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Low Field Microwave Absorption in Mn:Ni Co-Doped ZnO μm Size Powders

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Polycrystalline $Zn_{1-x}(Mn:Ni)_xO$ sample for $x = 0.02$ were synthesized by solid state route. We have observed low field microwave absorption in these powder samples. Low field microwave absorption signal is out of phase with the regular resonance signal indicating the microwave absorption has a minimum at zero field and the absorption of microwaves increases with increase of magnetic field. Low field microwave absorption in these powders is qualitatively different from their bulk pellets. Temperature dependence of the low field microwave absorption indicates a line shape evolution and a non-monotonic peak to peak intensity change. Further, we have observed the absence of 2nd harmonic in this low field microwave absorption, indicating low field microwave absorption in these transition metal co-doped ZnO powders is not non-linear in nature.

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PACS/topics: low field microwave absorption, transition metal co-doped ZnO, sintering effects

1. Introduction

Microwave absorption in certain magnetic materials is very sensitive to small applied magnetic fields. Particularly in the case of μm size manganite powders, Srinivasu et al. [1, 2] have reported a colossal effect of microwave loss dependence on fields in the range of a few hundred Oe. Thereafter, similar low field microwave absorption (LFMA) has been reported in several magnetic materials [3–11]. The phenomenon of LFMA is very useful in the context of designing microwave absorbing materials. Our group has recently reported LFMA in Mn:Ni and Mn:Fe co-doped ZnO system, in the bulk pellets [8]. As reported [1, 2], μm size powders could be more effective in microwave absorption than their bulk form. Therefore, it is interesting to study and compare LFMA in both bulk and powder form of the same sample or system. Here, we report the LFMA study in the μm size powders of $Zn_{1-x}(Mn:Ni)_xO$ ($x = 0.02$) system sintered at different temperatures.

2. Experimental details

$Zn_{1-x}(Mn:Ni)_xO$ ($x = 0.02$) bulk samples were prepared by solid state route and sintered at two different temperatures namely 500 °C and 800 °C. The bulk pellets were well characterised as reported in Ref. [8]. These pellets were then well grinded to obtain μm-sized powders using an agate mortar. The particles have formed agglomerates with their sizes ranging from subμm to μm as shown by SEM image in Fig. 1. LFMA measurements were carried out using a Bruker ESR spectrometer operating at 9.5 GHz. Modulation field was varied between 1 Gs to 9 Gs. Further microwave power was varied between 20 dB to 30 dB. All measurements were carried out at room temperature.

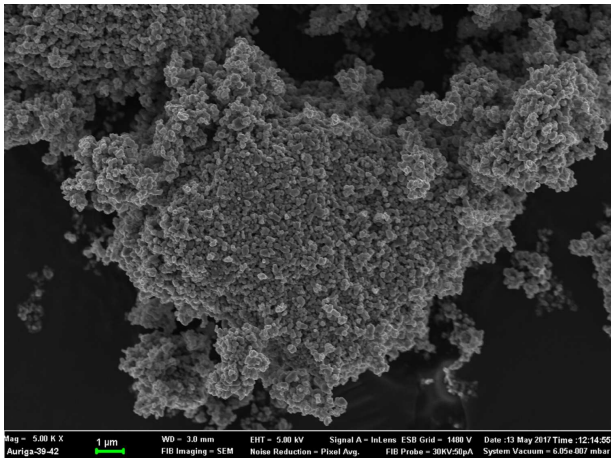

Fig. 1. SEM images of $Zn_{1-x}(Mn:Ni)xO$ ($x = 0.02$).

3. Results and discussion

Figure 2 presents the LFMA signals for both bulk pellet and powder forms of $Zn_{1-x}(Mn:Ni)_xO$ ($x = 0.02$). We observe that powdering did not bring in any appreciable change in LFMA in this system. In order to understand the sintering effect on LFMA in these powder samples, we measured LFMA for 500 °C and 800 °C sample, which is shown in Fig. 3. One can see that sintering temperature has good effect on the line shape of LFMA. The line shape of 500 °C sample is much narrower and saturates quickly as compared to the broader LFMA line

