Dielectric behaviour of MgFe$_2$O$_4$ prepared from chemically beneficiated iron ore rejects

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Abstract. Chemically beneficiated high silica/alumina iron ore rejects (27–76% Fe$_2$O$_3$) were used to synthesize iron oxides of purity 96–98% with SiO$_2$/Al$_2$O$_3$ ratio reduced to 0·03. The major impurities on chemical beneficiations were Al, Si, and Mn in the range 2–3%. A 99·73% purity Fe$_2$O$_3$ was also prepared by solvent extraction method using methyl isobutyl ketone (MIBK) from the acid extracts of the ore rejects. The magnesium ferrite, MgFe$_2$O$_4$, prepared from these synthetic iron oxides showed high resistivity of ~ 10^8 ohm cm. All ferrites showed saturation magnetization, 4pM$_s$, in the narrow range of 900–1200 Gauss and the Curie temperature, T_c, of all these fell within a small limit of 670 ± 30 K. All ferrites had low dielectric constants (e'), 12–15, and low dielectric loss, tan δ, which decreased with the increase in frequency indicating a normal dielectric dispersion found in ferrites. The presence of insignificant amount of polarizable Fe^{2+} ions can be attributed to their high resistances and low dielectric constants. Impurities inherent in the samples had no marked influence on the electrical properties of the ferrites prepared from the iron ore rejects, suggesting the possibility of formation of ferrite of constant composition, MgFe$_2$O$_4$, of low magnetic and dielectric losses at lower temperatures of 1000°C by ceramic technique.

Keywords. Ore reject chemical beneficiation; gamma ferric oxide; ferrite; hydrazine; dielectric constant; dielectric loss factor.

1. Introduction

Ever expanding electronic industry's need of ferrites, both hard and soft, is evident from the estimated world ferrite production (Ruthner 1989, 1997) of 5,16,000 metric tons per year (MTPY) in 1990 to 15,00,000 MTPY in the year 2005. The ferrite grade iron oxide, a-Fe$_2$O$_3$, required for such production of ferrites in year 2005 would be of about 10,50,000 MTPY. The production of ferrites has been on the rise ever since the commercialization of these took place some 60 years ago (Sugimoto 1999) and in comparison with the world ferrite producing countries (Ruthner 1989), the Indian contribution was mere 2% in 70s and 80s. And there is no significant improvement in the Indian ferrite production capacity, at present. India can certainly increase its ferrite production capacity, as we have huge iron oxide sources in our country. It was estimated (Ruthner 1989) that the iron oxide required for such a huge production of ferrites would come mostly from the up-graded hematite ore and we have plenty of that sort of iron oxide sources. But, the Indian iron mine industry caters high-grade ore for the domestic steel industry requirements and export, and the highly mechanized industry discards low-grade ore and tailings at the mining

areas which are creating environmental problems. And, considering deteriorating mineral resources, it is high time that one should look into the low-grade ores to make them value added materials. We (Verenkar 1997; Sawant 1998; Rane *et al* 1999) have been making a modest effort to make use of these ore rejects to synthesize active pure iron oxides and from these ferrites to see the suitability of such iron oxide sources in ferrite industry, after chemical beneficiation.

Advantages of chemically synthesized iron oxide are many as one can get (i) impurity free fine particles of high surface area and hence reactive and (ii) oxide of desired crystal structure. In order to exploit the low-grade iron ores to obtain value added materials such as active pure Fe$_2$O$_3$ and Al$_2$O$_3$, and from these, respectively, ferrites and lanthanum aluminates, we (Verenkar 1997; Sawant 1998; Rane *et al* 1999, 2000, 2001; Rajesh and Rane 2001) have been chemically beneficiating the high silica/alumina and alumina/silica rejects of Goan origin. The chemical beneficiation using HCl and precipitating agents such as NH$_3$, NaOH, Na$_2$CO$_3$ yield iron oxides of purity 96–98%. A 99·73% pure iron oxide could be prepared from solvent extraction using methyl isobutyl ketone (MIBK). Major impurities in these oxides are Al, Si and Mn together amounting to ~ 2–3%. The iron oxides obtained were mainly a-Fe$_2$O$_3$ of hexagonal form with corundum structure. However, a novel hydrazine method

used by us in the synthesis of iron oxides yielded mainly cubic spinel $\boldsymbol{g}$Fe$_2$O$_3$. And, we observed that the cubic spinel magnesium ferrite, MgFe$_2$O$_4$, prepared from these synthetic iron oxides, $\boldsymbol{g}$Fe$_2$O$_3$, showed superior magnetic and electrical properties as compared to the ferrite obtained from commercial grade $\boldsymbol{a}$-Fe$_2$O$_3$. Thus, the synthetic $\boldsymbol{g}$Fe$_2$O$_3$ from iron ore rejects enabled us to obtain value added MgFe$_2$O$_4$.

