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Nd: YAG laser irradiation effects on structural and magnetic properties of $Ni_{1+x}Zr_xFe_{2-2x}O_4$ nanoparticles

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Highlights

- The 112 mJ Nd: YAG laser irradiation and Zr substitution can alter the properties of nickel ferrite nanoparticles.
- High crystallinity and small crystallite size were observed in irradiated material.
- Morphology of the samples damaged after irradiation.
- The magnetic parameters were found to enhanced remarkably after irradiation.

Abstract

The effect of 112 mJ Nd: YAG laser irradiation on structural, morphological, infrared and magnetic properties of $Ni_{1+x}Zr_xFe_{2-2x}O_4$ spinel ferrite nanoparticles has been systematically investigated in the present work. The sol-gel auto combustion synthesis method was successfully executed for the synthesis of the present system. All the samples were characterized by X-ray diffraction technique (XRD), scanning electron microscopy (SEM) and infrared spectroscopy (IR) technique. The magnetic

properties of the present samples were measured by pulse field hysteresis loop technique. All the properties were measured for laser irradiated samples as well, to understand the effect of irradiation on the properties. The single-phase cubic spinel structure was confirmed by X-ray diffraction patterns of all samples and the disordered structure was observed for irradiated samples. The two principle absorption bands in IR spectra also confirm the formation of the spinel structure. Spherical and agglomerated morphology was observed for Zr^{4+} substituted nickel ferrite, whereas scratched morphology was observed for the irradiated samples. The grain size confirms the nanocrystalline nature, the crystallite size also evident the same. The magnetic parameters decreased after Zr^{4+} ion doping and strongly influenced by the irradiation.

Introduction

In the recent years, nanosize spinel ferrite particles received a considerable attention because of their interesting structural and magnetic properties (Jalaiah and Babu, 2017, Pawar et al., 2017, Mohseni et al., 2012). When the particle diameter reduces to nanometer dimension spinel ferrite particles may exhibit superparamagnetic behavior, which is of great interest from the point of view of their applications (Foresti et al., 2017). Spinel ferrites are compounds of iron oxides and some metal oxides and they possess important electrical and magnetic properties, which made them extensively useful in various applications such as magnetic storage, microwave devices, transformer core, etc (Akhtar et al., 2017). Nickel ferrite holds inverse spinel structure i.e. the tetrahedral (A) sites occupied by ferric ions and the octahedral [B] site by ferric and nickel ions. It is one of the important spinel ferrites which has various industrial and technological applications since it has interesting magnetic property (Ruthradevi et al., 2017).

During the last few decades, several researchers have made attempt to find the influence of the various type of ions i.e. divalent (Humbe et al., 2017), trivalent (Aghav et al., 2011), tetravalent (Kounsalye et al., 2017a, Kounsalye et al., 2017b) substitution on their remarkable properties. Also, the influence of various radiations viz. laser, gamma, neutron, swift heavy ion etc. on the physical properties of spinel ferrite (Angadi et al., 2017, Raut et al., 2016, Imam and Hashhash, 2014). It is known that high-energy photons interact with a solid by exciting electrons from one of the filled bands into the unbound continuum levels above the conduction band. In the present study, nonmagnetic zirconium ions are used for substitution since they easily enter the spinel structure and strongly prefer the octahedral [B] site. In literature, very few reports are available on the systematic study of laser irradiation effect on ferrite materials. According to the literature, our aim is

to synthesize nanoparticles of Zr^{4+} substituted nickel ferrite by sol-gel auto combustion technique and to investigate the effect of 112 mJ Nd: YAG laser irradiation on structural, morphological, infrared and magnetic properties.

Section snippets

Synthesis of $Ni_{1+x}Zr_xFe_{2-2x}O_4$ nanoparticles

The sol-gel auto combustion method was implemented to synthesize zirconium substituted nickel ferrite ($Ni_{1+x}Zr_xFe_{2-2x}O_4$) nanoparticles as shown in flowchart given below (Fig. 1). The nitrates of respective cations as oxidant and citric acid as a fuel were used in the process of synthesis. The metal nitrates to citric acid ratio were taken as 1:3 owing to propellant chemistry. The final pH of the solution was maintained at 7 by using ammonia solution. The solution mixture was slowly heated to 90…

X-ray diffraction (XRD)

The X-ray diffraction patterns of unirradiated and irradiated $Ni_{1+x}Zr_xFe_{2-2x}O_4$ (x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6) nanoparticles are shown in Fig. 2(a) and (b) respectively. The patterns revealed the formation of single phase spinel cubic structured nanoparticles. All the Braggs reflections observed in XRD pattern match well with those of nickel ferrites reported earlier (Shirsath et al., 2012) and also match well with the JCPDS reference card 10-0325 for both irradiated and unirradiated…

Conclusions

The zirconium substituted nickel ferrite ($Ni_{1+x}Zr_xFe_{2-2x}O_4$) nanoparticles were successfully synthesized by sol-gel auto combustion technique. The structural, Infrared and morphological properties of Ni-Zr ferrites are very sensitive, which in turn critically depends on the irradiation process. Thus, on laser irradiation, the structural and magnetic properties of Ni-Zr ferrite nanoparticles were modified. The XRD patterns of laser irradiated samples show a disordered cubic structure. The higher…

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