Evaluation of Thermal Properties of Ferrite Nanoparticles for Magnetic Hyperthermia Treatment

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Abstract: ***The thermal properties of Fe_2O_3, $Fe_3O_4$and $CoFe_2O_4$ nanoparticles (NPs) was evaluated in this study. Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$NPs exhibited high temperature rise (T ^oC), heating rate ($\Delta T/\Delta t$ ^oC/ sec) and specific absorption rate(SAR w/ g). Induction heater operated at 100 kHz was used. This study indicates that Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$NPs could be the most suitable for magnetic hyperthermia treatment (MHT).***

Keywords: Ferrite nanoparticles, hyperthermia, nano technology, thermal properties.

1. Introduction

Magnetic hyperthermia treatment (MHT) is a type of the cancer treatment in which the target is exposed to a temperature ranges 42- 46 ^oC, which is found to be more effective to cancer cells than to normal cells. MHT can be used alone to cancer tumor treatment or together with the radiotherapy or the chemotherapy or the surgery. The hazard and the side effect of the radiotherapy, chemotherapy and the surgery greater than the MHT. The MNPs must be studies dependence on two main branches, the first one is the thermal, while the second one is the magnetic properties. Ferrite NPs consisting of an iron oxide can be localization into the center of the tumor cancer by the direct injection or by carried in the bloodstream. The MNPs absorbed heat energy when it targeted by an external magnetic field (MF) and dispersed a heat. MNPs after localization generate heat, raising the temperature of the tumor and resulting in hyperthermia, if an alternating current magnetic field (ACMF) was applied [1-3].

The Deoxyribo Nucleic Acid (DNA) and the Proton molecules size are (20-200 nm) and (5-50 nm) respectively, for that the NPs have several potential biomedical applications, that is cause of it size. The NPs can be used in the biomedical as carriers of drug delivery system (DDS) and heat sources for cancer treatment after targeted by the MF[4-7].

In this study, the applicability of various ferrite NPs as drug delivery systems (DDS) and for MHT is investigated by evaluating their thermal properties.

2. Experiments

The Fe_2O_3, Fe_2O_3 and $CoFe_2O_4$ nanoparticles (NPs) was synthesized by the co-precipitation methods were purchased respectively from RJSITM, IJSR and RJSITM [8-10].

X-ray diffraction (XRD) patterns were recorded using Shimadzu (XRD-6000), target is Cu (λ=1.4506 Å), voltage is 40kV, current is 30mA. Divergence, scatter and receiving slit are 1 degree, 1 degree and 0.3 mm respectively. The range, mode and speed of scanning are 10 - 80, continues and 2 degree / minute respectively. The sampling pitch is 0.02 degree and the preset time is 0.6 second.

An induction heater operated at low frequencies and low powers (100 kHz and 100 W), was used to study the energy absorption as the heating rate ($\Delta T/\Delta t$ ^oC/ sec) and the specific absorption rate (SAR W/g) of these NPs were prepared previously.

Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ NPs having various sizes were prepared by co-precipitation method in a dried powder state. To study the temperature rise (T ^oC), the heating rate ($\Delta T/\Delta t$) and specific absorption rate (SAR) value of the Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ NPs, a suspension of any NPs alone was prepared by: 1ml de-ionizing (DI) water + 2mg of NPs. In the first 1 ml of DI water was exposed to the magnetic induction and no change on the temperature is noted. Then, 1mg of Fe_2O_3/ Fe_3O_4 / $CoFe_2O_4$ NPs was added to 1ml DI water and exposed to the same magnetic induction heating.

3. Results and Discussion

To determine the size 't' of the α-Fe_2O_3 was prepared, from the XRD data, the peaks positions and the full width at half maximum FWAHM 'B' of the three strongest peaks, shown in the table1, were substituted in the Scherrer's formula(1):

$$t = \frac{K\lambda}{B\cos\theta} \tag{1}$$

Where; t is the size of the crystallite, K≈ 0. 9 is constant depend on the crystallite shape, λ = 1.4506 Å is x-ray wavelength of the Cu target, B is full width at half maximum (FWHM) and θ_B is Bragg's angle [8-10].

