Laser Raman micro spectroscopy and high frequency dielectric properties of silica- xerogel loaded with different concentrations of α-Fe₂O₃

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Abstract

Sol-gel derived nano-composites silica-gel doped with different iron oxide concentrations at (3.5, 11, 33 and 37 mol. %) sintered at constant temperature at $1170^{\circ}C$, are illustrated in this work. Structure, surface morphology, high frequency dielectric and magnetic trends of the mentioned nano-composites analyzed and investigated through XRD, UV-Vis, TEM, FESEM and Magnetic hysteresis curves. Raman micro-spectroscopy gives rise to samples homogenous distribution. XRD illustrate that the Hematite (α-Fe₂O₃) is the optimum phase rather than the Maghemite (γ-Fe₂O₃) and Magnetite (ε- Fe₂O₃). Big amount of Hematite (α-Fe₂O₃) crystalline nano-particles are expected at 37 mol. % of Fe₂O₃. XRD confirmed that the average crystallite size increased from (25-31) nm with increasing the concentration of (α-Fe₂O₃) from 3.5 up to 37 mol%. The A.C. conductivity σ_{ac} increased by increasing the α-Fe₂O₃ content, according to the presence of oxygen vacancy and the crystalline size increases. The decreasing behavior in magnetization value (M_s) is related to the changes of the crystallite size, magnetic iron oxide particles and concentration. All analysis explains Hematite is extremely stable at ambient conditions and at high temperatures, so it is the better for particular applications.

Keywords: iron oxide; sol gel; laser Raman micro spectroscopy; Impedance analyzer (KEYSIGHT-E4991B).

1. Introduction

In modern research, transition metal oxide nanoparticles attracted a large attention because of their electrical and optical properties making them suitable for application in different kinds of opto-electronic devices [1], also have been at the heart of many dramatic advances in the material science [2], for these potential technological applications. Iron oxide has different phases, namely hematite (α-Fe₂O₃) anti ferromagnetic, maghemite (γ-Fe₂O₃) ferromagnetic and magnetite (ε- Fe₂O₃).Hematite (α-Fe₂O₃) is the most stable iron oxide under ambient conditions. It is a low cost non-toxic environment friendly material easily available in nature [3]. α-Fe₂O₃ shows antiferromagnetic (weakly ferromagnetic) at room temperature shows

paramagnetic above temperature of 948K[4].α -Fe$_2$O$_3$ displays wide ranges of applications such as, catalysis [5], gas sensors [6], solar cells [7], magnetic resonance imaging [8], pigments [9], and spin electronic devices[10]. Silica nanoparticles have gained importance in recent years because of their applications in various areas and easy synthesis process. Surface modification opens up the door for its future application in the field of biotechnology and medicine such as for cancer treatment, dental filling composites and drug delivery [11]. The silica gels are suitable for this application due to their high porosity, inertness chemical, large accessible surface area and transparency [12], also Silica have also been used as cell markers, catalytic substrates, absorbents, and matrix fillers[13]. Fe$_2$O$_3$/SiO$_2$, nano-composites have interesting properties and applications in catalysis, sensing and magnetism [14-15]. The conventional materials change their thermal, optical, magnetic properties in nano form corresponding to surface area increased and quantum effect. Recently, the magnetic nano particles (ferrite nano materials) have much attention and show interesting properties in many fields such as data storage, optical fiber, biomedical and medical fields etc....Sol gel is mainly interesting method due to its low cost, high purity, short preparation time, and homogenous solution of doping element and magnify the excellent polycrystalline samples. Information about A.C. conductivity can be gained by studying the influences of frequency and temperature on dielectric properties of different nano-composites [16]. The silica xerogel beads embedded with Fe$_2$O$_3$ nanoparticles used for more column stability to remove the product gases from the reactants without clogging the column unlike in the powder samples [17]. The Fe$_2$O$_3$ nanoparticles immobilized on SiO$_2$ support is explored, anticipating that the Fe$_2$O$_3$ - SiO$_2$ interactions may prevent self-agglomeration of Fe$_2$O$_3$ nanoparticles [18]

The properties of Fe$_2$O$_3$/SiO$_2$ materials in fact, depend on the nature of the interaction between silica xero-gel and iron oxide. Increasing temperature and/or iron concentrations the prepared samples are assumed to cause changes in the bond lengths and/or bond angles of the structural silicate units within network. In this work, Silica doped with Iron-oxide in different molar ratios 3.5, 11, 33 and 37 mol.%, were synthesized with the sol gel process sintered at 1170°C. The prepared nano-composite materials were characterized with laser Raman micro spectroscopy, X-Ray Diffract meter (XRD). The prepared samples compatibility was investigated by SEM. The dielectric parameters of the samples were studied for first time in a wide range of frequencies (1 MHz - 1 GHz). Finally, many efforts will be done to find the possibility to use the studied nano-composite prepared samples as promising candidates for sensors and magnetic devices.

2. Experimental

A composite of silica gel and different concentration of iron oxide was prepared by modified sol-gel process. By mixing tetra-ethoxy-saline, $(CH_3CH_2O)_4$ Si (TEOS) (Aldrich, 98%),ethyl alcohol (CH_3CH_2OH),distilled water and HCL with molar ratios 0.28: 0.174: 0.028: 0.0823 respectively.[19]

An aqueous solution of iron nitrate (Fe $(NO_3)_3$-$9H_2O$) was introduces in initial stage of the process with different concentrations (3.5, 11, 33 and 37 mol %) to doped the silica giving a nano-composites. These solutions were stirring for one hour. The clear sol was then poured into a Teflon beaker and allowed to gel in air. The gel was dried in an oven for one week by slowly raising the temperature up to $100^{\circ}C$ [20], and then kept for 24 h at 150ºC. Heating steps between $50^{\circ}C$ and $1170^{\circ}C$ at each temperature for 30 min respectively. After the treatment at higher temperature the samples changed and looked like ceramics. The overall process can be written as:

