Juniper Online
Journal Material Science
ISSN: 2575-856X

Juniper Publishers
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Opinion
Volume 1 Issue 3 - May 2017
DOI: 10.19080/JOJMS.2017.01.555561

JOJ Material Sci

Time Evolution of Structural and Magnetic Properties of Ni-Zn Nano Ferrite: An Opinion

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Submission: April 08, 2017; **Published:** May 04, 2017

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Abstract

We give our view on the time evolution of structural, magnetic properties, cationic distribution in $Ni_{0.5}Zn_{0.5}Fe_2O_4$ nano particles synthesized via sol gel auto combustion method. This distinctive study eventually provides an insight on most favorable synthesis time to get needed structural, magnetic properties needed for various applications eg- in heterogeneous catalysis, medical applications.

Keywords: Spinel ferrite; Time evolution of properties; XRD; Cation distribution; Magnetic properties

Opinion

In spinel nano ferrites their synthesis procedure, particle size, crystallinity and allocation of cations on tetrahedral A and octahedral B site plays a key role in determining their physical properties [1]. To have precise control on properties, time associated with synthesis process becomes a key parameter and in this context real-time monitoring of properties is important as well [2,3]. Thus, time evolution of synthesis process comprising a potential strategy for complete understanding of the involved formation mechanism is of fundamental importance in the nano particles synthesis, to have control on their properties, is important to have cost effective mass production [3].

Ni-Zn polycrystalline spinel ferrites nano particles are intensively studied both theoretically and practically owing to their low toxicity, chemical stability, mechanical hardness and reasonable cost [4]. Properties of the Ni-Zn ferrite are quite susceptible to the preparation method, the amount of substituting elements and their species [5]. Ni ferrite: inverse ferrite, Zn ferrite: normal ferrite [6], thus Ni-Zn ferrite. Ni-Zn ferrite thus is expected to exhibit mixed spinel structure, with strong preference of Zn, Ni ions to occupy respectively tetrahedral (A site), octahedral (B site) where cationic distribution can be shown by $(Zn_xFe_{1-x})^A\,[Ni_{1-x}Fe_{2-x}]^B\,O_4$.

Existing literature on Ni-Zn ferrites report correlation between structural, magnetic properties [7] but, it does not reveal essential study on time evolution of structural, magnetic properties of Ni-Zn ferrite. Thus, a study on time evolution of Ni-Zn ferrite essentially will fill the gap between laboratory researches and, the scale-up industrial production of nano-materials with desired properties, utilizing an energy efficient synthesis technique (e.g.- solution combustion method) with diminishing thermal costs whereas keeping the quality of materials [8]. Our vision on unique advantage of solution combustion method: even in as-burnt powder (no thermal treatment) we get formation of spinel phase with reasonably good magnetic properties [9].

Thus, we give our opinion on the importance of studying time evolution of structural, magnetic properties of $Ni_{0.5}Zn_{0.5}Fe_2O_4$ polycrystalline spinel nano ferrites prepared by sol-gel auto-combustion technique.

$Ni_{0.5}Zn_{0.5}Fe_2O_4$ nano particles were synthesized by solution combustion method, utilizing citrate-nitrate precursors as explained elsewhere [1]. During synthesis, as soon as the ‘dry gel’ starts to form, samples were taken out of the reaction vessel (were right away ice-quenched to room temperature) in a time interval ranging between 0-60 minutes, to obtain various stages of the formed ferrite phase. Structural, magnetic parameters of samples were obtained respectively by Cu K_α x-ray diffraction (XRD), vibration sample magnetometer (VSM).

XRD confirms the single phase (cubic structure, Fd3m space group) in the synthesized samples. Structural parameters were calculated by Rietveld refinement of XRD data by MAUD (Material Analysis Using Diffraction) software [10]. Cation distribution was obtained by using XRD intensities, employing Bertaut method, as described by Gastaldi et al. [11]. Figure 1 describes time evolution of structural, magnetic properties, cationic distribution.

