

Structural, Morphology and magnetic properties of nanostructured Ag doped BaSrFe_{12-x}O₁₉ hexaferrite nanoparticles prepared by Auto combustion method

A. Thippeswamy

Department of PG Studies in Industrial Chemistry, Government Arts and Science College(autonomous), Karwar, Karnataka, India.

OPEN ACCESS

Article Citation:

A.Thippeswamy, "Structural, Morphology and magnetic properties of nanostructured Ag doped BaSrFe_{12-x}O₁₉ hexaferrite nanoparticles prepared by Auto combustion method", International Journal of Recent Trends in Multidisciplinary Research, July-August 2026, Vol 6(04), 347-351.



©2026 The Author(s). This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. Published by 5th Dimension Research Publication

Abstract: Ag doped Ba strontium hexaferrite AgBaSrFe₁₂O₁₉ were prepared using urea precursor by auto combustion method. Samples were characterised by using different measurement techniques. X-ray diffraction (XRD) confirmed the formation of M phase with an average crystallite size of 24–45 nm. Observed tensile strain leads to the elongation of Ag, Ba grains and was calculated using Williamson Hall plot. Surface morphology of these samples was studied by using field emission scanning electron microscopy (FESEM) SEM image shows the agglomeration and flakes type nanoparticles and presence of the metals in the ferrite and its Composite was confirmed by EDX pattern. M–H loops of these samples were measured at room temperature using vibrating sample magnetometer (VSM). With concentration of Ag doped undoped nanomaterial, specific saturation magnetisation (Ms), coercivity (Hc) and retentivity (Mr) values were found to decrease. These parameters make this material a promising candidate for the applications such as high density magnetic recording and enhanced memory storage.

1. Introduction

In past few years, mixed ferrites have attracted much attention because of their vast applications, ranging from microwave to radio frequencies such as microwave devices, computer memories and magnetic recording [1]. Semiconductor technologies are developing magnetic random access memories where non-volatile magnetic dots are used for storage capacities of a traditional semiconductor. The typical grain size is essential in the storage of today's commercial magnetic hard disks [2]. The addition of silver to strontium hexaferrite will provide a new composite material with good magnetic behaviour. The influence of magnetic and antibacterial properties can make this material unique for applications in biomedicine [3]. studied the effect of silver substitution in magnesium ferrite and observed an enhancement in its thermal and electrical conductivity. Sun et al. have shown that the biological activity of Fe₃O₄ nanoparticle which was improved by coating a thin film of silver on to it. Nanoparticles of silver, TiO₂ and ZnO are used as antimicrobials and additives in consumer and industrial products [4]. Barium ferrites is possible to increase the magnetic and dielectric characteristics, which cause permanent magnets, catalysts, microwave devices.

In this work capping and uncapping of Ag embedded on synthesis the BaSrFe₁₂O₁₉ nano-hexaferrites by using Auto combustion method, which is an efficient cost effective process over other conventional preparation methods, and it is less time consumption. In addition to that, an effect of doping the composite materials morphological and structural properties of BaSrFe₁₂O₁₉ nanomaterial were examined. The structural, elemental and morphological properties of the ferrite nanoparticles can study by using XRD, EDX and SEM analyses. The obtained results very good as compared reported.

2. Experimental Procedure

2.1 Material used for synthesis of Ag doped BaSrFe₁₂O₁₉

For the synthesis of Ag doped BaSrFe₁₂O₁₉, the reagents were used as precursors are as follows: metal nitrate, (Fe(NO₃)₃·9H₂O, Sr(NO₃)₂, Ag(NO₃)₂, Ba(NO₃)₂ in ethylene glycol, sodium hydroxide, urea and deionized water as solvent. were used as product of Merck with purities exceeding 99% without further purification.

2.2 Synthesis procedure

Nano crystalline particles Ag doped BaSrFe₁₂O₁₉ were synthesized by Auto combustion method. The synthesis of Ag-BaSrFe₁₂O₁₉ nanoparticles, solutions containing (Fe(NO₃)₃·9H₂O, Sr(NO₃)₂, Ag(NO₃)₂ and Ba(NO₃)₂). All metal nitrates in the appropriate ratio and urea were dissolved in small amount of deionized water in a beaker to get homogeneous solution, which was stirred by a magnetic stirrer at room temperature. The mixture was kept in a furnace and heated to 500 °C about four min large amount of gas (N₂O and CO₂), released a large amount of heat was released by completing the whole reaction. The sintered fluffy powders were ground in an mortar with pestle and mixed with a binder polyvinyl pyrrolidone (PVP) (C₆H₉NO)_n. The fluffy powders are compressed a dia 10 mm and a thickness of about 3 mm by loading a pressure of 8-106 kg/m² for 6 min. The pellets were sintered in a furnace at the temperature of 900 °C for 3h and then gradually cooled to room temperature. The experimental condition favourable for obtaining significant crystalline nanoparticle.