$Si(O-CH_2CH_3)_4 +4H_2O \rightarrow Si(OH)_4+4C_2H_5OH$

$Si(OH)_4 \rightarrow SiO_2+2H_2O$
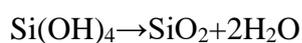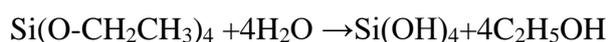
3. Characterization techniques:

The X-ray diffraction (XRD) patterns for the prepared samples are recorded with a Philips X-ray diffract meter using mono chromatid CuK_{α} radiation of wavelength 1.54056Å from a fixed source operated at 45 kV and 9 mA. Absorption spectra (200-1800 nm) were measured using a The Model V-570 UV/VIS/NIR spectrophotometer. The instrument specified by resolution 0.1 nm and wavelength accuracy ±0.3 nm (at a spectral bandwidth of 0.5 nm). The Raman single point measurement using Alpha 300 RA/S from Witec-Ulm Germany is used with 532 nm laser and 100X Ziss objective. The morphology of the prepared samples was depicted by using high resolution field emission gun quanta FEG 250 scanning electron microscope (FE-SEM). The FE-SEM gives information on the samples surface morphology. Dielectric properties were measured in a wide range of frequencies between 1 MHz and 1 GHz using network impedance analyzer (KEYSIGHT-E4991B).

4. Results and discussion

X-Ray diffraction (XRD) characterization:

The composition and crystalline phase purity of silica gel doped with different iron oxide concentration at (3.5,11,33,and 37 mol %) sintered at 1170°C were examined by XRD

pattern in the 2θ range of 10-80 degrees are shown in Figure (1:a→d). In all the cases a hump due to amorphous silica phase is visible at 2θ ~ 22 degrees (mineral name: crystobalite, tetragonal crystal system, ICSD card No. 47219) [21]. Also It is clearly seen that many diffraction peaks detected at $2\theta^o = 22^o$, 26°, 28.4^o, 31.9^o, and 36.5^o corresponding to α-Fe_2O_3 (mineral name: Hematite, Rombohedral phase, JCPDS card No. (98-017-3024)) indexed as (111),(120),(121),(031) and (201) respectively. Moreover, the figure illustrates some distinct characteristic peaks at 23.8^o,32.8^o,35.2^o,40.2^o,49.1^o,53° and 62.5^o,which are ascribed to α-Fe_2O_3 with preferred orientations (012),(122),(200),(132),(142),(204) and (026). Also, other very weak peaks are observed at 57.9°, 63.3°, 71.7° and 75.3° attributed to γ-Fe_2O_3 (mineral name maghemite, spinel structure with disordered vacancies, cubic crystal system)[22-23] and $\mathcal{E}$-Fe_2O_3 with preferred orientations as(035), (330),(235) and (401), respectively.[24] By increasing the Fe_2O_3 content on the host silica gel, it has been reported that the peaks intensity increased and shifted to higher $2\theta^\circ$ at 37 mol % of Fe_2O_3 suggesting a growing of crystal domain size[25]. Moreover, it can be noticed that the principal tetragonal α- crystobalite peak is observed at $2\theta^o$= 22° index at (111) increased and changed by increasing the Fe_2O_3 concentration due to the rearrangement acting in the structure as a result of doping with iron oxide. The obtained data revealed that the hematite α-Fe_2O_3 is the major phase and a very minor component of γ-Fe_2O_3 and $\mathcal{E}$- Fe_2O_3 in all the samples, pointing to high purity and succession of the nano-composite samples preparation. It has been noticed that the annealing at high temperature 1170°C and increasing the concentration gives rise to the crystallization into the more stable α-Fe_2O_3.The average crystalline sizes calculated using Scherer's equation [26] from the principle peak were found to be equal to 25,26, 27 and 31 nm for 3.5,11,33 and37 mol%, respectively. One can conclude that the Hematite (**α**-Fe_2O_3) phase is the dominant phase in all samples. [27] Lattice parameters of the synthesized of α-Fe_2O_3,ε- Fe_2O_3, and γ-Fe_2O_3 nanoparticles are tabulated in Table 1.
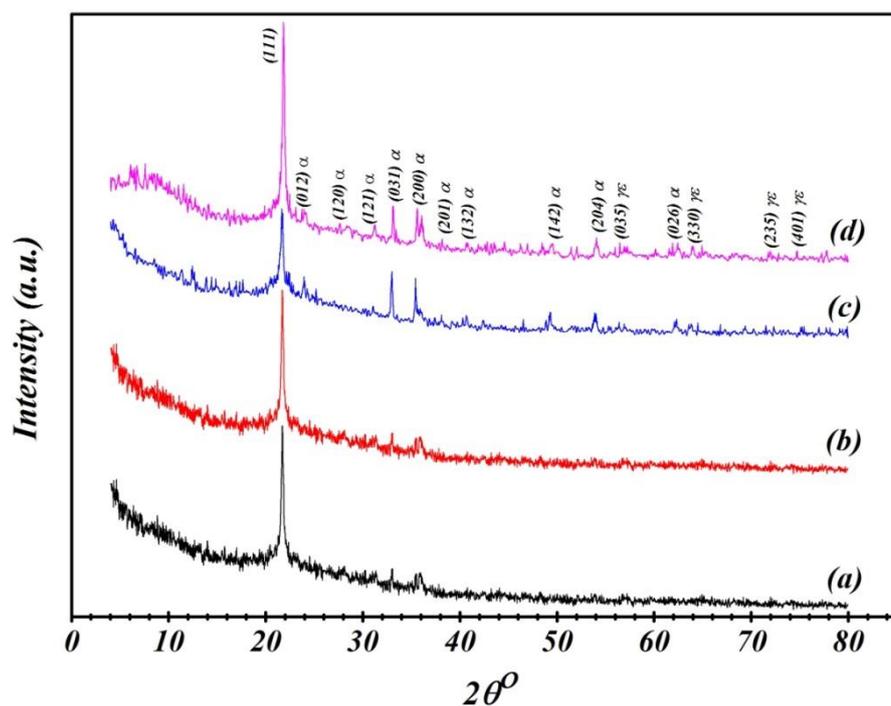
Figure 1. The XRD of silica gel doped with different concentration of Fe₂O₃ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, respectively sintered at 1170°C.