Magnesium ferrite and allied compounds have found (Wilhelm H von Aulock 1965) wide spread applications in microwave devices because of their low magnetic and dielectric losses, and high resistivities. We (Verenkar 1997; Sawant 1998; Rane *et al* 1999, 2000) have prepared MgFe$_2$O$_4$ of high resistance, ~ 10^8 ohm cm, from iron ore rejects and found the samples to have uniform composition as revealed by their constant saturation magnetization, $4\boldsymbol{p}M_s$, values of 900–1200 Gauss and Curie temperature, T_c, of 670 ± 30 K. These values compare well with the reported ones, but in our case the Curie temperatures fall in a very narrow range, 670 ± 30 K, while a wide range, 593–713 (653 ± 60 K), is observed in the literature (Wilhelm H von Aulock 1965). Now we intend to measure an important microwave device property such as the dielectric behaviour, as a function of frequency, to see whether our method of preparation is adequate. The dielectric properties of ferrites are dependent upon several factors such as method of preparation, chemical composition, and grain structure and grain size. Our scanning electron microscopic (SEM) studies revealed uniform particles in the range 0–2 µm of porosity ~ 20–25%. These observations suggest that there is no significant influence of the impurities such as Al/Si/Mn that are present in 2–3% in the chemically beneficiated iron oxides. Hence, a normal dielectric behaviour as a function of frequency is also expected. In the present paper results of dielectric properties are reported.

2. Preparation and characterization

2.1 *Synthesis of iron oxides from iron ore rejects*

Iron ore rejects of Goan origin are (i) high silica ore: 35·5% Fe (50·76% Fe$_2$O$_3$), 3·3% Al$_2$O$_3$, 40·28% SiO$_2$ and impurities like MnO, CaO, MgO and other trace elements and (ii) high silica/alumina ore: 41·00% Fe (57·49% Fe$_2$O$_3$), 9·15% Al$_2$O$_3$, 23·33% SiO$_2$, 0·83% MnO and other trace elements. Acid extraction of the ore with 1 : 1 HCl plus few drops of concentrated HNO$_3$ was carried out. The acid extract was then used (Verenkar 1997; Sawant 1998; Rane *et al* 2001) to precipitate iron hydroxides from NH$_3$, NaOH, NaOH + NH$_3$ and Na$_2$CO$_3$; iron oxyhydroxides: $\boldsymbol{a}$-FeOOH, $\boldsymbol{g}$FeOOH and amorphous FeOOH; hydrazinated iron hydroxides and iron oxyhydroxides; iron formates and their hydrazinates; iron(II) carboxylato-hydrazinates (Verenkar 1997; Rane and Verenkar

2001): –ferrous–fumarato-(FFH), succinato-(FSH), malonato-(FMH), maleato-, malato-, tartrato-hydrazinates (FTH). The thermal products of these iron oxides, Fe$_2$O$_3$ (mainly $\boldsymbol{g}$Fe$_2$O$_3$), were tested for the majority impurity contents like Al, Si, and Mn.

2.2 *Preparation of MgFe$_2$O$_4$*

1 : 1 mole% of the synthetic iron oxide and MgO (MgCO$_3$) were granulated in an acetone medium in an agate mortar and compacted into a pellet of 10×5 mm dimension. The pellet was preheated at 700°C, cooled, reground, recompressed into pellet (10×5 mm), torroid (20 mm outer dia and 10 mm inner dia) and slowly heated to 1000°C and held at that temperature for 24 h, then furnace cooled. Few samples were also sintered further at 1100°C for 24 h.

2.3 *Characterization*

2.3a *X-ray phase identification*: The phase identification of the thermal products of the various precursors and the MgFe$_2$O$_4$ prepared from these oxides were made on Rigaku DMAX II X-ray diffractometer using Cu target and Ni filter.

2.3b *Direct current (d.c.) electrical resistance*: The d.c. electrical resistivity measurements of pelletized ferrite samples were done on the home built resistivity cell by two-probe method from room temperature to 700°C. The pellet of 10×5 mm was coated with silver paste on both the sides to provide better electrical contacts.

2.3c *Dielectric measurements*: The dielectric measurements were made using two-probe method. The pellet of 10×5 mm was coated with silver paste on both the sides to provide better electrical contacts. Dielectric constants were calculated from the capacitance measurements made on Hewlett-Packard 4284A, in the frequency range 10 Hz–1 MHz using precision LCR meter with 16048 C test leads. The values of dielectric loss were also simultaneously recorded. Temperature variation of dielectric constant was also made on few samples using two-probe method between 300 and 600 K at 1 KHz on MIC 4060 D LCR meter.

3. Results and discussion

3.1 *Purity of synthetic iron oxides and X-ray analysis of MgFe$_2$O$_4$*

The iron hydroxides, iron oxy-hydroxides and their hydrazinates, iron formates and their hydrazinates and iron(II) carboxylato-hydrazinates prepared (Verenkar 1997; Sawant

1998; Rane *et al* 2001), decomposed mainly as **g**Fe₂O₃ which were well characterized by X-ray diffraction by matching the d_{hkl} values with the JCPDS file Nos. 13-534, 19-629, 24-81 and 25-1402. The major impurities like Al₂O₃, SiO₂, MnO had been chemically analysed and their results presented in table 1 for one particular iron ore reject.