3. Result and Discussion

3.1 Structural analysis

Fig. 1 shows the XRD patterns of calcinated, Ag doped and undoped BaSrFe₁₂O₁₉ samples. were determined using Bruker XRD with CuKα radiation having wavelength 1.5406 Å (Model: D8 Advance, Germany), in the Bragg angle range of 20 - 80° at a scan rate of 2° min at 300 K. The peaks with h, k, l values of planes (214), (222), (227), (247), and (264) and Ag doped and undoped BaSrFe₁₂O₁₉ 2θ at 24.5, 33.0, 38.5, 44.3, corresponds to planes. The value of lattice parameter (a) and the space group of this synthesized nanoparticles obtained from the XRD spectra.

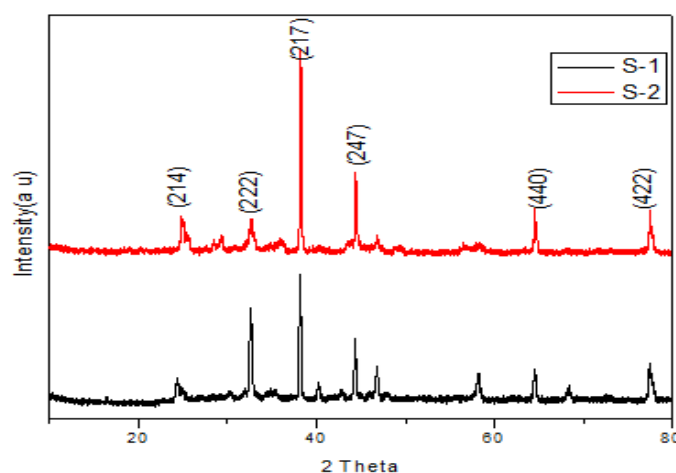


Fig. 1 XRD pattern of Ag-BaSrFe₁₂O₁₉ and BaSrFe₁₂O₁₉ hexaferrites.

In addition, it was observed that the sample Ag-BaSrFe₁₂O₁₉ and BaSrFe₁₂O₁₉ showed around 5% of phase of secondary ferrous oxide (ICSD: 202518). The lattice parameter calculated using the relation,

$$\frac{1}{d^2_{hkl}} = \frac{4}{3} \left(\frac{h^2 + hk + l^2}{a^2} \right) + \frac{l^2}{c^2}$$

Where d_{hkl} is the crystal planes comparing the distance; a and c are the lattice parameters; and (hkl) are the Miller indices. XRD studies showed that the lattice parameter increased slightly from 0.5107 to 0.5729 nm. The increase in lattice parameter with increasing the Ag concentration because of the substitution of larger ionic radius Sr²⁺ (0.112nm).

3.2 Funtional analysis

FTIR spectrum of calcinated capping Ag doped BaSrFe₁₂O₁₉ and uncapping Ag doped Ag doped ag-BaFe₁₂O₁₉ at 800 °C for 4 h is shown in Fig. 2 (a, b). hexagonal structure is confirmed by the most important absorption peak is detected in the range of 610-569 cm⁻¹. This peak is apporioned to the intrinsic stretching vibration of bonds between Fe²⁺ and oxygen ions. Another weakest peak detected in the range of 460-480 cm⁻¹ is assigned to the stretching vibration of bonds between Fe³⁺ and Sr²⁺ [5,6]. A reduction in the wavenumber value of 610 indicates that Sr²⁺ preferred tetrahedral sites involve sp³ hybrid orbital and forms covalent bonds. Also Ag⁺ pushes the Fe³⁺ ion to tetrahedral site owing to the higher atomic weight in assessment to Iron and oxygen and affects the bond length of Fe³⁺. The increase in cadmium content influences the metal oxygen bonds in the A-sites is due to the transition hexagonal structures. The absorption bands found at ~675 and ~1000-1300 cm⁻¹ is assigned to the C-H group and C-O stretching bands correspondingly[7].