Table.1: Crystallographic data obtained from XRD of α-Fe₂O₃ ε- Fe₂O₃, and γ-Fe₂O₃

property	Hematite	Magnetite	Maghemite
Molecular formula	α-Fe₂O₃	ε- Fe₂O₃	γ-Fe₂O₃
Crystallographic	Rhombohedral	Cubic	Cubic
Lattice parameter(nm)	a=0.508 ,b=0.878 ,c=0.947	a=0.939 ,b= 0.939 ,c=0.939	a= 0.928 ,b=0.928 ,c=0.928
Relative percentage	44.6%	1.4%	1.3%

| Applications	Catalysts, pigments, gas sensors				Solar energy conversion, drug delivery, environmental catalysis, recording devices	Magnetic recording, high frequency switch modes, electromagnetic absorbers
Crystalline size of α-Fe$_2$O$_3$	**3.5mol % 25 nm**	**11mol % 26nm**	**33mol % 27nm**	**37mol % 31nm**		

TEM and SEM analysis:

Transmission electron microscopy (TEM) of the α-Fe$_2$O$_3$ (3.5 mol%)/SiO$_2$ sample annealed at 1170°C are shown in figure (2). From the figure it is clearly exhibit that the SiO$_2$ particles are spherical with particle size in range ~ 30-50 nm. The small dots could be noticed, which may be due to α-Fe$_2$O$_3$ in form of spherical. The crystalline nano particle size of Fe$_2$O$_3$ is ~ 24 nm. This indicates the uniform dispersion of Fe$_2$O$_3$ grains on silica matrix.
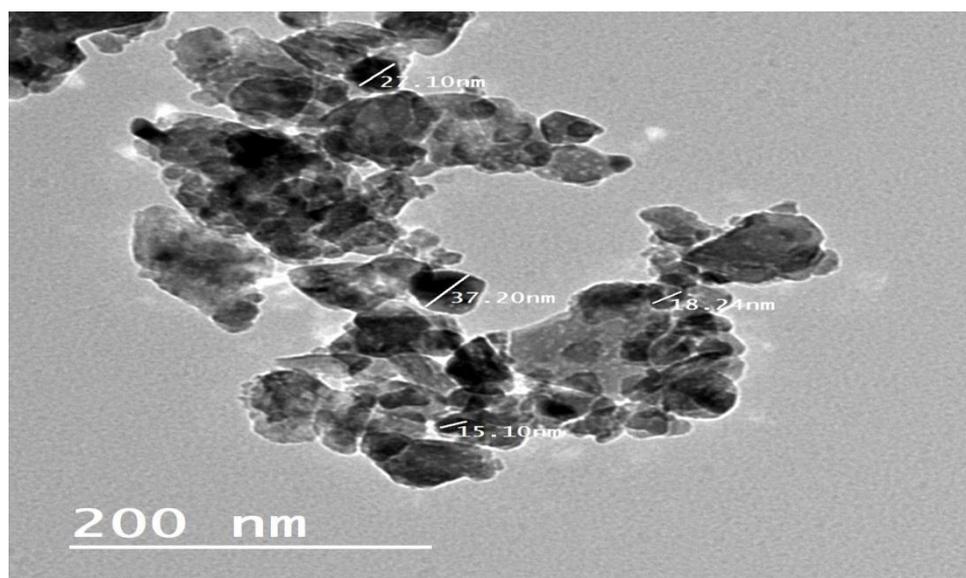
Figure 2. TEM micrograph of silica gel doped with 3.5 mol% of α-Fe$_2$O$_3$, sintered at 1170°C.

High resolution Surface electron microscopy (FESEM) images of α-Fe_2O_3 (37mol%)/SiO_2 nano-composite sintering at 1170°C is shown in figure(3). The mean grain size is in the nano-scale range, even at higher iron concentration calculated by the XRD. The SEM micro-graph shows a uniform grain size distribution, a fine monolith size and homogeneous microstructure appeared as shown in figure.3.In the graph, we can observe large particles were distribution over the bulk gel, which consists diffraction lines appear in the XRD patterns, whose peak positions are assigned to α-Fe_2O_3 phase.
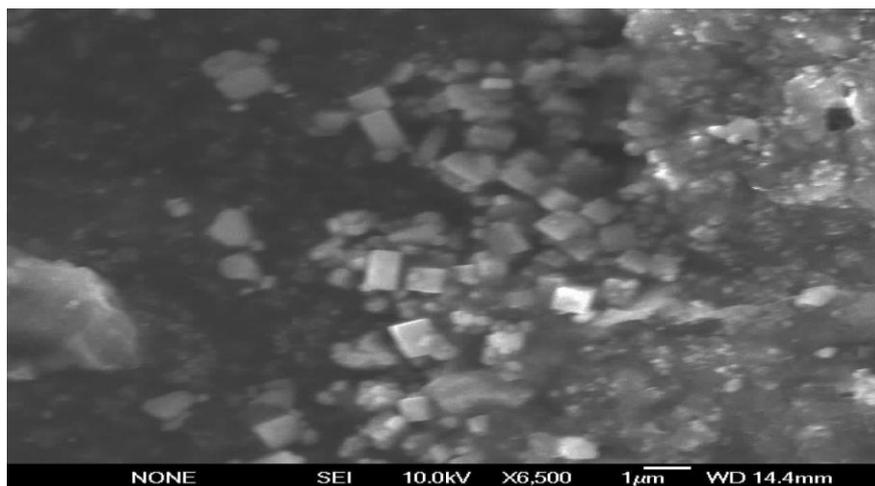
**Figure 3. FESEM image of silica gel doped with 37 mol% of α-Fe_2O_3, sintered at 1170°C.**

