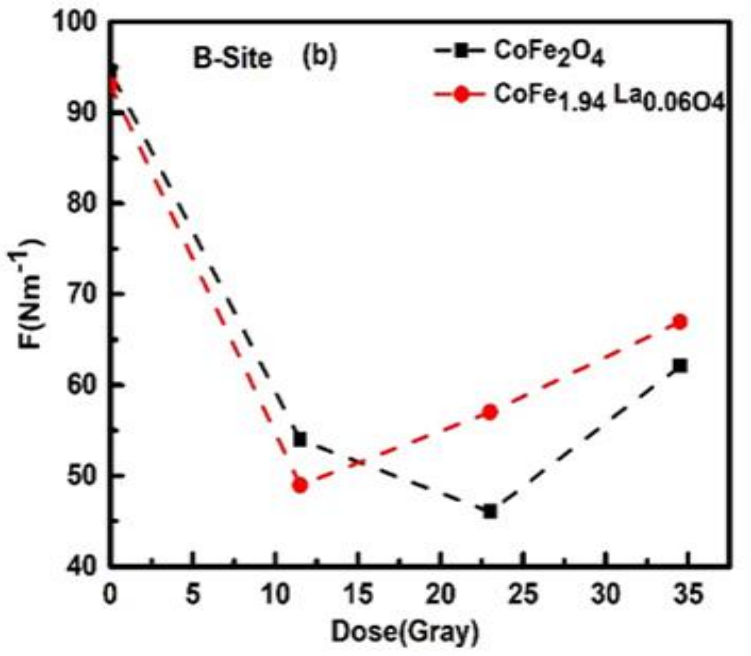
FT-IR Measurements





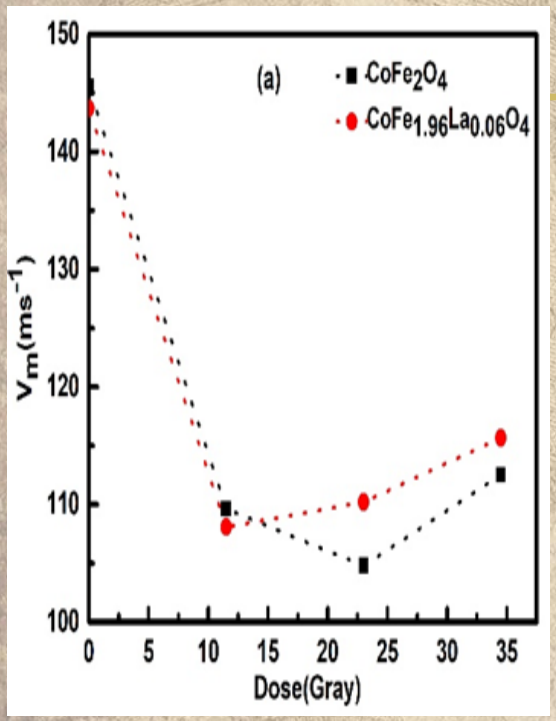
FT-IR

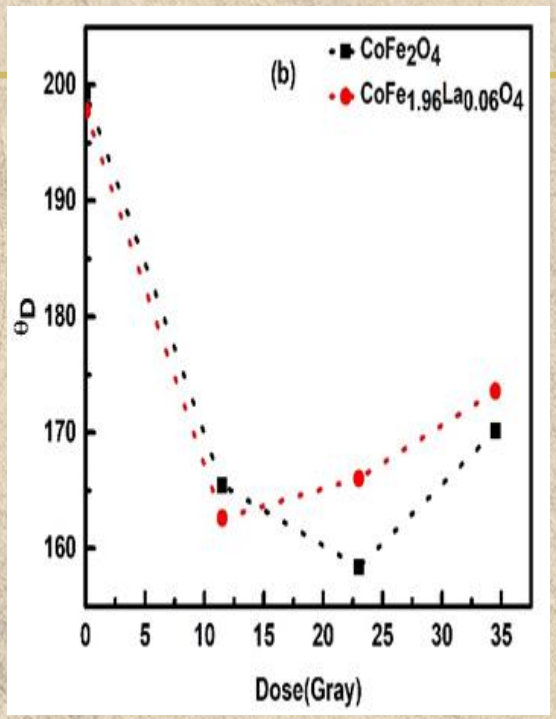


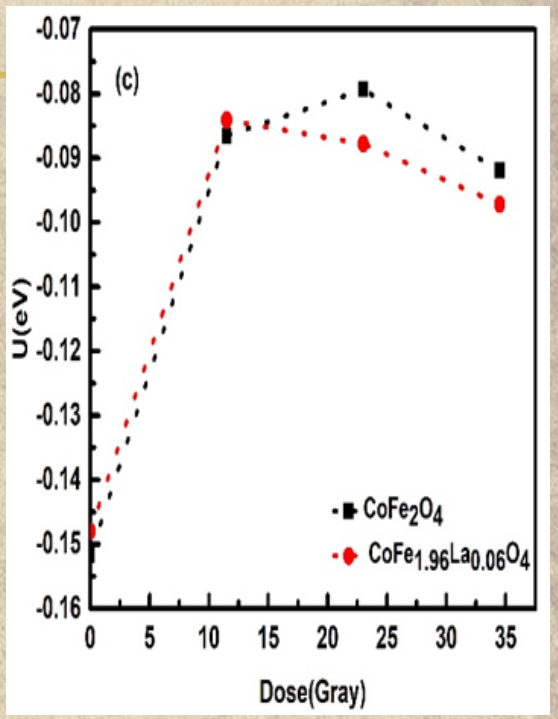


The force constant of $CoFe_2O_4$ and $CoLa_{0.06}Fe_{1.94}O_4$ nanoparticles at different doses.

