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Room temperature $Ni_{0.8}Zn_{0.2}Fe_2O_4$Thick FilmChlorine Sensor

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Abstract: The nano crystalline $Ni_{0.8}Zn_{0.2}Fe_2O_4$ powder was prepared by co-precipitation method and deposited on alumina substrate by screen printing method. The powder was characterized by XRD, FT-IR and SEM techniques. The XRD study shows the cubic spinel structure. The crystallite size is 26.32nm. The FT-IR spectrum shows two absorption bands near 400cm^{-1} and 600cm^{-1} corresponding to tetrahedral and octahedral sites respectively. The SEM study shows irregular shape grainsand average size is 0.85µm. The ferrite thick films show higher sensitivity to Cl_2than ethanol and LPG at room temperature.
Keywords: $Ni_{0.8}Zn_{0.2}Fe_2O_4$; cubic spinel; thick films;gas sensing.

Introduction

The environment is polluted by toxic and hazards gases. Ferrites play an important role in sensing and determining their existence [1]. Rezlescu*et al.* [2] reported that Zinc ferrite is sensitive and selective to ethanol but shows poor response to the acetone and LPG.The $NiFe_2O_4$ thick film sensor showed greater response than the $NiFe_2O_4$ pellet sensor [3]. Arshak*et al.* [4] deposited NiO/Fe_2O_3 polymer thick films by screen printing technique on glass substrate and studied them for gas sensing at room temperature. Gawas*et al.* [5] reported that the $Mn_{0.3}Ni_{0.3}Zn_{0.4}Fe_2O_4$ ferrite thick films have high sensitivity to 10ppm NH_3 at room temperature. The NiO/TiO_2 addition in $ZnFe_2O_4$ polymer thick films were studied for gas sensing properties [6]. Cao *et al*. [7] studied gas sensing properties of $ZnFe_2O_4$ and found high sensitivity, good selectivity and fast response/ recovery for ethanol and hydrogen sulfide.In this communication the deposition of nanocrystalline $Ni_{0.8}Zn_{0.2}Fe_2O_4$ thick films by screen printing method, their characterization and gas sensing behaviour at room temperature for various gases is reported.

Experimental

The nanoycrystalline $Ni_{0.8}Zn_{0.2}Fe_2O_4$ was prepared by oxalate co-precipitation method. The ferrite precipitate was dried on hot plate and presintered at 170 ºC for one hour. The pre-sintered powders were milled in agate mortar and final sintered 450 ºC for two hours.The ferrite thick films paste was prepared by mixing of $Ni_{0.8}Zn_{0.2}Fe_2O_4$ ferrite powder (90wt%), with organic binder, ethyl cellulose (5wt%) and inorganic binder, 2-(2-butoxyethoxy) ethyl acetate (5wt%). The $Ni_{0.8}Zn_{0.2}Fe_2O_4$was deposited on alumina substrate by using the screen printing technique. Finally these films were dried at 300ºC. These thick films were used as gas sensing elements.The X-ray diffraction pattern was recorded onBruker D2 Phaserin the range of 10-90° using CuKα radiation (λ=1.5424A°). The micrograph of the thick films was studied on the Hitachi S-4700 (Japan). The Infrared absorption spectrum was recorded at the range of 300-800cm^{-1} using Perkin Elmer spectrum one spectrometer by KBrpellet technique.

Results and Discussion

The X-ray diffraction pattern of $Ni_{0.8}Zn_{0.2}Fe_2O_4$ is presented in Fig.1 a). The presence of (220), (311), (222), (400), (422), (511), (440) and (533) planes in the pattern confirms the formation of single phase cubic spinel structure. The lattice constant of all samples under investigation is calculated by using Bragg's equation [8].The average crystallite size of the samples was calculated from the most intense (311) peak of XRD by using Debye Scherer equation [8].

The micrograph of the fractured surface of ferrite thick a film is presented in Fig.1 b).It shows that the grains are irregular in shape. The grain size calculated by the linear intercept method is presented in Table 1.