The XRD patterns figure 1, figure 2 and figure 3 indexing of the prepared Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ respectively, show that: this samples are cubic. Such the results in the table1 show a small sizes of Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ are 13, 64 and 8 nm respectively indicates that: the samples are the nanoparticles NPs [8-10].

Table 1: The parameters of the three strongest peaks in the XRD patterns

NPs	2theta deg.			FWAHM deg.			d (Å)			t (nm)		
Fe_2O_3	33.1	35.6	54.0	0.14	0.16	0.10	2.7	2.5	1.7	56.7	49.9	85.4
Fe_3O_4	35.9	63.2	30.5	0.86	0.92	0.90	2.5	1.5	2.9	9.8	10.2	9.3
$CoFe_2O_4$	35.7	62.9	57.3	0.58	0.68	0.62	2.5	1.5	1.6	13.3	12.8	13.5

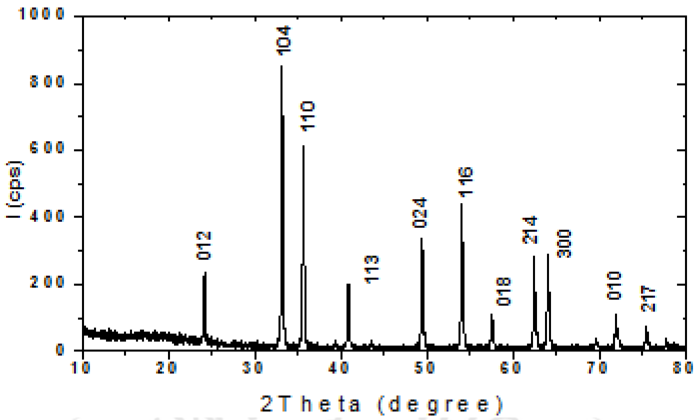

Figure 1: XRD pattern of Fe_2O_3

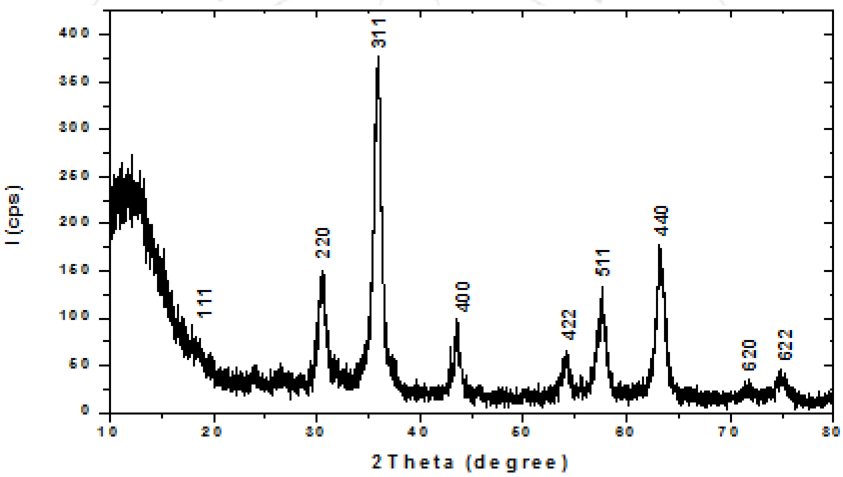

Figure 2: XRD pattern of Fe_3O_4

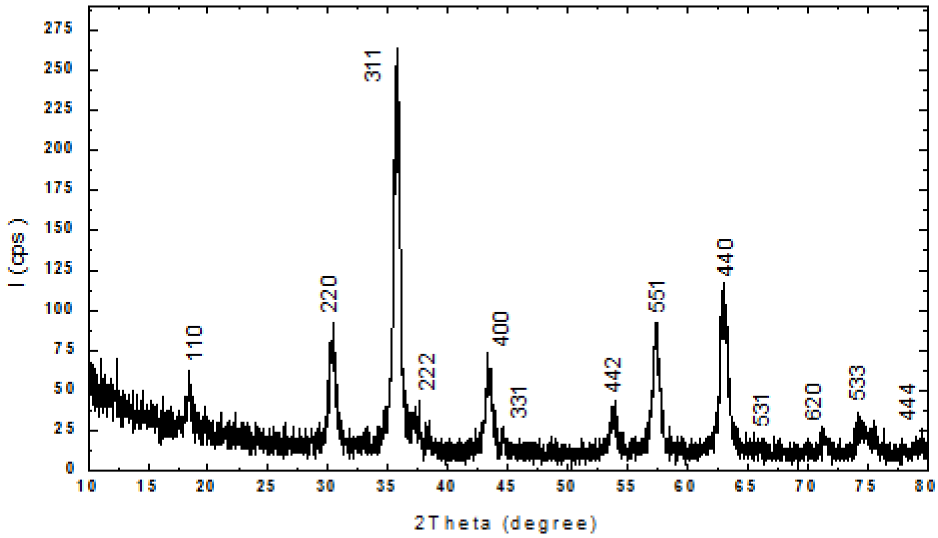

Figure 3: XRD pattern of $CoFe_2O_4$

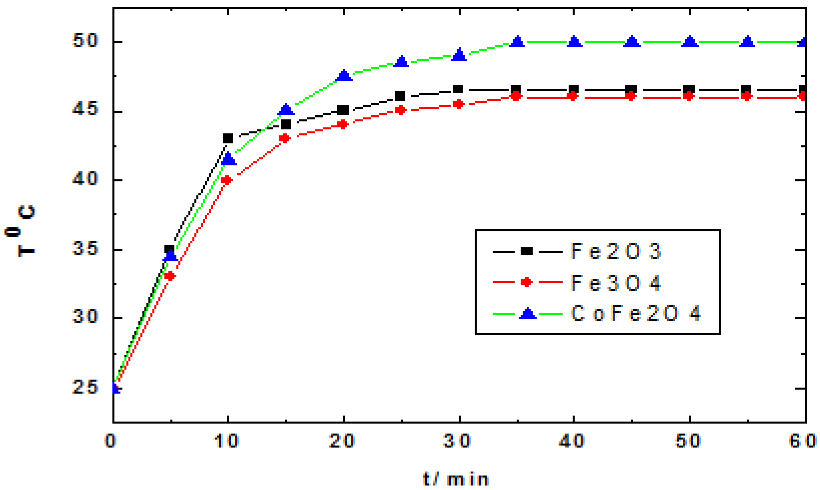

Figure 4: Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ heating rate

Table 2: Thermal properties of the Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ NPs

Sample	T °C	ΔT/Δt °C/ sec	SAR w/ g
Fe_2O_3	47	0.030	63
Fe_3O_4	46	0.025	53
$CoFe_2O_4$	50	0.028	58

After 35 minutes the temperature reached 47, 46 and 50 °C for Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$respectively and remained constant up to 60 minutes exposure to the magnetic induction heating. The temperature no longer changed over time when it reached to a certain value because the heat generated by the absorbed electromagnetic energy of Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$and the heat released towards the environment were equal that is shown in figure 4.

