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Microwave absorption studies of MgB_2 superconductor

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Abstract. Microwave absorption studies have been carried out on MgB_2 superconductor using a standard X-band EPR spectrometer. The modulated low-field microwave absorption signals recorded for polycrystalline (grain size $\sim 10\ \mu$m) samples suggested the absence of weak-link character. The field dependent direct microwave absorption has been found to obey a $\sqrt{H}$ dependence with two different slopes, which indicated a transition from strongly pinned lattice to flux flow regime.

Keywords. MgB_2 superconductor; microwave absorption; EPR.

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1. Introduction

The microwave absorption is a tool in understanding the various physical properties of superconductors such as surface resistivity, lower critical field, penetration depth, vortex dynamics etc. Here we present the results of microwave absorption studies carried out on recently discovered MgB_2 superconductor [1].

2. Experimental

Polycrystalline (grain size $\sim 10\ \mu$m) and large single-grain ($3\times 2\times 1$ mm^3) MgB_2 samples were synthesized using solid-state and liquid-phase assisted sintering processes, respectively [2].

The microwave absorption studies were carried out using a Bruker ESP 300, X-band (9–10 GHz) spectrometer. Both polycrystalline pellet and single-grain MgB_2, having nearly the same T_c ($\sim$ 39 K) and same size ($3\times 2\times 1$ mm^3), were used in the present investigations. Low field modulated microwave absorption signals (LFS) (measured in the EPR mode of detection with 100 kHz field modulation) and field dependent direct microwave absorption signals were recorded at different temperatures between 15 and 50 K.

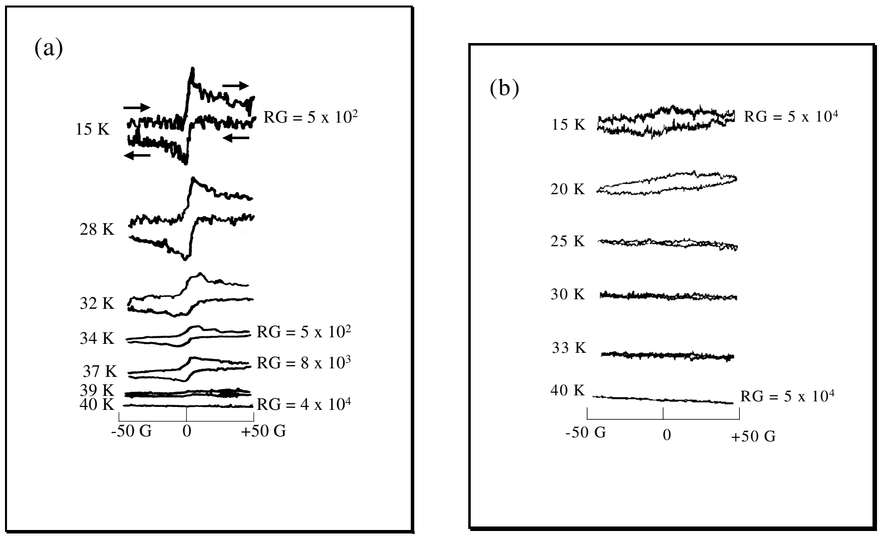

Figure 1. The temperature dependence of low field signal (LFS) recorded for (**a**) polycrystalline and (**b**) single-grain MgB_2 samples.

3. Results and discussion

The low field signals (LFS) for polycrystalline and single-grain MgB_2 samples, recorded at different temperatures, are shown in figure 1. In the normal state (above $T_c \sim 39$ K), no LFS was observed for both the samples. As the temperature is decreased below T_c, a LFS centered on zero magnetic field is observed. In the case of polycrystalline sample, the LFS exhibit a step-like shape with large hysteresis, which indicated that sample does not show a weak-link character and microwave loss is essentially due to Lorentz force induced vortex motion [3]. The intensity of LFS is found to increase almost by two orders of magnitude on cooling from 40 to 15 K. On the other hand, for single-grain MgB_2 sample, very weak LFS were observed, and the intensity increased very slowly by lowering the temperature. Since the size of polycrystalline pellet and single-grain samples are nearly the same, the poor intensity in single-grain sample indicates that it has almost no grain boundaries and therefore, is like a single crystal.