FT-IR

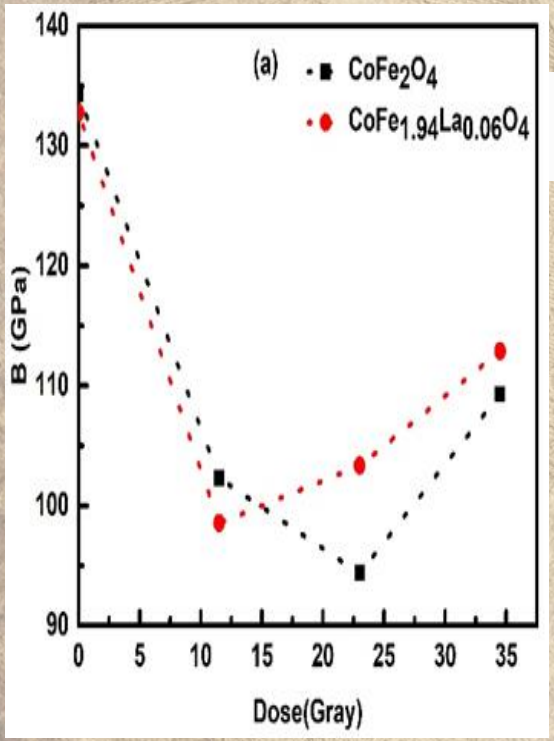


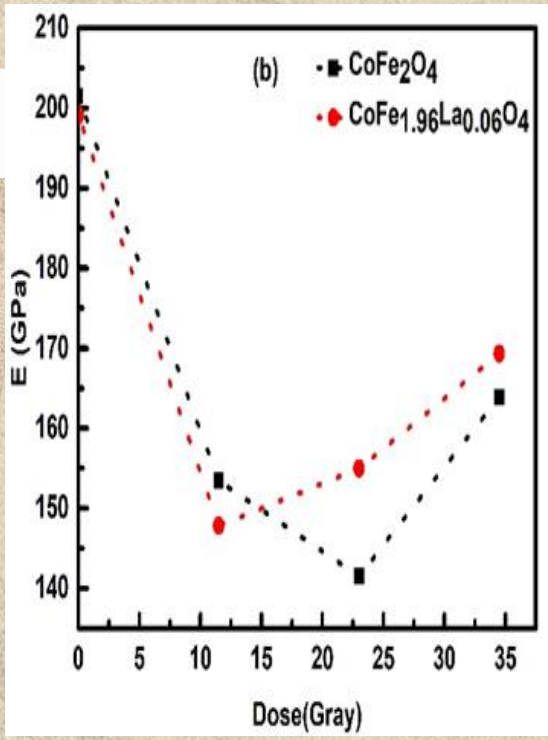


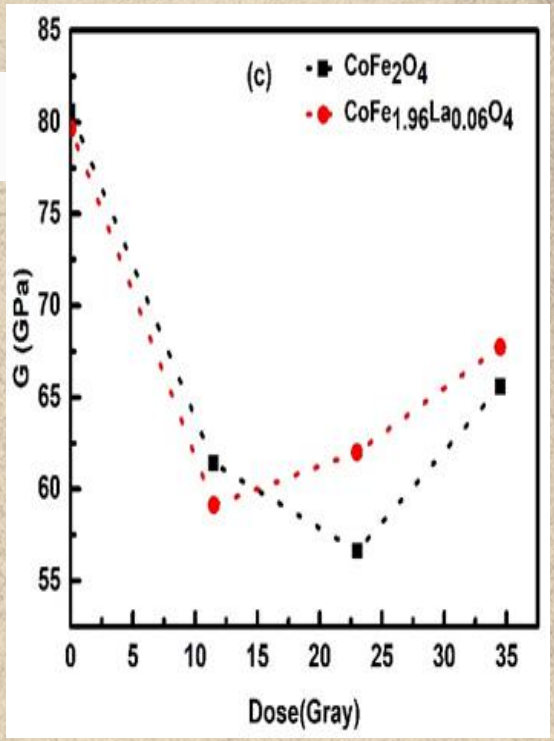


The dose dependence of: (a) mean velocity of elastic waves (V_m) ,(b) The Debye temperature (θ_D), (c) The lattice energy (U) for $CoFe_2O_4$ and $CoLa_{0.06}Fe_{1.94}O_4$ nano-ferrites.