From the table it can be seen that the iron hydroxide (FH) obtained by precipitating the acid extract using NaOH, NH₃, NaOH + NH₃ and Na₂CO₃ help in decreasing the major impurities present in the ore. However, further decrease in these impurities is observed in the iron formates (FF) prepared from the hydroxides. The thermal product, Fe₂O₃, of these precursors is found to have purity between 91·82 and 98·38%. But, the acid extract when extracted with methyl isobutyl ketone (MIBK) and then precipitated as hydroxide on thermal decomposition gave iron oxide of purity 99·73%. The iron oxides thus prepared have SiO₂/Al₂O₃ ratio of 0·03 in the majority cases and 0·02 in the oxide obtained from formate precursor that had been prepared from the hydroxide using Na₂CO₃ as precipitant for the acid extract. Thus, the ore consisting of SiO₂/Al₂O₃ ratio of 2·55 was brought down to 0·02 to 0·03 by chemical beneficiation and accordingly the low grade iron ore containing 57·49% Fe₂O₃ was upgraded to 99·73%. Similar observations were also made (Verenkar 1997; Sawant 1998) on the other ore rejects.

The synthetic iron oxides obtained as above were mixed with MgO and heat treated at 1000°C for 24 h and the phase analysis was carried out by matching the d_{hkl} values obtained from X-ray diffraction studies with the reported values for MgFe₂O₄ in JCPDS files No.17-464 and 17-465. These ferrite samples are coded for convenience based on the iron oxides obtained from

1. Iron hydroxides (FH) and formates (FF)
   MgFH/NaOH, MgFH/NH₃, MgFH/NaOH + NH₃, MgFH/Na₂CO₃, MgFF/NaOH, MgFF/NH₃, MgFF/NaOH + NH₃, MgFF/Na₂CO₃.
2. Hydrazinated iron hydroxides and formates (FHH, FFH)

MgFHH/NaOH, MgFHH/NH₃, MgFHH/NaOH + NH₃, MgFHH/Na₂CO₃, MgFFH/NaOH, MgFFH/NH₃, MgFFH/NaOH + NH₃, MgFFH/Na₂CO₃.

3. Hydrazinates **g**FeOOH, **a**-FeOOH and amorphous FeOOH
   Mg**g**FA, Mg**a**FA, MgAmpFA.
4. Iron(II) carboxylato-hydrazinates
   MgFFHA, MgFSHA, MgFMHA, MgFTHA.
5. Commercial grade **a**-Fe₂O₃ (hematite) and **g**Fe₂O₃ (needle shape maghemite)
   MgHeM, Mg**g**td.

X-ray characterization of all ferrite samples showed that the d_{hkl} values compare well with the reported ones in the JCPDS files suggesting that there exists (Verenkar 1997; Sawant 1998; Rane *et al* 1999, 2000) a single phase MgFe₂O₄. However, the ferrite, MgHem, prepared from commercial grade hematite, showed the presence of some unreacted **a**-Fe₂O₃ in the product, indicating incomplete formation of the ferrite.

3.2 *Electrical and dielectric behaviour of MgFe₂O₄*

3.2a *Electrical behaviour:* All MgFe₂O₄ samples showed high resistivity of ~ 10^8 ohm cm at room temperature (*RT*) and the temperature variation of the resistivity indicated an Arrhenius behaviour, $\mathbf{r} = \mathbf{r}_0 e^{\Delta E/kT}$. The log $\mathbf{r}$ (resistivity) vs $1/T$ plots of the entire sample between *RT* and 700°C showed (Verenkar 1997; Sawant 1998) a decrease in the resistivity with the increase in temperature. Some typical experimental plots of log $\mathbf{r}$ vs $1/T \times 10^3$ are shown in figure 1. A break in the slope is observed in all plots and the temperature at which such break observed in the Arrhenius plot for $Mg_{1+t}Fe_{2-2t}Ti_tO_4$ (Semary *et al* 1983) was identified as the Curie temperature, T_c. The temperature at which the low temperature ($T < T_c$) ferrimagnetic MgFe₂O₄ changes to paramagnetic is the Curie temperature and the plots clearly indicate the two regions with two different activation energies, $\Delta E = ~ 0·68$ eV ($T > T_c$)

Table 1. Chemical analysis of iron ore reject and precursors: Ferric hydroxide (FH), ferric formate (FF) and their thermal product, iron oxide, Fe₂O₃.