The magnetic field dependence of direct microwave absorption for polycrystalline sample, recorded at various temperatures, is shown in figure 2a. It is seen that at temperatures above T_c, the leakage current (i.e. measure of microwave absorption) does not depend on the magnetic field. However below T_c, the leakage current is initially independent of the applied field, but abruptly increases after a certain value of magnetic field, which depends on the temperature. Since increase in microwave absorption in the sample, at a given field, implies penetration of the magnetic field into the sample [4], this field therefore, corresponds to the lower critical field H_{c1} of the sample at the given temperature. The H_{c1} values (marked by arrows in figure 2a) obtained at 15, 20 and 25 K were respectively 85, 122 and 155 G. Assuming a linear dependence of H_{c1} on temperature, as reported by Li *et al* [5], $H_{c1}(0)$, is estimated to be $\sim$ 250 G. The magnetic field dependent microwave absorption

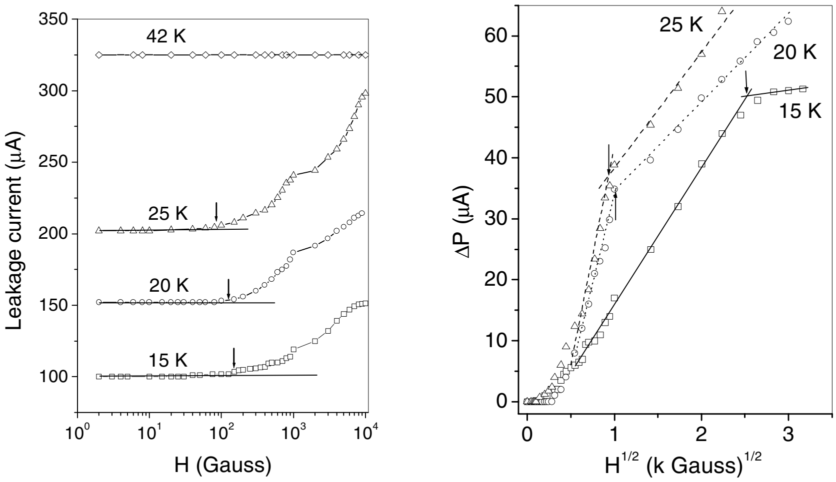

Figure 2. (**a**) The magnetic field dependence of microwave absorption recorded for polycrystalline MgB_2 sample. The magnetic field from where the absorption increases abruptly (marked by arrow) is identified as lower critical field H_{c1}. (**b**) Variation of microwave absorption ($\Delta P = P(H) - P(0)$) as a function of $\sqrt{H}$. The positions of arrows correspond to crossover field H^* at which the system changes from strongly pinned state to flux flow regime.

data, presented in figure 2a, is replotted as change in leakage current ($\Delta P = P(H) - P(0)$) as a function of $\sqrt{H}$, and shown in figure 2b. It is observed that the absorbed power obeys $\sqrt{H}$ dependence with two distinct slopes. The field at which the change in slope takes place is known as characteristic field (H^*) (marked by arrows in figure 2b). The H^* signifies a crossover from a strongly flux pinned state to the flux flow regime [6]. The values of H^* were found to be 6.3, 1 and 0.8 kG for temperatures of 15, 20 and 25 K, respectively.

4. Conclusion

Microwave absorption studies have been made on MgB_2 superconductor. The low field signals suggested the absence of weak links in the polycrystalline sample. The lower critical field ($H_{c1}(0)$) of $\sim$ 250 G has been determined from the magnetic field dependence of direct microwave absorption. The absorbed microwave power showed two distinct slopes when plotted as a function of $\sqrt{H}$, which indicated a transition from rigid flux lattice to flux flow regime.

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