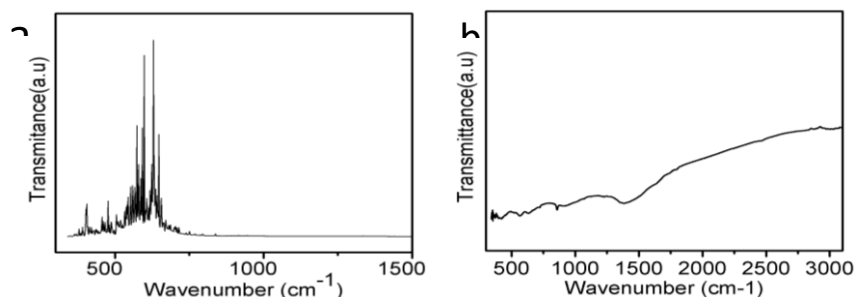


Fig.2 FT-IR spectra of Ag-BaSrFe₁₂O₁₉ hexaferrites

3.3 UV-visible spectroscopy

The optical properties were investigated by using UV-Visible spectrophotometer for calcinated doped Ag doped BaSrFe₁₂O₁₉ and undoped doped BaSrFe₁₂O₁₉ ferrite nanoparticles as presented in Fig. 3. In the condensed phase, Fe³⁺ exhibits three kinds of electronic transitions, first owing to ligand field transition, second owing to ligand metal charge transfer (LMCT from O to Fe) and third corresponds to paired excitation of magnetically coupled Fe ions occupying the adjacent sites in the crystals. The band at 264 nm is accredited to Fe←O charge transfer of isolated Fe ion in octahedral coordination [8]. The band at 373 nm is owing to charge transfer between oxygen and Fe positioned in tetrahedral sites [9].

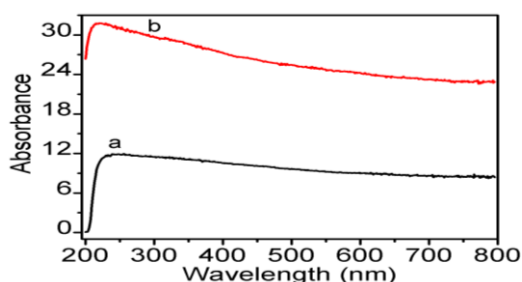


Fig. 3 UV-Visible-spectra of Ag-doped and undoped BaSrFe₁₂O₁₉

3.4 Morphological and elemental analysis

The morphology structure of the prepared ferrite nanoparticles is investigated by using SEM technique. Surface morphology of the prepared sample calcinated Ag-BaSrFe₁₂O₁₉ and BaSrFe₁₂O₁₉ are as revealed in Fig. 4 (a, b). SEM image of calcinated Ag-BaSrFe₁₂O₁₉ and BaSrFe₁₂O₁₉ samples demonstrate the formation of porous, microstructure, spongy and similar to network like structure are shown in Fig. 4. (a) and It can be observed that sample exhibit entirely interannular network with homogenous cavities and pores. In Fig. 4 (b) shows the nearly spherical morphology. exhibit the EDX investigation of pure Ag doped BaSrFe₁₂O₁₉ and calcinated Ag doped BaSrFe₁₂O₁₉ nanoparticles carried out at room temperature for the elemental corroboration and purity of the sample. The EDX spectrum confirms the homogeneity and gradient of the elements Ag, Ba, Sr and Fe are present in the sample. The outcomes suggested that the precursors have completely reacted in the chemical reaction to form the single phase calcinated Ag doped BaSrFe₁₂O₁₉ and undoped nanoparticles as well as it approves that there is definitely not additional impurity existing in the samples. It is suggested that the comparative atomic mass ratio of the metal ferrites are acceptable matched along with the stoichiometry in preparation. The sample is silver coated for the improved visibility of the morphology shows in EDX spectra in form of peak. No impurity, indicating the high purity of all the samples and confirms high crystallinity of all the samples.