FT-IR

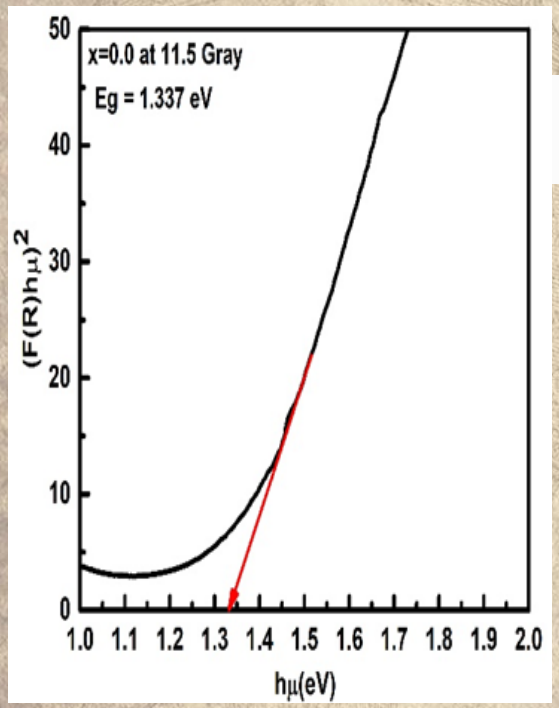


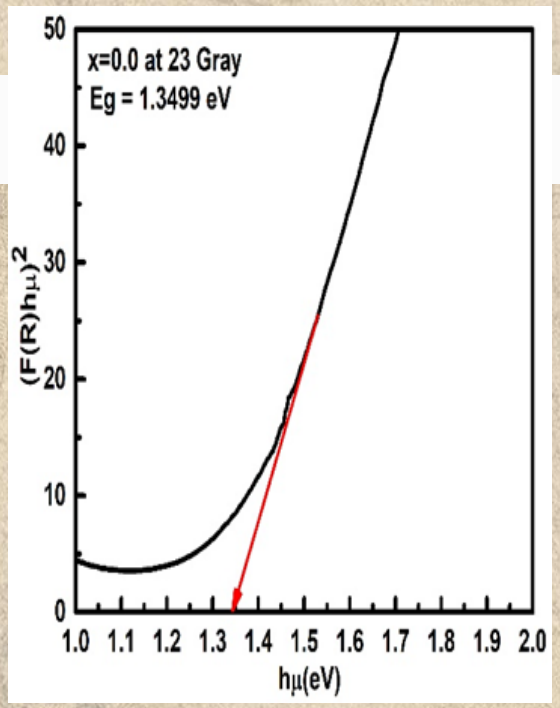


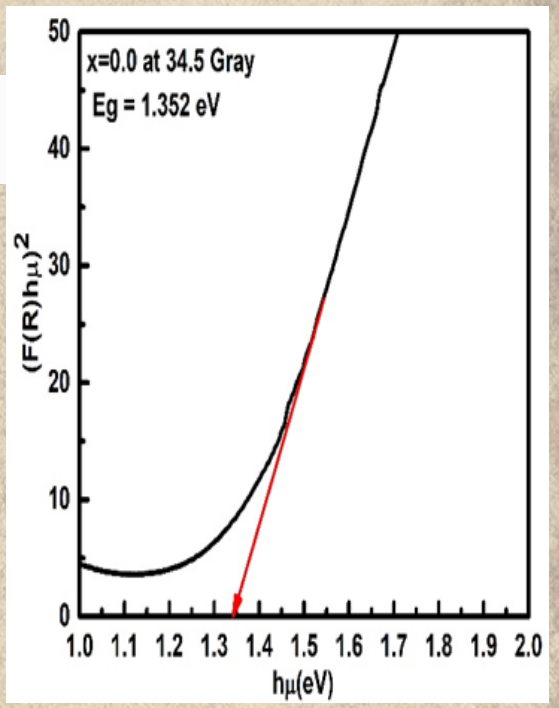


Dose dependence of different elastic parameters of $CoFe_2O_4$ and $CoLa_{0.06}Fe_{1.94}O_4$ nano-ferrites (a) Bulk modulus (B) ,(b) Young's modulus (E) and (c) rigidity modulus (G).