UV-vis spectroscopy:

To estimate optical properties of the α-Fe_2O_3 (3.5→37)mol%/SiO_2 sintered at 1170°C, the UV-vis absorption spectra in wavelength range (200-800)nm are showed in figure(4). The figure illustrated the α-Fe_2O_3 have two absorption peaks in wave length ranges of the ultraviolet and visible light, respectively. The first region ranged from 238 to 353nm is assigned to the transfer spectra between metal and silica matrix, and the second region ranged from 500 to 575nm is the finger print region of hematite. Moreover, the absorption strength of the α-Fe_2O_3 / SiO_2 increases with the increase of Fe_2O_3 content. These facts may be attributed to the transition in crystal field and the charge transfer process, which increased with increasing Fe_2O_3.[28] Furthermore, the band gap energies of the α-Fe_2O_3 / SiO_2 could be estimated by the following equation[29]

$E_g = 1240 / \lambda_g$ (1)

Where E_g is the band gap energies of the α-Fe_2O_3 /SiO_2 nanocomposite, λ_g is the wavelength at the overlap of the vertical and horizontal portions on the band edge.

As seen in figure(4), the values of λ_g is shifted to higher wavelength with increasing α-Fe_2O_3 concentration, which shifts from 550 to 575nm corresponding to band gap energy from 2.25 eV to 2.15 eV respectively. This result illustrated that the value of band gap of nanocomposite decreased with increasing α-Fe_2O_3 nanoparticle, also the reduction in the band gap is due to increase in the grain size.[30]
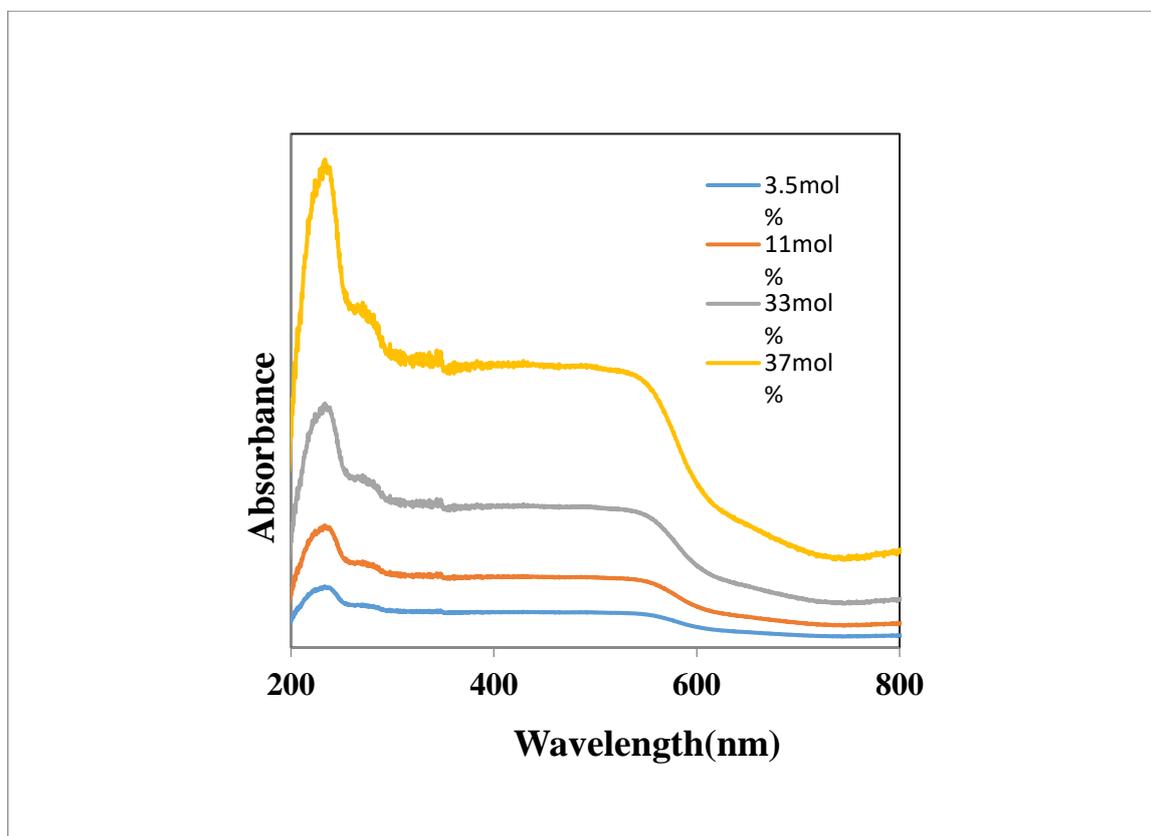
Figure 4. UV-vis Absorbance of silica gel doped with different concentration of α-Fe_2O_3 (3.5→37)mol%/SiO_2, sintered at 1170°C.
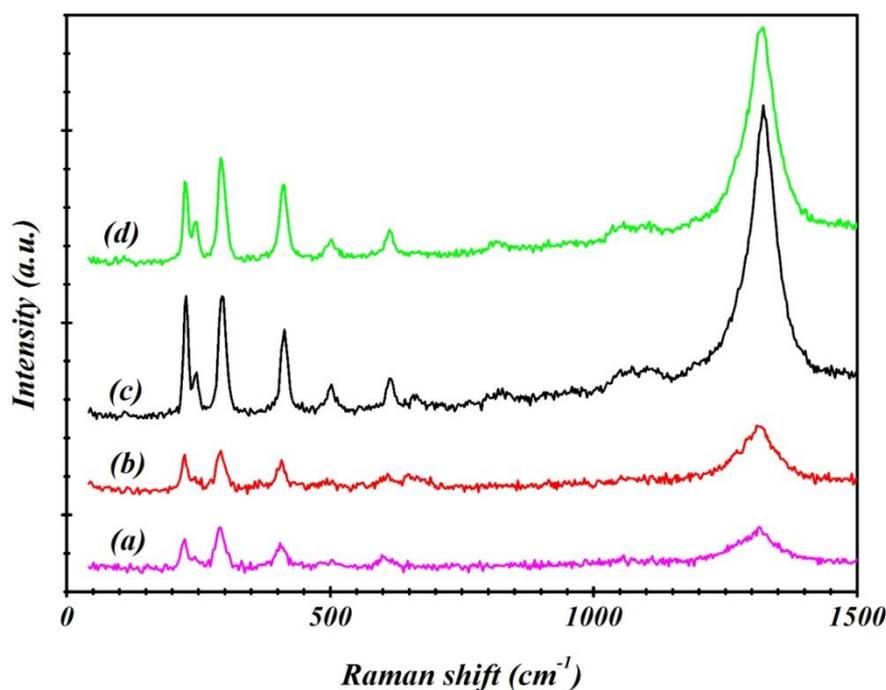
Raman spectrum