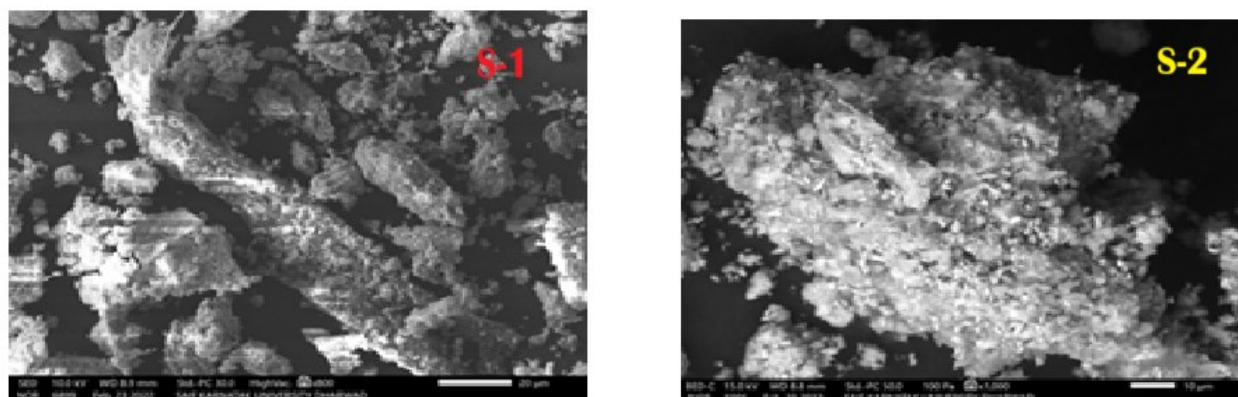


Fig.4 FE-SEM Micrographs of Ag doped(S-1) BaSrFe₁₂O₁₉ and undoped(S-2) nanoparticles.

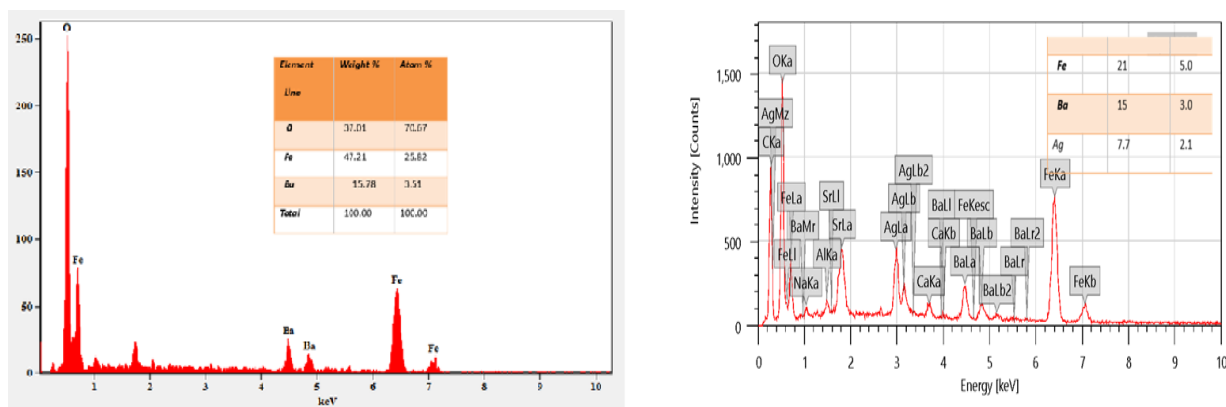


Fig.5 EDAX of Ag doped(S-1) BaSrFe₁₂O₁₉ and undoped(S-2) nanoparticles.

3.5 Magnetic properties

The effects of Ag doped BaSrFe₁₂O₁₉ and undoped nanoparticles were analysed by vibrating sample magnetometer at room temperature operated at an applied magnetic field of 10 kOe. The magnetic parameters i.e., saturation magnetization (Ms), coercivity (Hc) and remnant magnetization (Mr) were determined based on these curves and The hysteresis curves of all samples of M- types hexaferrites with the formula, Ag doped BaSrFe₁₂O₁₉ and undoped nanoparticles. On the whole, the Ms of these samples were more than 25 emu/g, Similarly, the Hc of the nano composites were more than 4500 G, the composites are in comparison to a conventional ferromagnetic and could be considered as hard-magnetic materials as shown in fig.6 [10,11].