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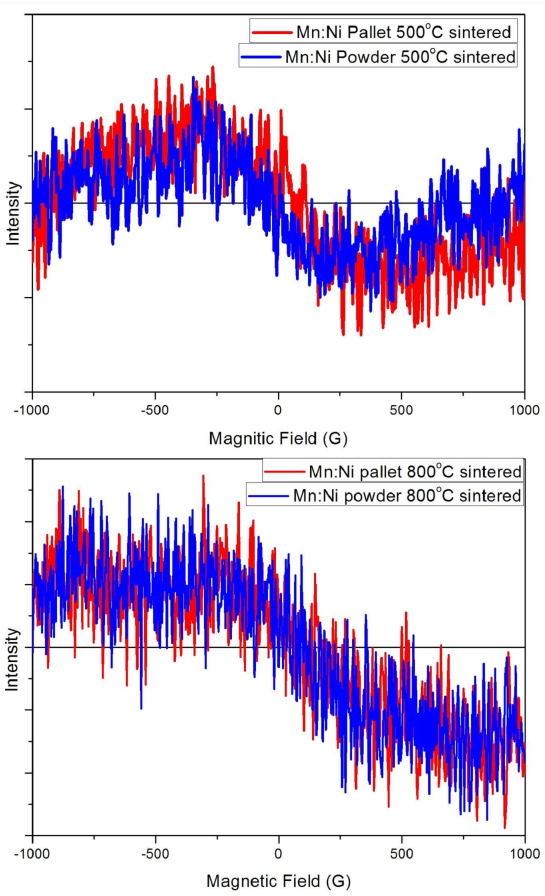

Fig. 2. A comparison of LFMA between bulk pellet and powder $Zn_{1-x}(Mn{:}Ni)_xO$ ($x = 0.02$) samples sintered at (a) 500 °C and (b) 800 °C temperatures.

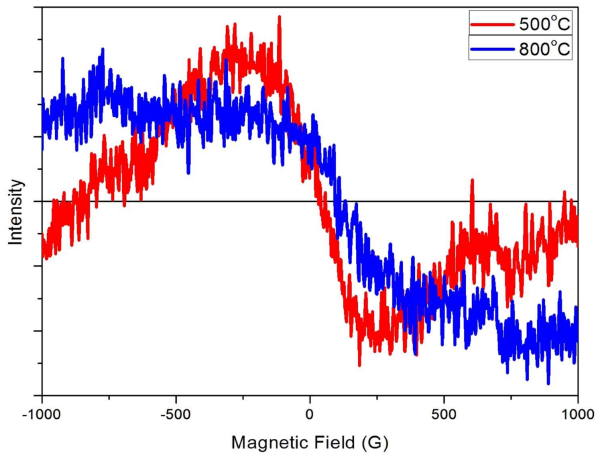

Fig. 3. LFMA signals for 500 °C and 800 °C sintered powder sample of $Zn_{1-x}(Mn{:}Ni)_xO$ ($x = 0.02$).

shape in the 800 °C sintered sample. This indicates that microwave absorption is more sensitive to applied field in the case of 500 °C sintered sample as compared to that of the one sintered at 800 °C. This could be due to the defects and disorder in the 800 °C sintered sample as evidenced by PL spectra in this sample [8]. These defects can restrict the spin rotation and hence one needs higher field to rotate the spins completely, leading to a higher saturation field in LFMA. Further the LFMA in these samples is out of phase with the regular resonant ESR signal, indicating that the LFMA has minimum of microwave absorption at zero and then increases as the field is swept away from zero. This is in contrast, totally opposite with the LFMA observed in manganite powders [1, 2] where the microwave absorption is maximum at zero and decreases as the field is swept away from the zero.

Figure 4 shows the microwave power dependence of LFMA for both 500 °C and 800 °C sintered powder sample of $Zn_{1-x}(Mn{:}Ni)_xO$ ($x = 0.02$). We found that the signal strength increases as microwave power is increased. As the microwave power is increased, microwave currents in the sample increases leading to increased joule losses and therefore we expect the LFMA signal strength to increase. Further as shown in Fig. 5 LFMA signal intensity increases as the modulation field amplitude is increased. This indicates that the LFMA is strongly dependent on the amplitude of modulation field. We also measure the 2nd harmonic however the 2nd harmonic is absent, indicating that the LFMA is not nonlinear in nature.