UV–Vis Spectra

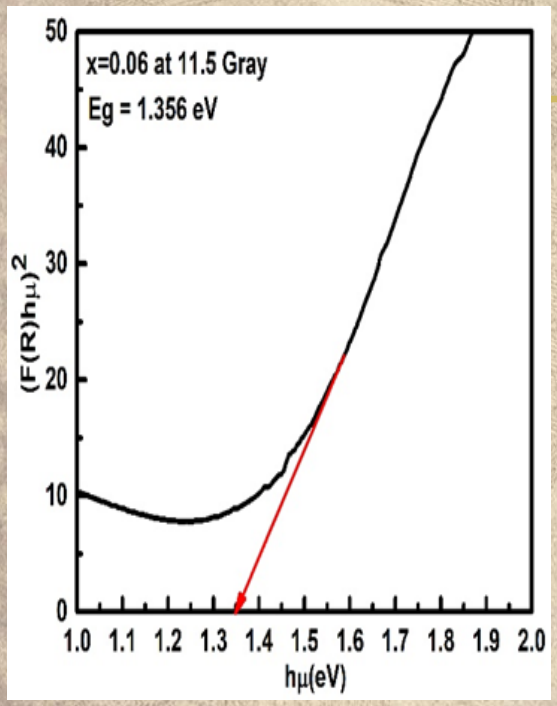


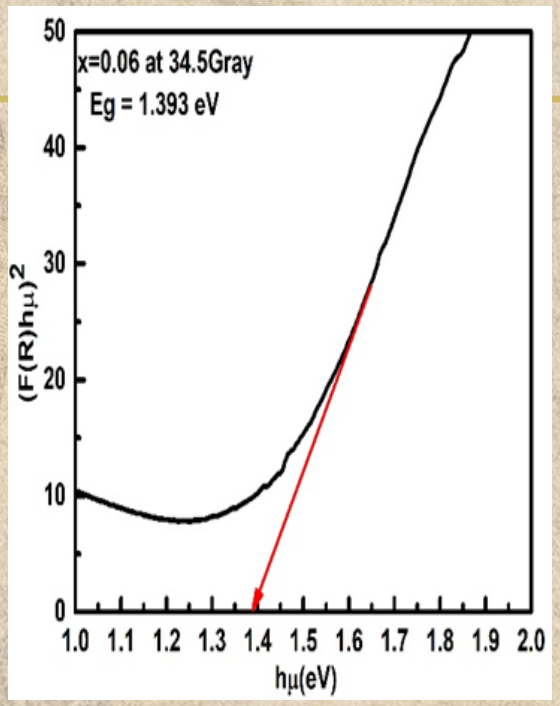


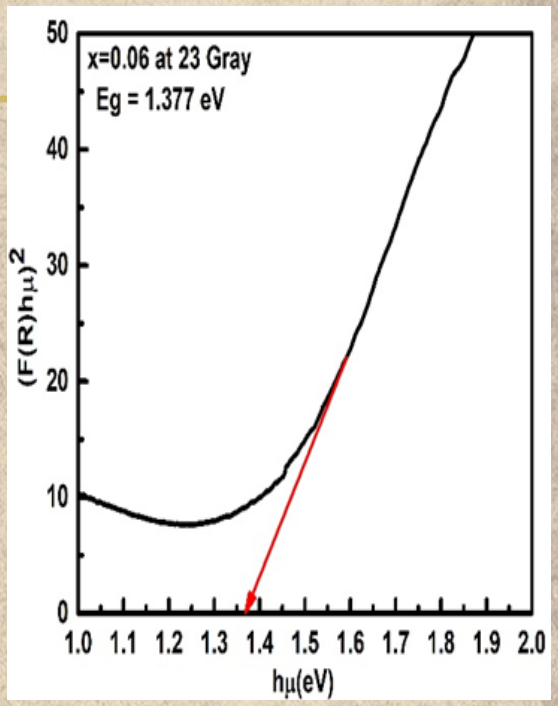


Variation of $\alpha h\nu^2$ with photon energy (hν) of as-fabricated $CoFe_2O_4$ nano-ferrites samples after irradiation

UV–Vis Spectra





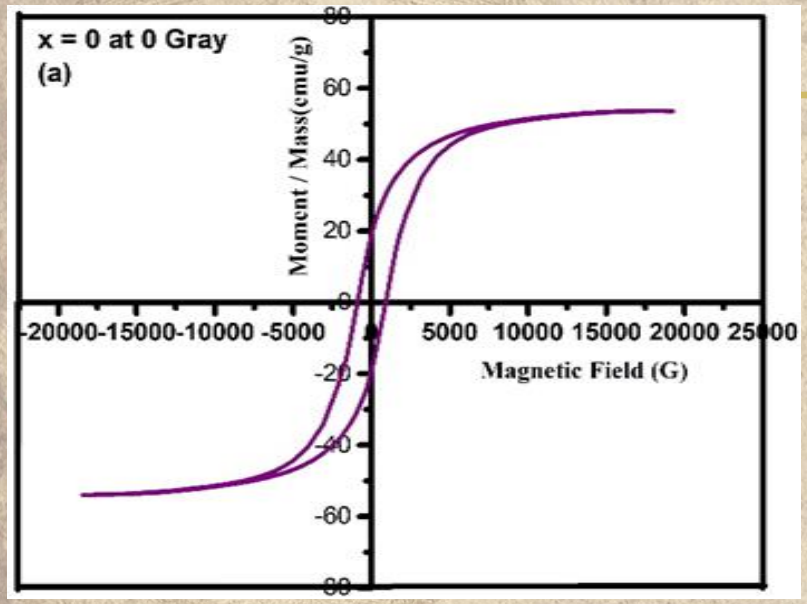


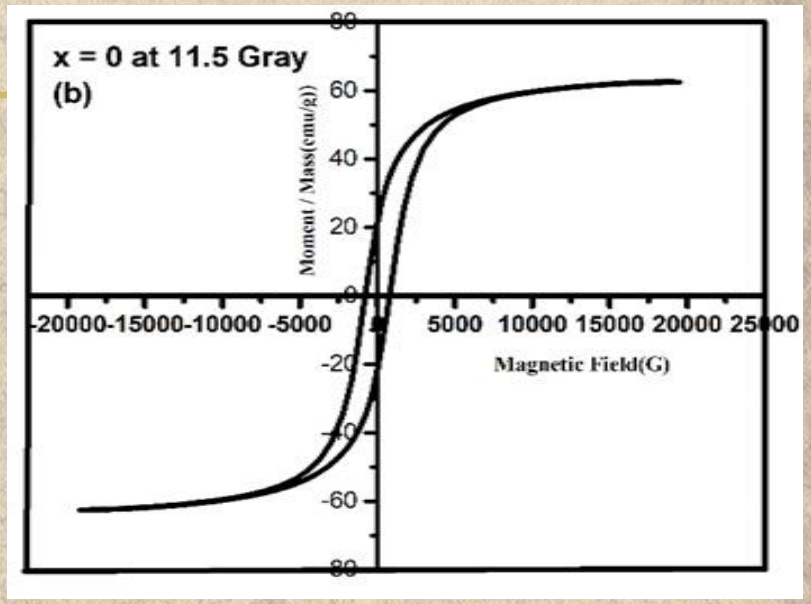
Variation of $\alpha h\mu^2$ with photon energy (hμ)of as-fabricated Co$La_{0.06}Fe_{1.94}O_4$ nano-ferrites samples after irradiation.