Raman spectroscopy for silica gel doped with different concentration 3.5, 11 33 and 37mol% of Fe_2O_3 sintered at 1170°C, is observed in Fig(5), respectively. The most pronounced Raman bands for the prepared samples are given and assigned in Table (1). The low intense peak appeared at about 1070 Cm^{-1} is according to Si-O-Si stretching vibrating bond asymmetric. The small peaks at 820 Cm^{-1} are attributed to the Si-O-Si symmetric stretching vibrating mode. The Raman spectra at 496 and 609 Cm^{-1} corresponding to the presence of Si-O rings for 4 and 3-fold, respectively.

The appearance of the peak at 413 Cm^{-1} could is attributed to Si-O-Si, bending oxygen mode. Band with sharp intensity located at 228 Cm^{-1} is the fingerprint of the Raman spectrum

of α-crystobalite. These results are compatible with that obtained from XRD patterns and previous studies. The observed difference is the sharpness of the appeared peaks of samples, which may be due to the increase of the degree of crystallinity as indicated by XRD. Also, from the table (2), shows the assigned bands corresponding toα-Fe_2O_3 (hematite) phase [31].

Table (2): Raman bands assignment of silica gel doped with different concentration of Fe_2O_3: 3.5, 11, 33 and 37mol%, respectively sintered at 1170°C

Raman bands					The assignment
SiO_2/Fe_2O_3	3.5 mol%	11 mol%	33 mol%	37 mol%	
228 Cm^{-1}	223	223	223	226	α-cristobalite
----------	292	289	292	294	α-Fe_2O_3
430 Cm^{-1}	430	430	430	430	Si-O-Si bending oxygen mode
---------	404	407	413	413	α-Fe_2O_3
496 Cm^{-1}	496	496	496	496	Four and three-fold Si-O rings
609 Cm^{-1}	609	609	609	609	Four and three-fold Si-O rings
----------	609	611	619	608	α-Fe_2O_3
820 Cm^{-1}	820	820	820	820	Si-O-Si symmetric stretching vibration mode
1070 Cm^{-1}	1070	1070	1070	1070	Si-O-Si asymmetric stretching vibration mode
----------	1311	1324	1321	1316	α-Fe_2O_3

Figure 5. Raman spectroscopy spectra of silica gel doped with different concentration of α- Fe₂O₃ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, respectively sintered at 1170°C

Magnetic measurements:

The magnetic properties of α-Fe$_2$O$_3$ / Sio$_2$ nanoparticles using different concentration (3.5, 11, 33 and 37 mol%) of Fe$_2$O$_3$ sintered at 1170°C were drawn in Figure (6). The saturation magnetization (M$_s$), remnant magnetization (M$_r$) and the value of coactivity (H$_c$) are presented in Table (3). The values of the saturation magnetization (M$_s$) decreases from 0.813 emu/g to 0.0397 emu/g with increasing α-Fe$_2$O$_3$ from 3.5 to 33mol%, respectively. This decreasing behavior in magnetization value is related to the changes of the crystallite size, magnetic iron oxide particles and concentration. [32] The results shows that the (M$_s$) increases up to 0.0659 emu/g for α-Fe$_2$O$_3$ (37 mol%)/SiO$_2$.This is attributed to the larger particle size of Fe$_2$O$_3$ embedded in silica matrix. The high (H$_c$) of the sample obtained at (37 mol%) of α-Fe$_2$O$_3$ may be attributed to the magneto static dipole interactions and / or the shape anisotropy in the high crystalline complex nanostructures in this work[33]. When α-Fe$_2$O$_3$ nano- particles embedded in silica, the Si-O-Fe bond has been formed .The magnetic moment of iron ions of α-Fe$_2$O$_3$ nanoparticles disappeared through the Si-O-Fe connection and as a result, the magnetization decreased.
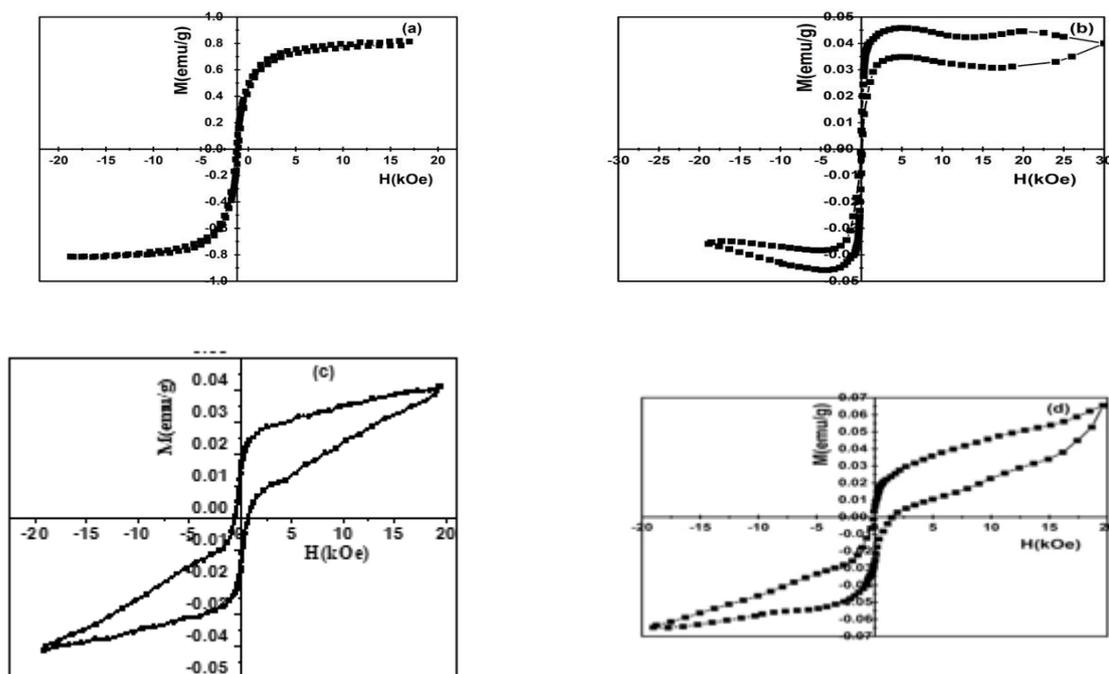
Figure 6. Magnetic hysteresis curves of silica gel doped with different concentration of α-Fe$_2$O$_3$ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, sintered at 1170°C