The magnetic properties of substituted hexagonal ferrites are impacted by the electronic configuration of substituted or doped cations. The substituted silver (Ag⁺) has an electronegativity of 1.17. The Fe³⁺ ion has five unpaired electrons and the hexagonal ferrites have a total of 12 Fe³⁺ occupied in five distinct sub-lattices [12,13]. One is tetrahedral (4f₁), three are octahedral (12k, 2a and 4f₂), and one is trigonal bipyramidal (2b). Of the twelve Fe³⁺ ions, four are oriented downwards, at 4f₁ (2 Fe³⁺) and eight 4f₂ (2Fe³⁺), are oriented upwards, at 12k (6 Fe³⁺), 2a (1 Fe³⁺), and 2b (1 Fe³⁺). The magnetic moment is caused by the remaining 4Fe³⁺ ions, which have an upward orientation and the four downward and four upward spins cancelled each other [14,15].

Saturation magnetization (Ms) is reduced due to addition of Ag⁺ ions. The magnetic parameters were calculated using the following relationship

$$\eta\beta = \frac{M \times M_s}{5585 \frac{Mr}{Ms}}$$

$$s = \frac{Ms}{Hc \times Ms}$$

$$K = \frac{2a0.64}{Ms}$$

Where $\eta\beta$ is the magnetic movement/ formula unit in μb , Ms - saturation magnetization (emu/g) Mr - remanence magnetization, M - molecular weight in g, 5585-magnetic factor, K-magnetic anisotropic constant and Hc- coercivity. A site substitutes increase magnetization. Compared to Fe³⁺ ions, Ag⁺ ions have a lesser magnetic moment. The magnetization of B sublattices increased as a result of an increase in Fe³⁺ ions at the B location [16,17]. Thus, in the Ag⁺ replaced samples, the magnetization increased. According to results, the saturation magnetization and remanence increase with increasing silver doping. The rise in the Ms value, a larger magnetism in the lattice is generated by an increase of hyperfine fields in the 12K and 2b sites as a result of the superexchange interaction in Fe³⁺-O - Fe³⁺ [18], Which affects the Ag⁺ and (host) Fe³⁺ ions respective ionic radii as well. The values of Ms and Mr with content are compared in fig.6.

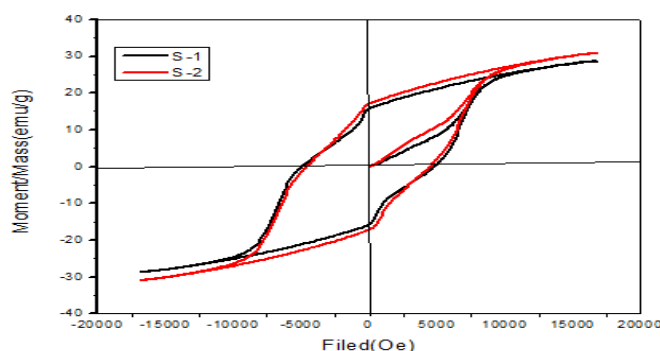


Fig.6. Hysteresis curves of Ag doped BaSrFe₁₂O₁₉ and undoped nanoparticles.

4. Conclusion

In the present study I have synthesized calcinated, Ag doped and undoped BaSrFe₁₂O₁₉ for the effect of temperature on BaSrFe₁₂O₁₉ by auto combustion method. From XRD pattern found calcinated Ag doped and undoped BaSrFe₁₂O₁₉ ferrite nanoparticles is hexagonal structure. The FT-IR spectrum showed two absorption band that are characteristic of nanoferrites and with force constant the KT values were less than the KO values in the samples substituted with Ag⁺ ions. FE-SEM micrographs images were confirmed that the morphological structure is aggregated to the size of nanoparticles. The EDX spectrum confirms the doping Ag concentration and freedom from impurity elements. The VSM analysis of coercivity showed a peak with particle size at a value smaller than the previously reported value of single-domain limit for Ag doped and undoped BaSrFe₁₂O₁₉ that has been attributed to the enhanced role of the surface anisotropy as compared to the bulk for small sizes, which is the result of reduction in super exchange interaction.

Acknowledgments: The authors would like to thank SAIF Karnatak University Dharwad for powder XRD, Characterization facility, SAIF Mysore University, Sahyadri Science College for FT-IR spectra measurement.

Conflict of interest: The authors declare that they have no conflict of interest.