Analytes (%)	Study sample I	FH NaOH	FH NH₃	FH NaOH + NH₃	FH Na₂CO₃	FH/NH₃ *MIBK	FF NaOH	FF NH₃	FF NaOH + NH₃	FF Na₂CO₃
Fe	41·00	58·00	56·00	56·50	57·00	64·20	45·76	44·33	43·62	34·10
Si	–	0·55	0·15	0·17	0·10	0·08	0·46	0·07	0·10	0·04
SiO₂	23·33	–	–	–	–	–	–	–	–	–
Al	–	0·228	2·90	2·95	2·64	0·21	0·10	1·72	1·63	1·89
Al₂O₃	9·15	–	–	–	–	–	–	–	–	–
Mn	–	0·93	0·62	0·62	1·05	NIL	0·46	0·38	0·41	0·60
MnO	0·83	–	–	–	–	–	–	–	–	–
Total wt. loss	–	10·63	16·32	8·52	11·80	7·46	41·06	52·00	53·00	53·12
Fe₂O₃	57·49	98·38	93·67	92·24	91·82	*99·73	98·67	96·52	97·24	96·95

in paramagnetic and ~ 0·44 eV in ferrimagnetic region. The activation energies in the paramagnetic regions are higher than in the ferrimagnetic and these observations are in conformity with the results on $Mg_{1+t}Fe_{2-2t}Ti_tO_4$ and other ferrite systems (Rao and Murthy 1989; Otari *et al* 1990). T_c values thus observed (652 ± 36 K) in $MgFe_2O_4$ are found to be comparable to the values obtained from magnetic measurements (Verenkar 1997; Sawant 1998) such as, temperature variation of a.c. susceptibility, c_T/c_{RT}, (633 ± 40 K) and initial permeability, m_i (679 ± 41 K). The typical plots of the temperature variation of a.c. susceptibility and initial permeability of few representative $MgFe_2O_4$ samples are also shown in figure 1. The reported values (Wilhelm H von Aulock 1965) of T_c, however, cover a wide range of temperatures, 593–713 K (653 ± 60 K) indicating difficulty in optimizing the heat treatment in obtaining the ferrite of fixed composition. Our results indicate that the ferrite of uniform composition could be synthesized easily at 1000°C by the present method of preparation.

The saturation magnetization values, $4\pi M_s$, of all ferrite samples measured (Verenkar 1997; Sawant 1998) at *RT* from high field hysteresis loop tracer described by Likhite *et al* (1965), and supplied by M/s Arun Electronics,

Mumbai, India, fell in the range 900–1200 G. The saturation magnetization values are found to be within the range reported (Wilhelm H von Aulock 1965) for the several members of magnesium ferrites family, $Mg_xM_{1-x}Fe_2O_4$ (M = Al, Mn, Cu, Zn), however, the reliability of the values depends on the actual distribution of the various ions in the lattice. The distribution is sensitive to the heat treatment given to the ferrite. Since all our $MgFe_2O_4$ samples show a narrow range of T_c and $4\pi M_s$ values, we consider that the method of preparation adopted by us is adequate. And, the minor impurities, Al, Si, Mn that are present in our starting iron oxide rejects, have no much influence on the cation distribution of the ferrite.

3.2b *Dielectric behaviour*: As uniform electrical and magnetic properties are observed for $MgFe_2O_4$ prepared from iron oxides synthesized from iron ore rejects, the impurities such as Al, Si, Mn ($< 2\%$) seem to be tolerable, as far as cation distribution is concerned. Since $MgFe_2O_4$ and related ferrites are widely used components in microwave family due to their low magnetic and dielectric losses, we investigated the dielectric behaviour of these ferrites. The dielectric properties of ferrites are dependent upon several factors, including the method of preparation,
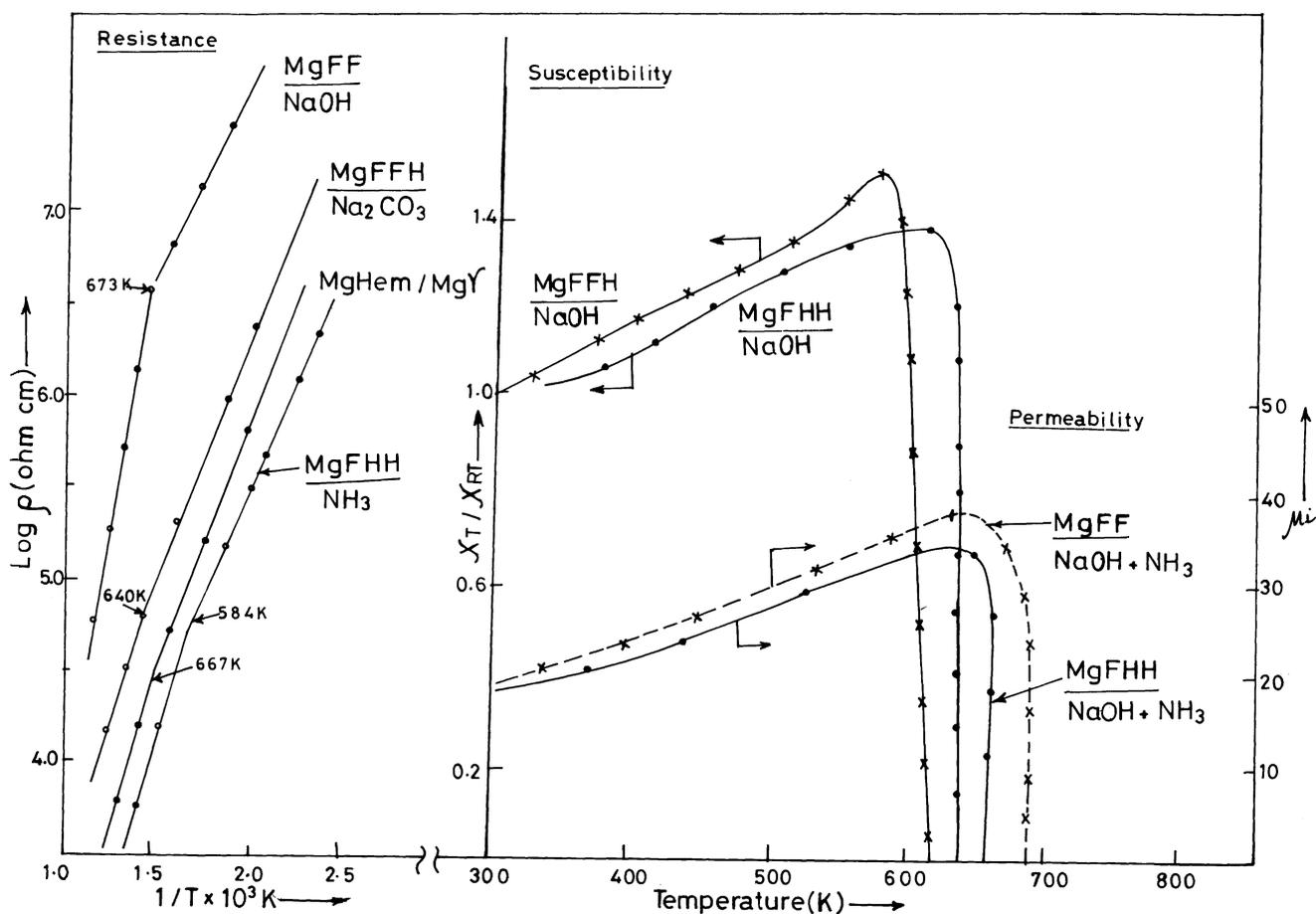