Table (3) The (H$_C$), (M$_r$), (M$_S$) and (M$_r$/M$_S$) of silica gel doped with different concentration of α-Fe$_2$O$_3$ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, sintered at 1170°C

Sample	(H$_C$) (kOe)	M$_r$ emu/g	M$_S$ emu/g	M$_r$/M$_S$
3.5	0.0387	0.2325	0.8138	0.2856
11	0.4641	0.03056	0.0458	0.6672
33	0.5477	0.02125	0.0397	0.5343
37	1.367	0.01593	0.0659	0.2417

Dielectric and Conductivity properties:

The AC conductivity σ_{ac} of α-Fe_2O_3 / Sio_2 nanoparticles using different concentration (3.5, 11, 33 and 37 mol%) of Fe_2O_3 sintered at 1170°C in frequency range (1MHz-1GHz) illustrated in figure(7). The figure shows that σ_{ac} increases by increasing frequency. The observed conductivity in the lower frequency can be attributed to the weakly localized carriers which drift over large distances. At higher frequency the mean displacement of these carriers is reduced to show proximity in the conductivity [34]. Also it can be noticed that, σ_{ac} increased by increasing the Fe_2O_3 content, this may be due to the increasing in the mobility of the free charge carriers in silica matrix [35]. The lower values of σ_{ac} for Fe_2O_3(3.5 mol%)/SiO_2 should be assigned to its particles size (25 nm), which leads to a decrease of the free ions number [36]. However, the higher values of σ_{ac} at higher iron oxide concentration (37 mol%) with particle size (31 nm)[37]. Hence, it may be understood here that the particle size plays an important role in conductivity [38].

The dielectric constant ($\varepsilon^{'}$) and Dielectric loss ($\varepsilon^{''}$) of α-Fe_2O_3/SiO_2 nano particles sintered at 1170°C were also studied in the frequency range (1MHz-1GHz) in figures (8, 9). It was observed that the ($\varepsilon^{'}$) and ($\varepsilon^{''}$) showed the same decreasing trend with increasing frequency. This observed decrease might be according to the charge carriers scattering and the electric filed fast variation accompanied with the frequency, which leading to random orientation of the dipole moments. It can be noticed that, ($\varepsilon^{'}$) and ($\varepsilon^{''}$) detect an increasing behavior by increasing α-Fe_2O_3 content. This increase in dielectric constant may be attributed to the decrease of the distance between grains [39].The dielectric properties of ferrites are dependent upon several factors: including the method of preparation, chemical composition, grain structure and particle size[40]. So the observed dielectric increasing behavior of our samples may be due to the increase in the particle size (25-31) nm of Fe_2O_3 concentration (3.5-37mol%).