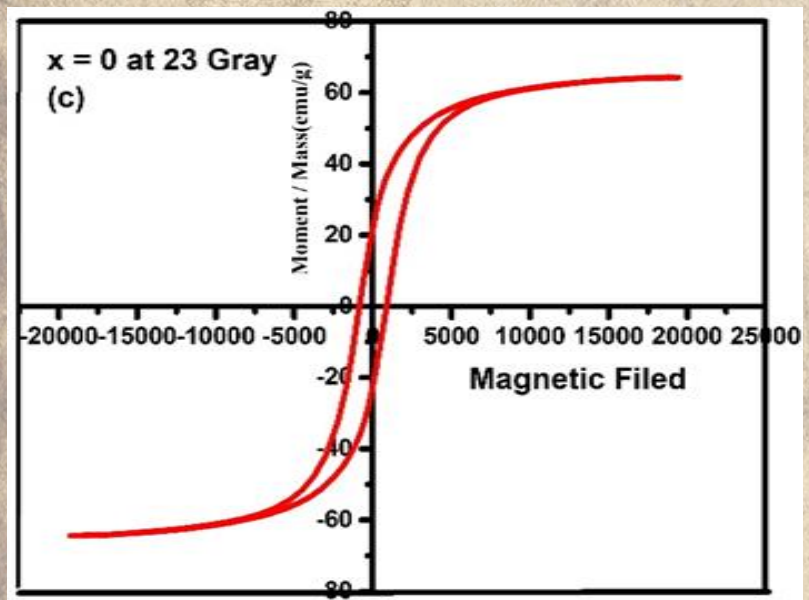
UV–Vis Spectra

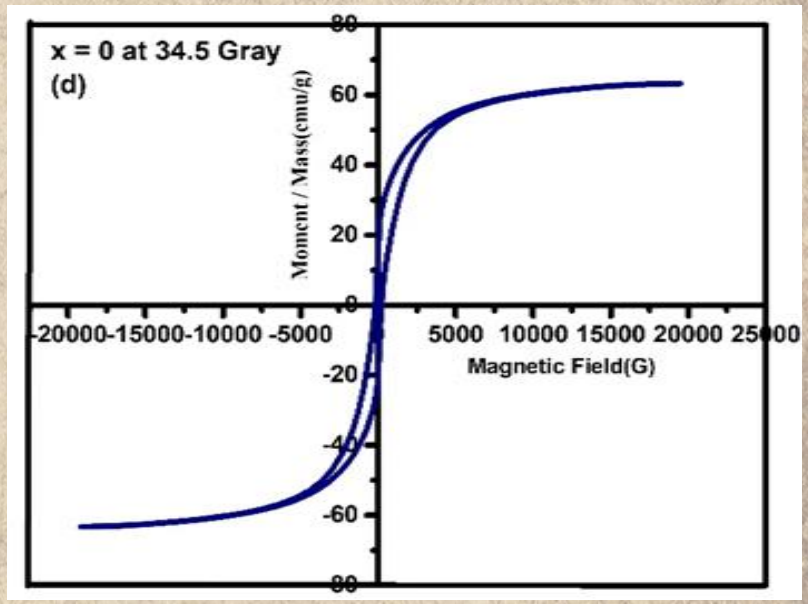
Sample	X=0			X=0.06		
	11.5 Gray	23 Gray	34.5 Gray	11.5 Gray	23 Gray	34.5 Gray
Energy gap (eV)	1.337	1.349	1.352	1.366	1.377	1.393

