Frequency dependence of the microwave surface resistance of MgB_2 by coaxial cavity resonator

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Abstract. We report on the frequency dependence of the mw surface resistance, R_s, of MgB_2 by coaxial cavity resonator. We have determined the temperature dependence of R_s of a cylindrical MgB_2 rod prepared by the reactive liquid Mg infiltration technology at EDISON SpA. , at fixed frequencies, and the frequency dependence of R_s, at fixed temperatures.

MgB_2 material

The bulk MgB_2 rod have been prepared by the **reactive liquid Mg infiltration technology**, which consists in the reaction of pure liquid Mg and a preform of B powder in a sealed stainless steel container. In particular, crystalline B powder (99.5% purity, original chunks mechanically grinded and sieved under a 38 μm sieve) and thermal annealing at 850 °C for 3 h.

Experimental results

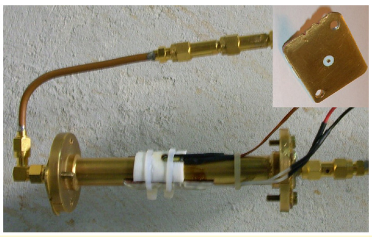

Figure 1. Hybrid Cu/MgB2 coaxial cavity and the modified SMA connector (inset), prepared to match the cavity's ends.

We have manufactured a coaxial cavity with a Cu tube as outer conductor and a MgB_2 rod as inner conductor.

External Cu tube:
105.4 mm long
inner diameter 10.2 mm

MgB_2 rod:
diameter 3.8 mm
length 94.3 mm

The resonant cavity has been characterized measuring its frequency response in the range 1 – 13GHz by an hp-8719D Network Analyzer, in the temperature range 4.2K – 50K.
The cavity exhibits 8 resonant modes, shown in **Figure 2**.

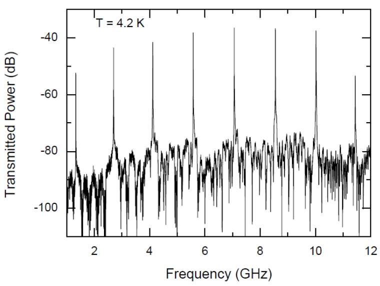

Figure 2. Spectrum of the coaxial cavity; the cavity shows 8 modes in the range 1 – 13 GHz.

R_s vs. T

From Q_U, one can determine R_s of the MgB_2 material by which the inner rod is done:

$$R_s = \frac{1}{Q_u}\left[a\mu_0\omega \ln\left(\frac{b}{a}\right)\right] - \frac{a}{b}R_s^{Cu}$$

Figure 3 shows:

Q_U vs. T of the MgB_2/Cu cavity (left axis)

R_s vs. T of the MgB_2 (right axis)

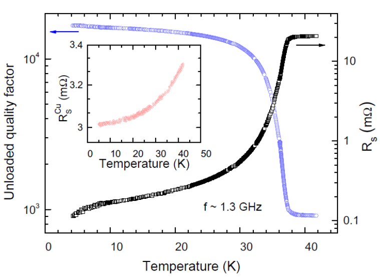

Figure 3. Q_U and R_s vs T at f = 1.3 GHz. The inset shows R_s vs. T of Cu.

We obtained the highest quality factor Q_U = 17000 at T = 4.2K; it remains of the order of 10^4 up to about 30K and reduces by a factor of about 20 when the SC rod goes into the normal state. The correspondent values of R_s go from R_s = 0.1mΩ, at T = 4.2K, up to R_s = 20mΩ at T = T_c = 38.5K.

Frequency dependence of R_s

To determine the frequency dependence of R_s, the temperature was set at desired values, then the resonance curves for the different modes were acquired and analyzed to obtain the curves of R_s vs. T shown in **Figure 4**.

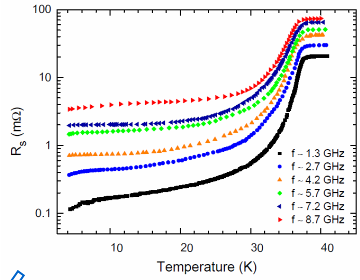

Figure 4. R_s vs T at different frequencies.

For each temperature, the deduced R_s vs. f curves plotted in a log-log scale have highlighted a linear behavior indicating a f^n law; two examples of $R_s(f)$ curves, one at low T and one near T_c, are shown in **Figure 5**.

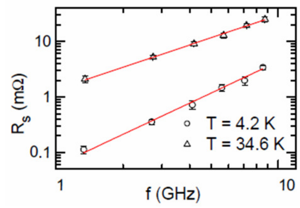

Figure 5. R_s vs. frequency.

Discussion and conclusion

Our results show that the $R_s(f)$ curves follow a f^n law, where the exponent n decreases on increasing T, from n ≅ 2, at T = 4.2 K, down to n ≅ 0.7 at T ≅ T_c.

The temperature dependence of the exponent n is shown in **Figure 6**.

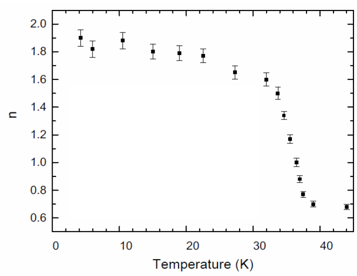

Figure 6. Temperature dependence of n.

The double-gap nature of MgB_2 manifests itself in the presence of a wide low-T tail in the $R_s(T)$ curves, which can be ascribed to the quasi-particles thermally excited through the π-gap even at relatively low temperatures.

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