Fig.7: The σ_{ac} variation against frequency of of silica gel doped with different concentration of α-Fe$_2$O$_3$ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, sintered at 1170°C in frequency range (10^6-10^8) Hz.
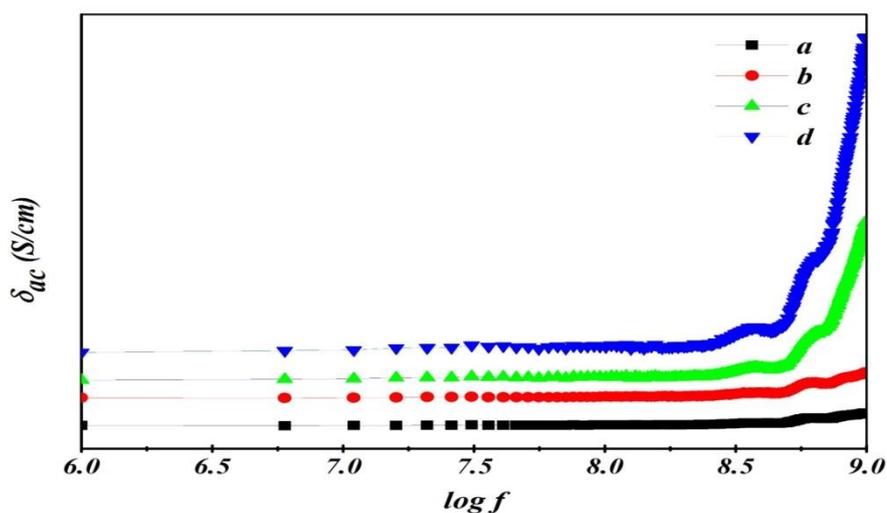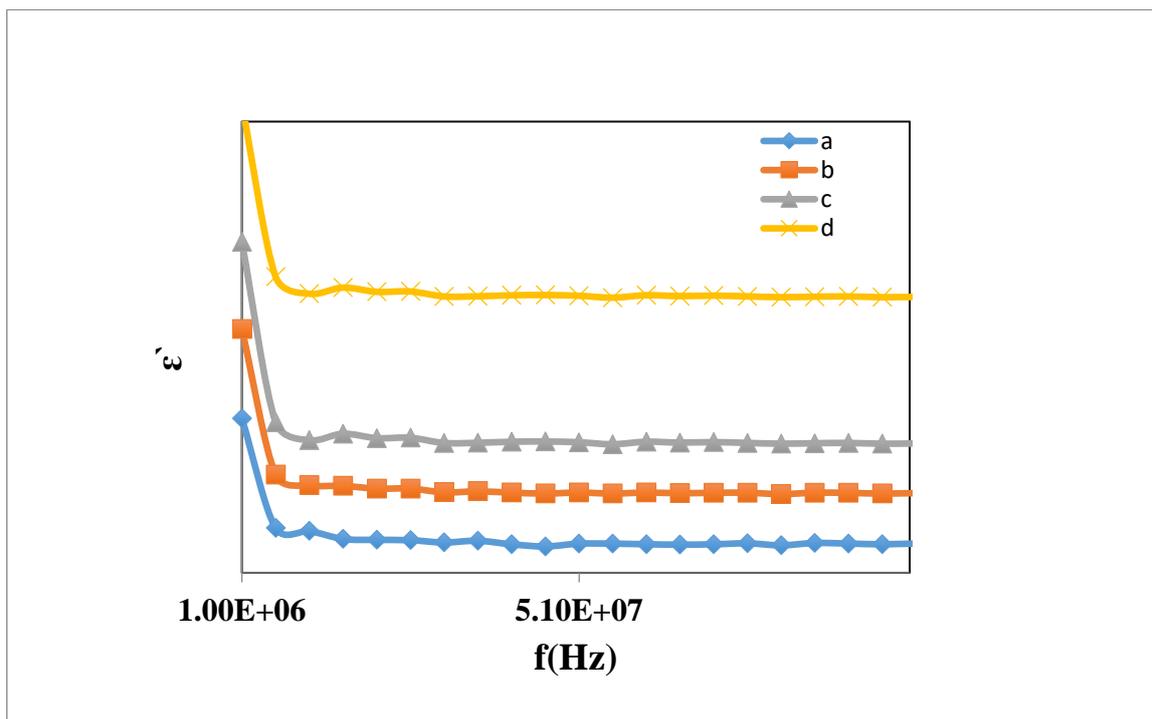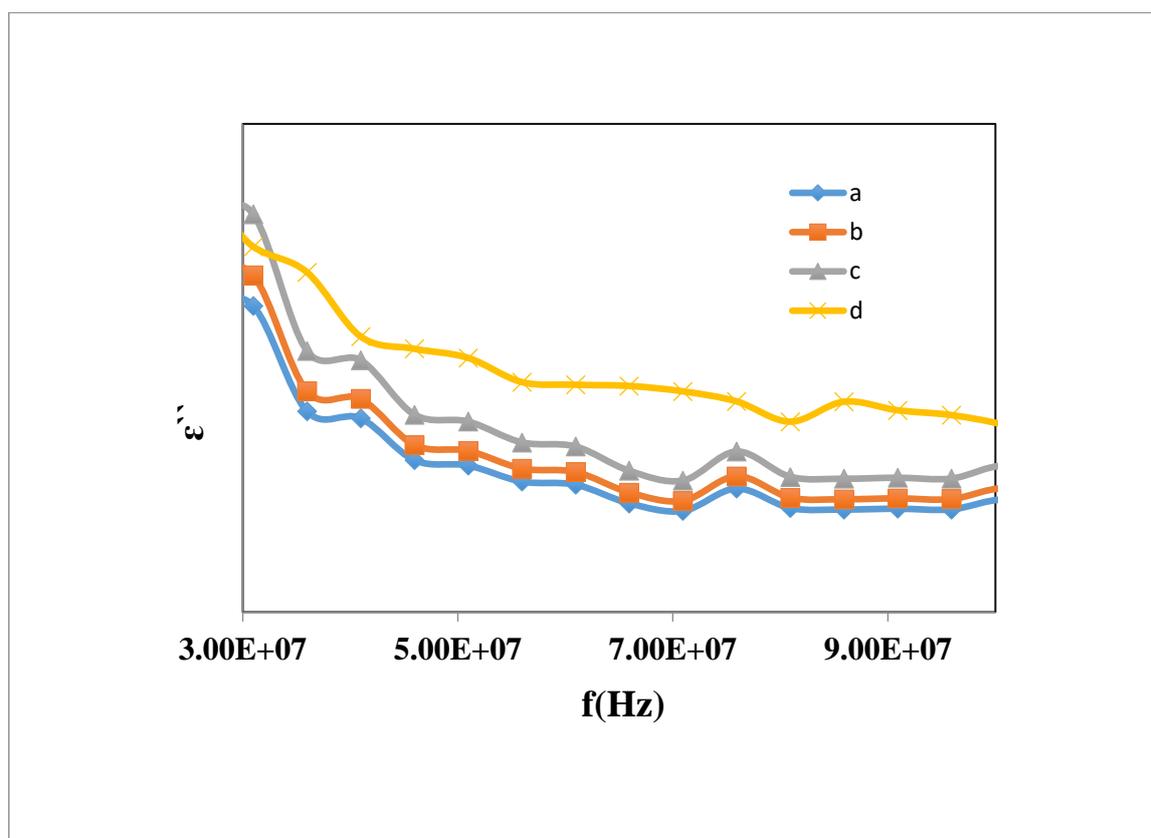

Fig. 8: The $\varepsilon`(\omega)$ variation against frequency of of silica gel doped with different concentration of α-Fe$_2$O$_3$ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, sintered at 1170°C in frequency range (10^6-10^8) Hz.