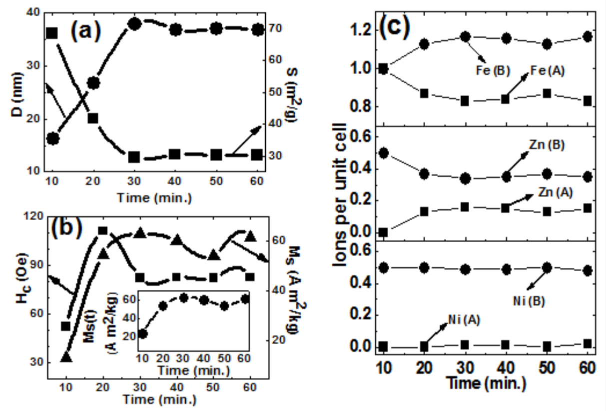

Figure 1: Variation of: (a) D, S (b) Ms, Hc Inset: Ms(t), (c) Ni, Zn, Fe

concentration at A, B site. Line connecting points is guide to the eye.

Fig. 1a depicts the variation of particle size D and Specific surface area S with progression of synthesis time. Perusal of (Figure 1a) D initially increases and saturates after 30min. synthesis time (range between 16.4nm to 38.0nm) suggests particle agglomeration. In ferrites total surface area/unit mass or specific surface area 'S' has inverse relationship with D (Figure 1a), and is of particular importance for heterogeneous catalysis due of better surface to bulk fraction. Obtained results show that the sample collected after 10 minutes with S=68.6 m^2/g of the synthesis is more appropriate for catalytic activity, instead of other samples, where S~30.3 m^2/g.

Fig. 1b displays time evolution of coercivity Hc; Experimental M_s (at 300K), inset theoretical $M_{s(t)}$ (at 0K). The M_s, H_c increases (Figure 1b) with increasing synthesis time (up to 30 min) is attributable to rearrangement of cations at A, B sites (Figure 1c) known to affect magnetic properties [7]. Highest M_s of 62.8 A•m^2/kg, moderate H_c of 82.1Oe was obtained for the Ni-Zn sample collected after 30 minutes. Similar variation of M_s, $M_{s(t)}$ with time validates the presence of Néel-type magnetic ordering in Ni-Zn ferrite. Observed M_s, H_c values suggest perspective applications of Ni-Zn nano particles in hyperthermia applications [9], synthesized via an energy efficient synthesis process with lower thermal costs while maintaining the material quality. Fig 1c illustrates the cationoccupation of $Ni2^{+}$, $Zn2^{+}$, $Fe3^{+}$ ions on A, B site Perusal of (Figure 1c) depicts that for all the studied samples with increase in synthesis time, Fe^{3+}, Ni^{2+} ions remains more populated on B-site (as compared to A-site). It may be noted that absence of any post-preparation thermal treatment encourages a non-equilibrium cation distribution, evident from the presence of Zn^{2+} ions on both A, B- sites. Presence of both Ni, Zn in the sample, Ni forces Zn to move on A-site with increasing synthesis time, only when Ni replaces Zn, its presence on B-site becomes considerable. Such non monotonous development of the cationic distribution with time will have notable effect on magnetic properties, as seen in (Figure 1b).

Summary

In summary, energy efficient sol gel auto combustion method has been used to monitor time-progression of structural, magnetic properties of Ni-Zn ferrite. Using these studies, we demonstrate the tenability of magnetic properties, establishing suitability of Ni-Zn ferrites as materials for catalytic, biomedical applications.

This work, SR funded by Project: CSR-IC/CRS-74/ 2014-15/2104. We thank Dr. M. Gupta, for XRD data.

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DOI: 10.19080/JOJMS.2017.01.555561

How to cite this article: Raghuvanshi S, Mazaleyrat F, Kane S. Time Evolution of Structural and Magnetic Properties of Ni-Zn Nano Ferrite: An Opinion. JOJ Material Sci. 2017; 1(3): 555561. DOI: 10.19080/JOJMS.2017.01.555561