VSM measurements of $CoFe_2O_4$

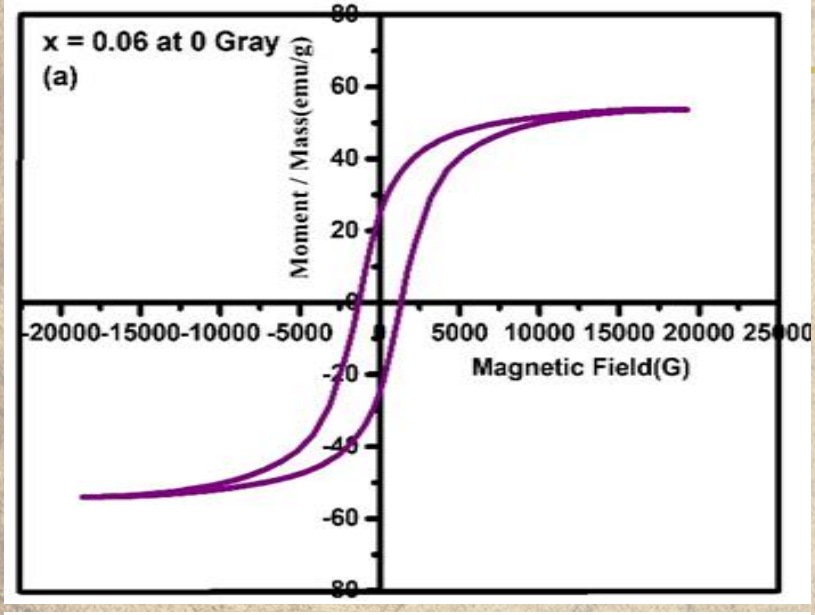


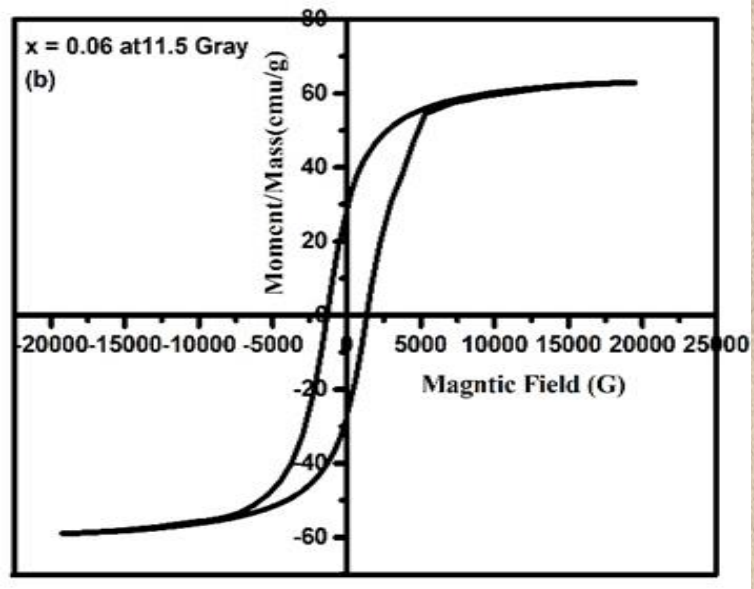


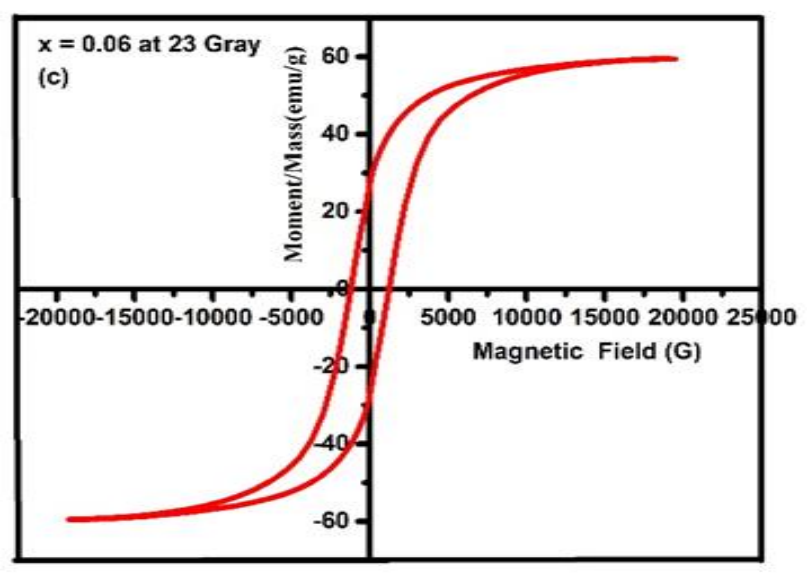


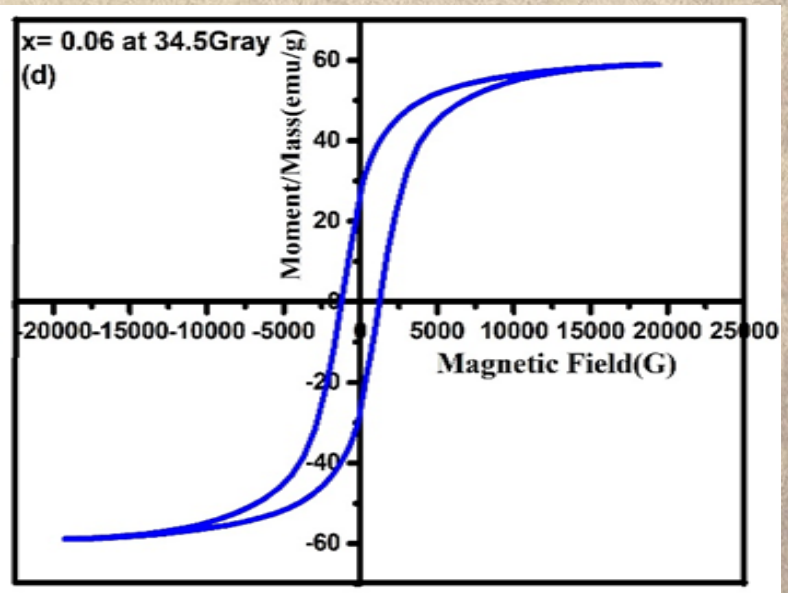


VSM measurements of $CoFe_{1.94}La_{0.06}O_4$





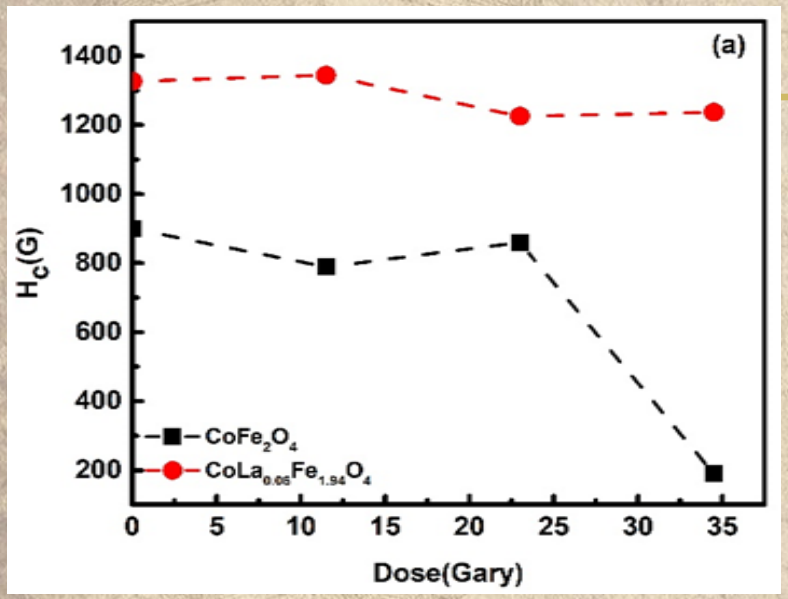


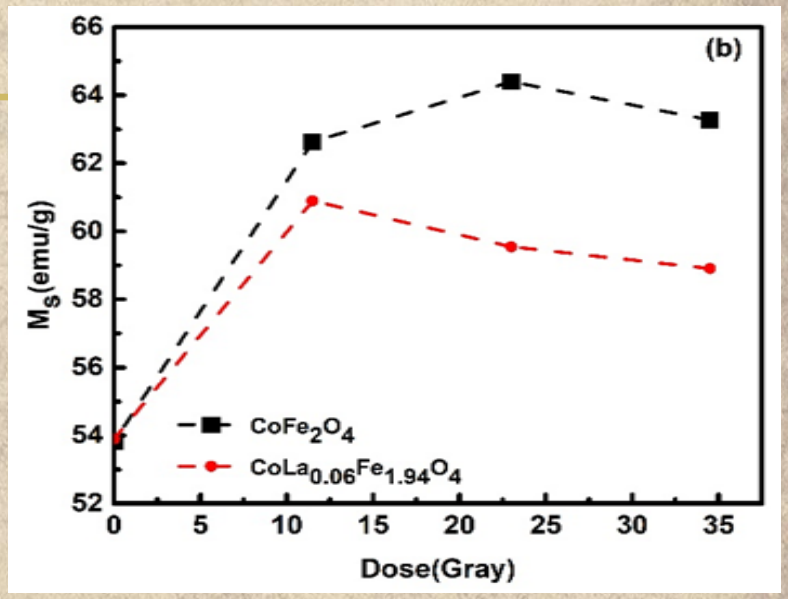


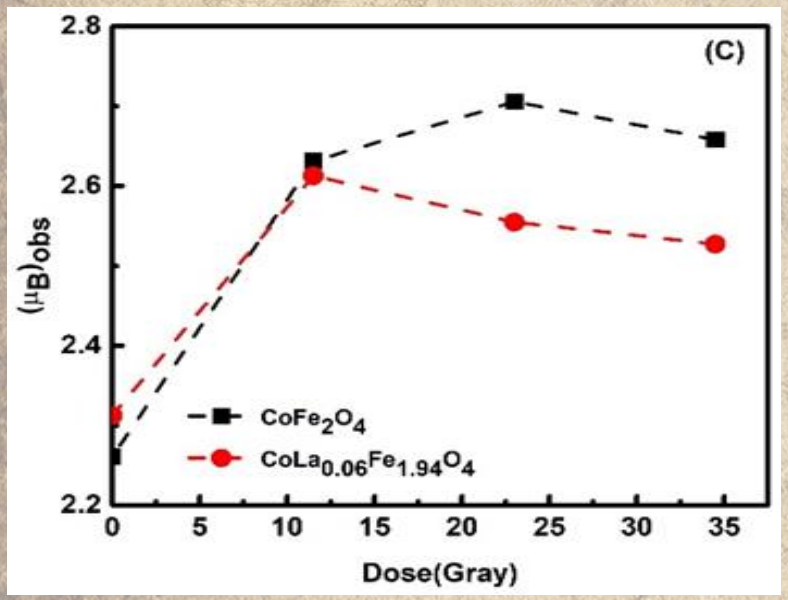
VSM Results

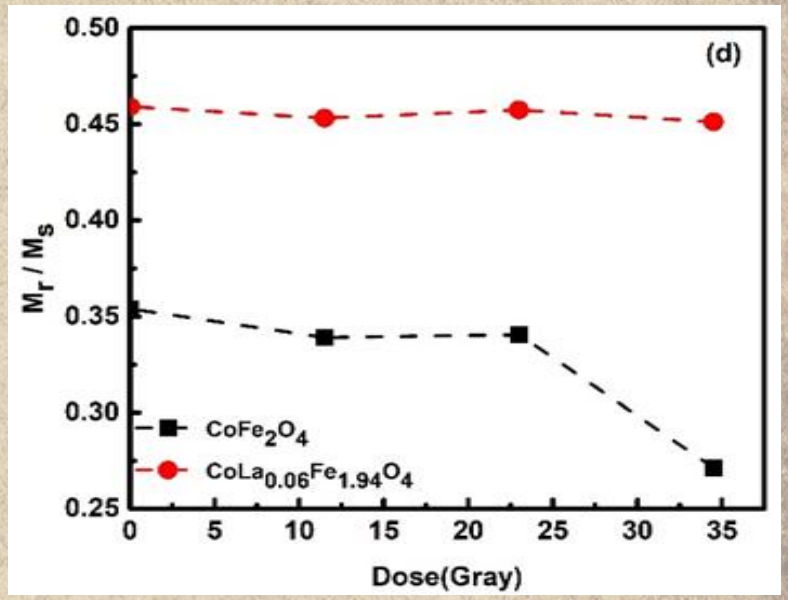
	$CoFe_2O_4$				$CoLa_{0.06}Fe_{1.94}O_4$			
Dose	0	11.5	23	34.5	0	11.5	23	34.5
H_{ci} (G)	899.7	789.21	859.4	189.8	1327	1344	1225.4	1236.7
M_r(emu/g)	19.05	21.239	21.93	17.17	24.76	27.99	27.239	26.580
M_s emu/g)	53.82	62.629	64.40	63.27	53.91	60.91	59.545	58.905
$R^2=M_r/M_s$	0.354	0.3391	0.341	0.272	0.461	0.461	0.4575	0.4513
$(\mu_B)_{obs}$	2.261	2.6307	2.703	2.658	2.313	2.613	2.5546	2.5272