Figure 9. The ε'' (ω) variation against frequency of silica gel doped with different concentration of α-Fe$_2$O$_3$ (a) 3.5,(b) 11, (c) 33and(d) 37mol%, sintered at 1170°C in frequency range (10^6-10^8) Hz.

Conclusion

In the present work, the silica-gel glasses doped with different concentrations of Fe$_2$O$_3$, and their structural, dielectric, magnetic and morphological trends have been evaluated. The Silica-gel doped with different concentrations of Fe$_2$O$_3$ (3.5, 11. 33 and 37 mol. %) were prepared by sol gel process. The used process give rise to hematite α-Fe$_2$O$_3$/SiO$_2$ phase annealed at 1170°C with homogenous distribution of the nanoparticles. In addition the X-ray measurements detect the hematite phase presence. Moreover, the iron oxide embedded in silica gel host material is always in nano-structure range. The SEM measurements confirm the nano-scale presence; it is enhanced by high α-Fe$_2$O$_3$concentration in the mentioned prepared samples. The Laser Raman is used to clarify the structural group's presence. The dielectric properties will be studied in frequency range (1MHz-1GHz) for first time. The obtained data revealed that the A.C. conductivity σ_{ac} increased by increasing the Fe$_2$O$_3$ content at (3.5, 11, 33 and 37% mol. %), the dielectric permittivity increases. Finally, the values of the saturation

magnetization (M_s) decreases from 0.813 emu/g to 0.0397 emu/g with increasing α-Fe_2O_3 from 3.5 to 33mol%, respectively. This decreasing behavior in magnetization value is related to the changes of the crystallite size, magnetic iron oxide particles and concentration. The all results supplied a new strategy to design and prepared the high – temperature photonic crystals, thermal protects and magnetic materials.

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الملخص العربى

التحليل الطيفي الدقيق بالليزر Raman وخصائص العزل الكهربائي عالية التردد للسيليكا- xerogel محملة بتركيزات مختلفة من α-Fe$_2$O$_3$

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فى هذا البحث تم تحضير مركبات Fe$_2$O$_3$/SiO$_2$ السليكا جل النانومتريه والمطعمه بتركيزات مختلفة من اكسيد الحديد (% 5,11,33 and 37 mol) وتسخينها عند درجة حراره (1170°C).اظهرت نتائج حيود الاشعه السينيه وجود بللورات سيليكا رباعيه α-cristobalite كما اظهرت وجود مراحل الحديد المختلفه وهى Hematite(α-Fe$_2$O$_3$) مع قليل من Magnetite (ε-Fe$_2$O$_3$), Maghemite (γ-Fe$_2$O$_3$) . وبزيادة تركيز الحديد ظهرت قمم ضيقه وحاده دليل على زيادة بللوريه العينه بزيادة نسبه الحديد. عند درجات الحراره المنخفضه تكون مراحل الحديد الموجوده هى ( ) γ-Fe$_2$O$_3$ او (ε-Fe$_2$O$_3$) وهذا يرجع الى بطء اكسدة ايونات الحديد اما زيادة درجة الحراره الى 1170°C يؤدى الى سرعة اكسدة ايونات الحديد مما يسبب تحول مراحل الحديد من Maghemite الى Hematite . وبحساب الحجم الجزيئى للمركبات وجد انها تزيد من 25 الى 31 نانومتر بزيادة نسبة الحديد.وباستخدام الميكروسكوب الاكترونى النافذ (TEM) وجد ان متوسط الحجم الجزيئى للعينات 24 نانومتر مما يتفق مع نتائج XRD . بينما صور الميكروسكوب الالكترونى الماسح (SEM) اوضحت تجانس توزيع الجزيئات دون اى تكتلات ولها شكل بللورى رباعى الزوايا - α cristobalite . من خلال قياسات Raman للعينات المحضره اوضحت وجود α -cristobalite و (α-Fe$_2$O$_3$) مما يتفق مع نتائج XRD . وبدراسة الخصائص الكهربيه للمركبات فى مدى تردد (1 MHz - 1 GHz) وجد ان التوصيليه الكهربيه σ$_{Ac}$ تزيد بزيادة التردد وهذا يرجع الى وجود حاملات الشحنه التى تتحرك فى اتجاه المجال الكهربى مما يتسبب فى تدفق الشحنات عبر العينه. اما بزيادة تركيز الحديد فذلك يؤدى الى زيادة حركة حاملات الشحنه داخل سلسلة السيليكا مما يؤدى الى زيادة التوصيليه الكهربيه σ$_{Ac}$.وبقياس خصائص العزل عند الترددات المنخفضه يكون قيم `ε و `` ε كبيره وبزيادة التردد تقل قيمتهما وذلك لعدم قدرة حاملات الشحنه على تتبع الزياده فى المجال الكهربى. كما وجد ان قيم ` ε و `` ε تزيد بزيادة تركيز اكسيد الحديد.وبدراسة تأثير زيادة نسبة الحديد على الخصائص المغناطيسيه للعينات يتضح ان المغناطيسيه تقل بزيادة نسبة الحديد. ومن نتائج القياسات وجد ان ال Hematite هو اكثر انواع الحديد استقرارا فى الظروف المحيطه وكذلك تحت تاثير درجات الحراره العالية لذلك يفضل استخدامه فى معظم التطبيقات .