Figure 1. Temperature dependence of electrical resistivity (r), magnetic susceptibility (c_T/c_{RT}) and initial permeability (m_i) of $MgFe_2O_4$.

chemical composition, and grain structure or size. As our preparation conditions have reliably fixed the cation distributions, they all have uniform composition. The uniform particle size distribution (0–3 μm) and low porosity (~ 25%) observed in our ferrites (Sawant 1998; Rane *et al* 1999) accompanied by almost fixed composition and high resistivity should, therefore, make these ferrites to behave normally in their frequency dependent dielectric properties with low dielectric loss factor.

3.2c *Dielectric constant*: The frequency variation of room temperature dielectric constant, ε', and the dielectric loss tangent, tan δ of all the MgFe$_2$O$_4$ samples were carried out from 10 Hz–1 MHz and few representative plots are shown in figure 2. All samples show a dielectric constant of 12–15 at 10 Hz and there is a decreasing trend in the value as the frequency is increased which is the normal behaviour of ferrimagnetic materials. The dielectric dispersion is sharp initially and then the ε' value

decreases slowly with the increase in frequency followed by a frequency independent behaviour. Such observations are made on ferrites such as Mg–Zn (Suryavanshi *et al* 1991; Ravinder and Latha 1999), Li–Cd (Radha and Ravinder 1995), Li–Mg (Bellad *et al* 1999) and Ni–Zn (Verma *et al* 1999). The normal dielectric behaviour of spinel ferrites was explained by Maxwell–Wagner interfacial type polarization, which is in agreement with Koops theory (Wagner 1913; Koops 1951; Maxwell 1954).