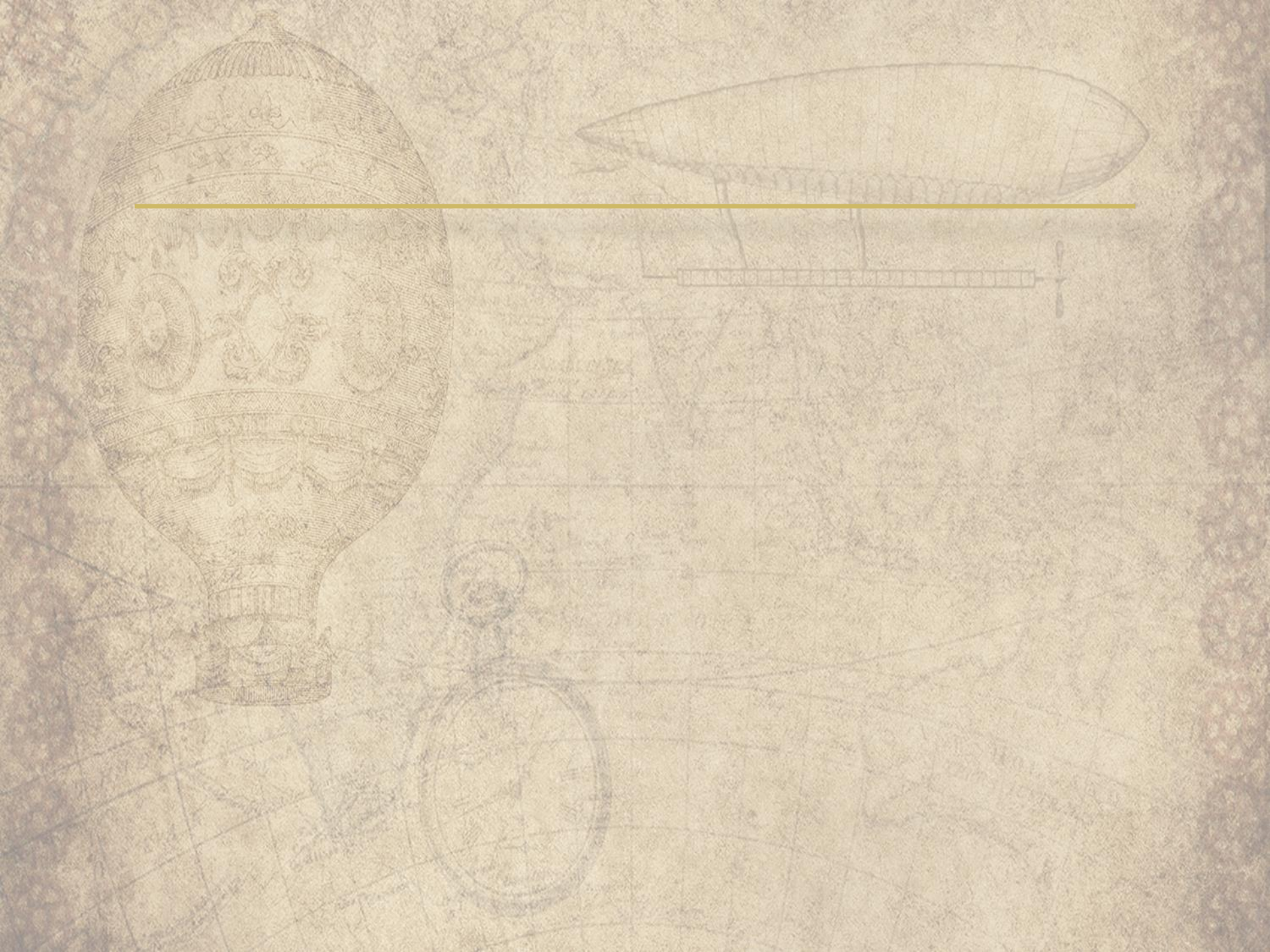
VSM Results


(a)
H_c(G)
Dose(Gary)
$CoFe_2O_4$
$CoLa_{0.06}Fe_{1.94}O_4$


(b)
M_s(emu/g)
Dose(Gray)
$CoFe_2O_4$
$CoLa_{0.06}Fe_{1.94}O_4$


(C)
$(\mu B)_{obs}$
Dose(Gray)
$CoFe_2O_4$
$CoLa_{0.06}Fe_{1.94}O_4$


(d)
M_r / M_s
Dose(Gray)
$CoFe_2O_4$
$CoLa_{0.06}Fe_{1.94}O_4$



Thank

you for

your attention