The SAR value can be calculated by the following equation(2)

$$SAR = C\frac{\Delta T}{\Delta t}\frac{1}{m_{ferrite}} \qquad (2)$$

Where; C = 4.185 J g $^{-1}$K $^{-1}$ is the sample specific heat capacity which is calculated as a mass weighed mean value of magnetite and water. ΔT/Δt °C/ sec is the initial slope of the time dependent temperature curve, m $_{ferrite}$ is the ferrite content per mg of the sample tube.

There are as good as the linear relations in the first rising of the temperature figure4. The linear relation in 0 –10 minutes intervals was used to calculate the SAR value of the Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ NPs by equation above table2.

Figure4 shows that $CoFe_2O_4$ (13 nm) NPs exhibited the highest temperature rise as compared to the other Fe_2O_3(64 nm) and Fe_3O_4 (8 nm) NPs. This was because of the magnetic properties of $CoFe_2O_4$, Fe_2O_3 and Fe_3O_4 NPs.

4. Conclusion

In this study the high temperature rise (T °C), the heating rate (ΔT/Δt °C/ sec) and the specific absorption rate (SAR w/ g) of Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ NPs were evaluated. These NPs exhibited a high temperature rise (47, 46 and 50 °C), the heating rate (0.030, 0.025 and 0.028°C/ sec) and the SAR value (63, 53 and 58 w/ g) of Fe_2O_3, Fe_3O_4 and $CoFe_2O_4$ respectively and good biocompatibility. Thus, these NPs are suitable for used in the MHT.

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