Iwauchi (1971) gave a strong correlation between conduction mechanism and the dielectric behaviour of the ferrites. In ferrites the conduction is due to electron hopping between Fe^{2+} ⇔ Fe^{3+} on the octahedral sites of the spinel structure. A higher concentration of Fe^{2+} ions in the spinel structure leads to higher conductivity and it is observed that the high conductivity ferrites also show high dielectric constant. Thus, it is the number of ferrous ions that play dominant role in the process of conduction as well as dielectric polarization. In the solid solution
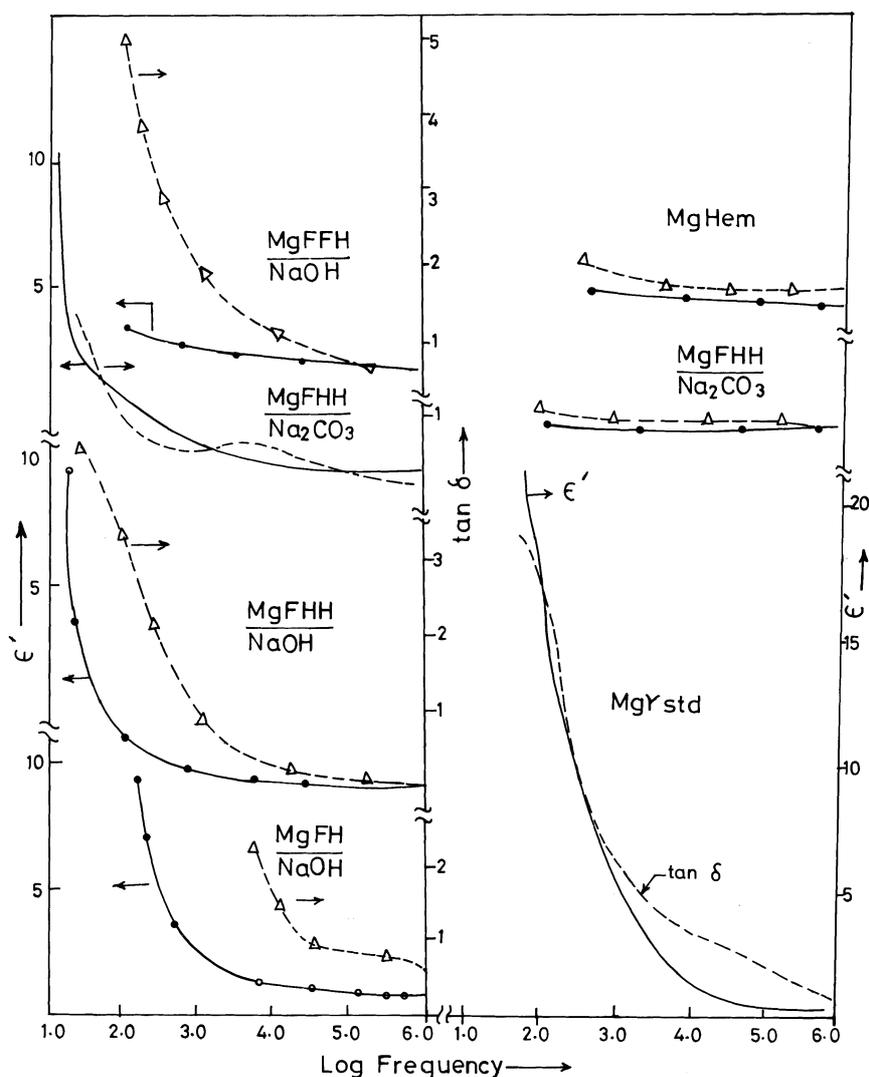

Figure 2. Frequency dependence of dielectric constant (ε') and tan δ loss of MgFe$_2$O$_4$.

(Ravinder and Latha 1999) of $MgFe_2O_4$ and $ZnFe_2O_4$: $Mg_{1-x}Zn_xFe_2O_4$, the high resistive Mg ferrite ($1·21\%$ Fe^{2+}) showed dielectric constant 31, while the high conducting Zn ferrite ($1·82\%$ Fe^{2+}) indicated a very high $\varepsilon' = 3·2 \times 10^5$; the least dielectric constant of 3 is observed for $Mg_{0·6}Zn_{0·4}Fe_2O_4$ which had least Fe^{2+} concentration ($0·84\%$) in the series of the ferrite. The dielectric constants of $MgFe_2O_4$ ferrite in the present study all lie within 10–15 and hence, the Fe^{2+} concentrations in our samples are low and, therefore, we observed high resistivity of $\sim 10^8$ ohm cm for all our samples.

3.2d *Loss tangent*: The frequency variation of loss tangent, tan δ of magnesium ferrites (figure 2), show a normal behaviour of decrease with the increase in frequency up to 1 kHz and, thereafter, there is a frequency independent behaviour in few cases, while few among the samples showed a maximum at certain range of applied frequencies. As there is a strong correlation between conduction mechanism and dielectric behaviour in the high resistive magnesium ferrites, the frequency of the hopping of electrons ($Fe^{2+} \Leftrightarrow Fe^{3+}$) may be matching with the applied external field to give this loss maximum. Then, no such maximum was observed in few ferrite samples indicate that there may be less number of Fe^{2+} ions on the octahedral sites whose frequency may match at much higher frequency range. Our study here is restricted up to 1MHz. Less number of Fe^{2+} is expected in our samples as all the ferrites have high resistance. In other words, the $MgFe_2O_4$ prepared from synthetic iron oxides obtained from the chemically beneficiated iron ore rejects give cation distribution in such a way that there occurs not much change in the Fe^{2+}, in spite of the impurities like, Si, Al, Mn inherently present in the starting iron oxides. The method of preparation adopted here also contributes to such a constant composition ferrite formation.