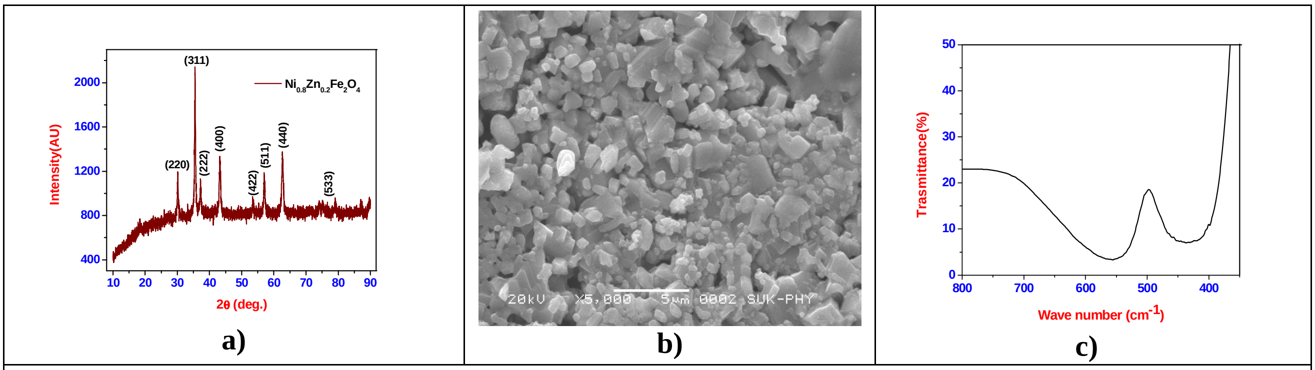

Fig.1.a) XRD, **b)** SEM, **c)** FTIR of $Ni_{0.8}Zn_{0.2}Fe_2O_4$

The infrared spectrum of $Ni_{0.8}Zn_{0.2}Fe_2O_4$ is presented in Fig.1 c). It shows two major absorption bands near about 400cm^{-1}and 600cm^{-1} for octahedral and tetrahedral sites respectively.The lattice constant, crystallite size, grain size, absorption band and sensitivity are presented in the Table 1.

Table. 1. Parameters estimated from XRD, SEM, FTIR and gas sensing of $Ni_{0.8}Zn_{0.2}Fe_2O_4$.

Lattice constant a (A°)	Grain size (µm)	Crystallite size (nm)	Absorption bands (cm^{-1})		Gas sensitivity (%) at 1000 ppm		
			υ_1	υ_2	Cl_2	LPG	Ethanol
8.3856	0.85	26.32	555	435	84	79	61

The gas sensing characteristics were measured by using lab made gas sensor unit**.** A known amount of Cl_2, LPG, ethanol, was inserted in the chamber with the help of syringe and change in the resistance was noted with time and temperature.

The variation of gas sensitivity with temperature for Cl_2,LPG and ethanol is presented in Fig.2 a). From the figure it can be noticed that, the $Ni_{0.8}Zn_{0.2}Fe_2O_4$ ferrite thick film responds at about room temperature to the gases mentioned, thereby increasing the sensitivity at room temperature. The sensitivity of the film is highest to Cl_2. It is in the order of Cl_2 > LPG>ethanol. The sensitivity for Cl_2, LPG and ethanol decreases as temperature goes on increasing.Kamble*et al.* reported $NiFe_2O_4$ thick film as an efficient gas sensor at room temperature giving 96% and 68% sensitivities for $Cl_2$and ammonia respectively [3].

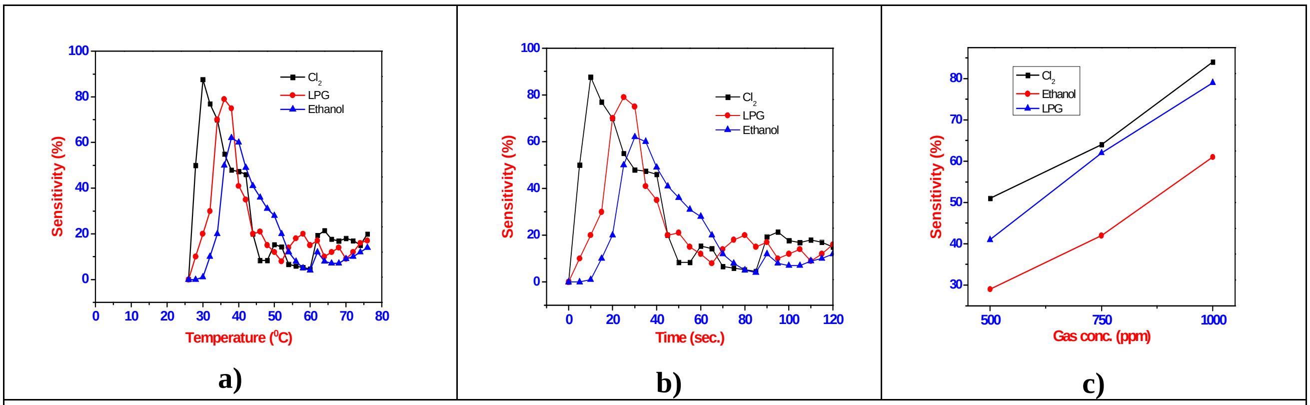

Fig. 2. **a)** Variation of sensitivity with temperature to $Cl_{2,}$ LPGand ethanol, **b)** Variation of sensitivity with time for $Ni_{0.8}Zn_{0.2}Fe_2O_4$, **c)** Variation of sensitivity with gas concentration.

The variation of sensitivity with time is presented in Fig.2 b). The figure shows that, response increases with increase in time and then decreases. The sensor shows highest sensitivity at 11 sec to Cl_2. The variation sensitivity of the sensor with gas concentration is presented in Fig.2 c). It shows that the sensitivity of the sensor under investigation is lower at lower gas concentration and increases for increased concentration.

Conclusions

The nano crystalline $Ni_{0.8}Zn_{0.2}Fe_2O_4$ was synthesized by co-precipitation method. The cubic spinel structure is observed in the ferrite. The thick films of this ferrite were deposited by screen printing method. The films show highest sensitivity to Cl_2 at room temperature. The sensitivity is lower for ethanol and LPG. The response time is lowest for $Cl_{2.}$

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