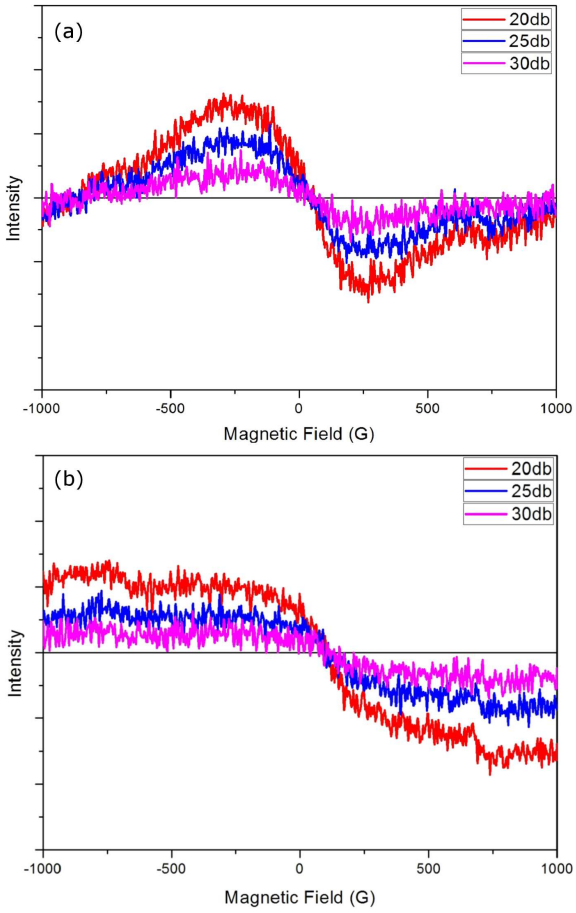

Fig. 4. Power dependence of LFMA in (a) 500 °C and (b) 800 °C sintered powder samples of $Zn_{1-x}(Mn{:}Ni)_xO$ ($x = 0.02$).

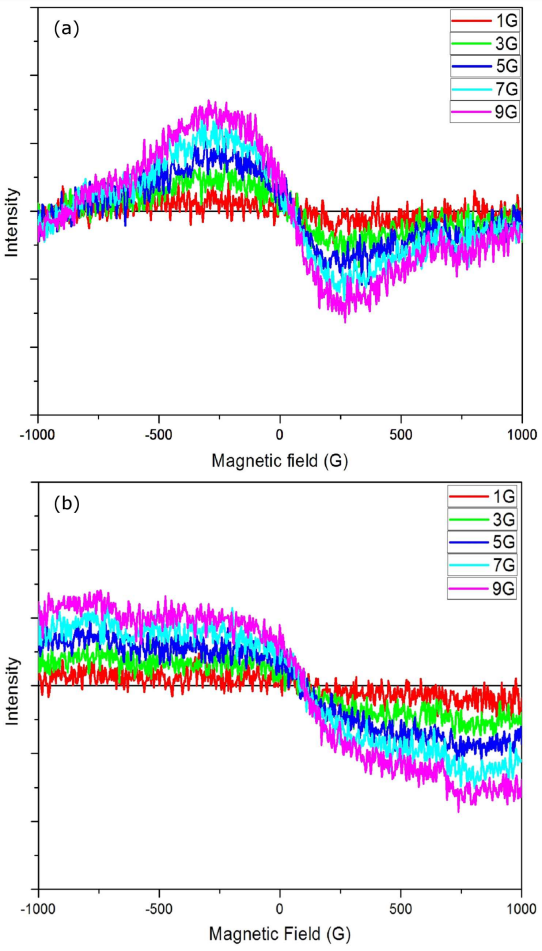

Fig. 5. Modulation field dependence of LFMA in (a) 500 °C and (b) 800 °C sintered powder samples of $Zn_{1-x}(Mn{:}Ni)_xO$ ($x = 0.02$).

4. Conclusion

In conclusion, we have studied low field microwave absorption phenomenon in the μm size powders of Mn:Ni co-doped ZnO system. Firstly, LFMA in these powders have a minimum of microwave absorption at zero field and then increases as the magnetic field is swept away from zero. We found that sintering temperature has strong effect on the line shapes of LFMA signal. The line shape is narrower and saturates quickly in the sample sintered at 500 °C as compared to that of the sample sintered at 800 °C. Strong microwave power dependence was observed, indicating joule losses .Also, LFMA in these powders depends on modulation amplitude, increases with increase of modulation. There is no 2nd harmonic, indicating that the LFMA in this system is not non-linear by nature. We did not observe any appreciable differences in the LFMA signals for the powder and bulk pellet forms of these samples.

Acknowledgments

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