3.2e *Effect of sintering on dielectric behaviour*: On comparing the dielectric behaviour of the $MgFe_2O_4$ samples prepared at 1000°C from synthetic iron oxides of nano-metre size (mainly γFe_2O_3) studied here and that prepared from (i) standard γFe_2O_3 ($Mg\gamma_{td.}$) and (ii) commercial grade α-Fe_2O_3 (MgHem), with those sintered at 1100°C, it can be seen in figure 3 that higher sintering temperatures also allows them to behave normally. However, few behave differently. MgHem sample prepared at 1000°C from commercial grade hematite, α-Fe_2O_3, on sintering to 1100°C shows an overall increase in dielectric constant in the entire range of measurement, while others indicate lower values. But, the behaviour of the loss tangent is interesting in few cases. MgHem prepared at 1000°C shows a normal decrease in the loss tangent, while 1100°C sintering make it to show a broad maximum in the frequency range 10–100 kHz. Whereas, the samples such as MgαFA and MgFTHA which were showing a maximum in certain frequency range indicate no such

maximum on sintering to higher temperatures. This may be qualitatively attributed to the increase in the Fe^{2+} concentration in MgHem with the increase in heat treatment as the dielectric constant is also increased. The grain growth can also take place in case of MgHem on sintering to higher temperatures, on the other hand, the other ferrites find the heat treatment beneficial.

The ferrite, MgHem, prepared from commercial grade α-Fe_2O_3 gave (Verenkar 1997; Sawant 1998; Rane *et al* 1999) high porosity ($> 40\%$) particles of sizes ranging from 0–6 μm, as shown in the scanning electron micrographs in figure 4, while the ferrite from the synthetic iron oxides showed low porosity ($\sim 25\%$) grains (0–3 μm).

Hence, the higher sintering may be allowing uneven growth of MgHem particles, whereas the other ferrites from synthetic iron oxides (of nanometre size) end up into well compact materials useful in device applications.
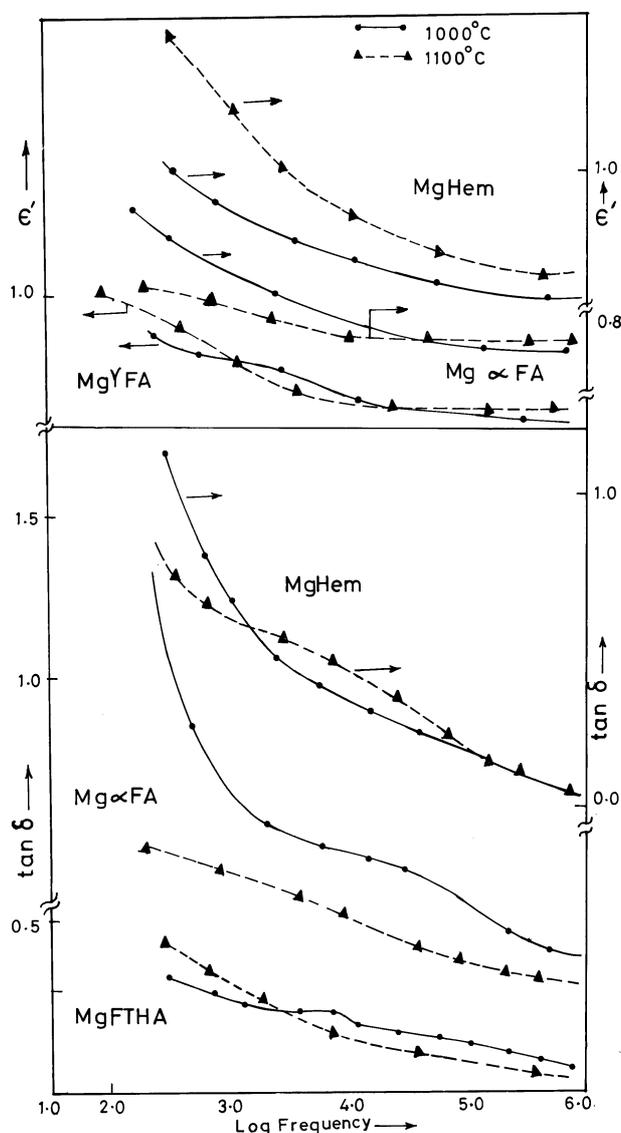