References

1. OKASCHA, A. Spectroscopic Analyses of the Photocatalytic Behavior of Nano Titanium Dioxide. *Spectrochimica Acta Part A: Molecular And Biomolecular Spectroscopy*, 136, 2015, 504-509
2. Dursun, S. et al. Comparison of the structural and magnetic properties of submicron barium hexaferrite powders prepared by molten salt and solid state calcination routes. *Ceramics International*, 38(5), 2012 pp.3801–3806.
3. Thakur, A., Singh, R.R. & Barman, P.B., Crystallization Kinetics of Strontium Hexaferrite : Correlation to Structural , Morphological , Dielectric and Magnetic Properties. , 8(6), 2012pp.595–603.
4. Liu, X. et al., 2012. Magneto-optical Kerr spectra and magnetic properties of Co-substituted M-type strontium ferrites. *Materials Chemistry and Physics*, 133(2–3), pp.961–964.
5. Haq, A. & Anis-ur-rehman, M., 2012. Effect of Pb on structural and magnetic properties of Ba-hexaferrite. *Physica B: Physics of Condensed Matter*, 407(5), pp.822–826.
6. Online, V.A. et al., 2013. induce multiple photoluminescence and room. , pp.1885–1895.
7. Thankachan, S. et al., 2014. Effect of rare earth doping on structural , magnetic , electrical properties of magnesium ferrite and its catalytic activity. , 3(4), pp.529–537.
8. Ke Zhou¹ · Wei Chen¹ · Hui Zheng¹ · Peng Zheng¹ · Liang Zheng¹ · Qiong Wu² · Yang Zhang, Effects of Crystal Structure, Morphology and Ion Difusion During Annealing on Magnetic Properties of Hexagonal Barium Ferrite Films, *Journal of Electronic Materials* (2021) <https://doi.org/10.1007/s11664-021-09019-y>
9. Sandhya Singh, Gaurav Hitkari, G. Pandey. Synthesis and Characterization of Cadmium Doped Nickel Ferrite (Ni_{0.6}Cd_{0.4}Fe₂O₄) Nanoparticles and its Optical Properties. *International Journal of Scientific & Engineering Research* , May-2017 p1630-1635
10. S. Alone, S.E. Shirsath, R. Kadam, K. Jadhav, Chemical synthesis, structural and magnetic properties of nano-structured Co–Zn–Fe–Cr ferrite, *J. Alloys Compd*, vol.509 (2011) 5055-5060.
11. L.B. Tahar, M. Artus, S. Ammar, L. Smiri, F. Herbst, M.-J. Vaulay, V. Richard, J.-M. Grenèche, F. Villain, F. Fievet, Effect of Nb³⁺ Substitution on the Structural, Magnetic, and Optical Properties of Co_{0.5}Ni_{0.5}Fe₂O₄ Nanoparticles, *J. Magn. Magn. Mater*, vol.320 (2008) 3242-3250.
12. A. Nikumbh, R. Pawar, D. Nighot, G. Gugale, M. Sangale, M. Khanvilkar, A. Nagawade, Structural, electrical, magnetic and dielectric properties of rare-earth substituted cobalt ferrites nanoparticles synthesized by the co-precipitation method *J. Magn. Magn. Mater.* Vol.355 (2014) 201-209.
13. O.M. Hemeda, M.Z. Said, M.M. Barakat, Spectral and transport phenomena in Ni ferrite-substituted Gd₂O₃, *J. Magn. Magn. Mater.* (2001), vol.224, 132–142.
14. A.B. Nawale, N.S. Kanhe, K.R. Patil, S.V. Bhoraskar, V.L. Mathe, *J Alloys Compd*, 509(12) (2011) 4404-4413.
15. H. Nathani, R.D.K. Misra, Misra, Surface effects on the magnetic behavior of nanocrystalline nickel ferrites and nickel ferrite-polymer nanocomposite. *Mater. Sci. Eng. B, Solid-State Mater. Adv. Technol.* Vol. 113(2004), no.3, 228-235
16. J. Hu, Y. Ma, X. Kan, C. Liu, X. Zhang, R. Rao, M. Wang, G. Zheng, Structural, magnetic properties and magneto-caloric performances in the antiferromagnetic RECoSi₂ (RE = Er and Tm) compounds, *J. Magn. Magn. Mater.* (2020).
17. K. B. Modi, M.K Rangolia, M.C. Chhantbar, H.H. Joshi, *J. Mater. Sci.* 41 (2006)
18. T.P. Poudel, B.K. Rai, S. Yoon, D. Guragain, D. Neupane, S.R. Mishra, T.P. Poudel, B.K. Rai, S. Yoon, D. Guragain, D. Neupane, S.R. Mishra, *J. Alloy. Compd.* 802 (2019) 609–619 *J. Alloy. Compd.* vol. 802 (2019) .609–619.