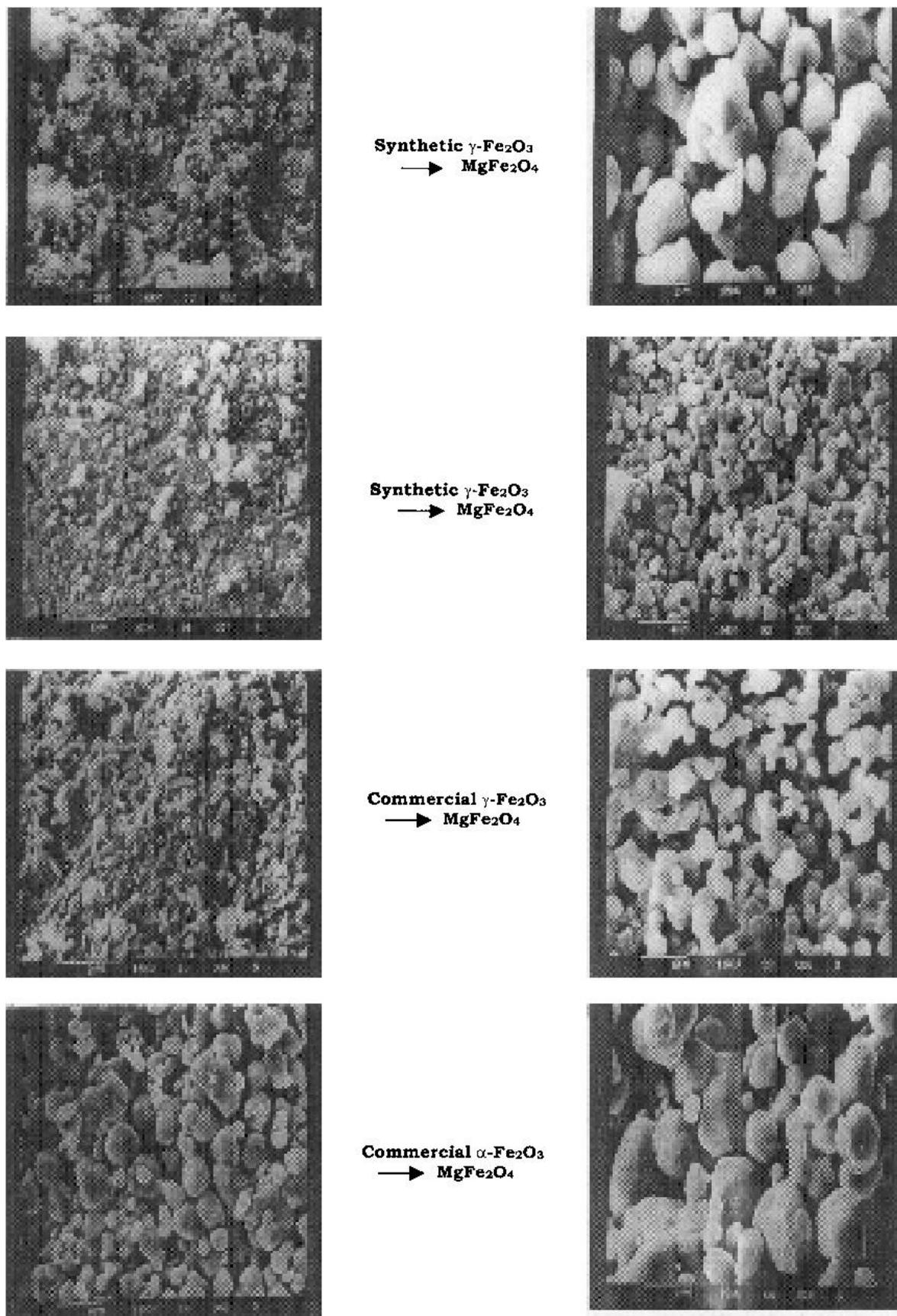**Figure 3.** Effect of sintering on the dielectric behaviour of $MgFe_2O_4$.

Figure 4.   SEM micrographs of iron oxides and MgFe₂O₄.

Mgg_{td} which is prepared from commercial grade needle shaped gFe$_2$O$_3$ is of interest as this gives the ferrite of dumbbell shape (figure 4) of high dielectric constant (figure 2). Particle size may be one of the criteria for these ferrites to behave differently, but the influence of the major impurities such as Al/Si/Mn which are, in general, present < 2–3% in our iron oxide sources from chemically beneficiated iron ore rejects (table 1), is difficult to assess.

4. Conclusions

(I) High silica/alumina = 2·55 iron ore rejects consisting of 57·49% Fe$_2$O$_3$ are chemically beneficiated to 92–98% purity having SiO$_2$/Al$_2$O$_3$ less than 0·03, but 99·73% purity oxide could be obtained from acid extract using methyl iso-butyl ketone (MIBK) as an extractant.

(II) The acid extracts of the ore rejects were precipitated as hydroxides by using the precipitants such as NaOH, NH$_3$, and Na$_2$CO$_3$. The hydroxides were used to prepare iron oxyhydroxides, formates, iron(II) carboxylates and the hydrazinates of all these.

(III) The thermal products of all above are mainly iron oxides of gFe$_2$O$_3$ form. All were used to synthesize magnesium ferrite, MgFe$_2$O$_4$.

(IV) The ferrite formation was confirmed by X-ray diffraction. Electrical resistivities of all the ferrites at room temperature are ~ 10^8 ohm cm.

(V) Dielectric constants at low frequency of all the ferrites were in the range 12–15 and with frequency increase from 100 Hz–1 MHz, a normal dispersion is observed. Loss tangent, tan d also showed a decrease with the frequency.

(VI) Few ferrite samples showed broad maxima (10–100 KHz) after the usual initial decrease.

(VII) Low content of polarizable Fe^{2+} ions on the octahedral were responsible for low dielectric constant and high resistivity in the ferrite samples. Impurities such as Si, Al, Mn do not make any marked influence on the properties.

(VIII) Chemically beneficiated iron ore rejects can, hence, be effectively used in the synthesis of high quality ferrites.

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