

Complex conductivity at audio and radio frequencies in superconducting $\text{YBa}_2\text{Cu}_3\text{O}_7$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_7$ thin films

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Complex Conductivity at Audio and Radio Frequencies in Superconducting $\text{YBa}_2\text{Cu}_3\text{O}_7$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ Thin Films

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Abstract:

The complex ac conductivity $\sigma^* = \sigma' - i\sigma''$ has been measured in thin films of $\text{YBa}_2\text{Cu}_3\text{O}_7$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ at frequencies $1\text{kHz} \leq \nu \leq 1\text{GHz}$ and temperatures $10\text{K} \leq T \leq 300\text{K}$. In both compounds, just at T_c , a peak shows up in the T-dependence of the real part of the conductivity. The origin of this peak is interpreted in terms of fluctuation effects which are weak in $\text{YBa}_2\text{Cu}_3\text{O}_7$ but strong in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$. No coherence-like phenomena were detected.

1) Introduction

Measurements of the dynamic response in superconductors at $T \leq T_c$ have provided important informations on the nature of the superconducting state. In the framework of the BCS theory a maximum below T_c , the so-called "coherence peak", has been predicted to occur in the temperature dependence of the nuclear magnetic relaxation rate and also of $\sigma'(T)$ for frequencies well below the gap /1/. For "normal" superconductors this peak has been found in NMR and microwave measurements /2, 3/.

Recently, a peak below T_c has been found in superconducting $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ /4/ and $\text{YBa}_2\text{Cu}_3\text{O}_7$ /5/ single crystals in microwave experiments conducted at 60GHz and in superconducting $\text{YBa}_2\text{Cu}_3\text{O}_7$ thin films using coherent time-domain terahertz spectroscopy /6/. In contrast, no peak in the NMR

relaxation rate could be detected in these materials /7, 8/.

These findings have stimulated a number of theoretical and experimental investigations (see Ref. /9/ and references therein). Although the experimental situation and its interpretation /10/ is confusing, it became quite clear that the microwave results are strongly sample dependent and it appears that the occurrence of a peak just below the superconducting transition temperature is driven by a distribution of T_C 's rather than by coherence effects. However, it has been pointed out by Horbach et al. /11/, following earlier work by Schmidt /12/, that fluctuation effects can play an important role.

Here we report measurements of the complex ac conductivity in thin films of superconducting cuprates for frequencies $1\text{kHz} \leq \nu \leq 1\text{GHz}$ and temperatures $10\text{K} \leq T \leq 300\text{K}$. We present data for $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ as well as for $\text{YBa}_2\text{Cu}_3\text{O}_7$. It is well known that fluctuation effects are much more pronounced in the former compound.

2) Experimental Details

Thin films of $\text{YBa}_2\text{Cu}_3\text{O}_7$ and $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ were prepared by dc-sputtering from single targets /13/. Silver contacts were evaporated onto the films and were subsequently annealed in O_2 atmosphere /13/. SrTiO_3 , MgO , ZrO_2 and LaAlO_3 substrates have been used.

The high-frequency data ($1\text{MHz} \leq \nu \leq 1\text{GHz}$) were recorded using an HP 4191A impedance analyzer connected to a refrigerator system via an air line /14/. This reflectometric method requires two-point contact configurations. The audio-frequency measurements were performed using fully automated auto-balance-bridges which allow the use of four-point contact geometry.

3) Results and discussion

Figure 1 shows the real (left row) and imaginary part (right row) of the complex admittance $G^* = G' - iG''$ in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ measured at 1, 27.5 and 83.2MHz. With decreasing temperatures, the real part of the conductivity reveals a continuous increase with a sharp peak close to T_C and a rapid drop at $T \leq T_C$. The height of the peak decreases as ν^{-1} . The temperature of the maximum conductivity is almost independent of frequency. For frequencies $\nu \geq 100\text{MHz}$ the peak becomes suppressed and $G'(T)$ reveals a steplike drop at T_C only. These results reveal the characteristic features of two-dimensional fluctuation effects /11/. G'' is small in the normal conducting state and increases rapidly below T_C . Within the framework of the BCS theory, from the temperature dependence of the imaginary part of the conductivity the T -dependence of the energy gap $\Delta(T)$ can be calculated. We

found that $\Delta(T)$ remains constant below T_c and drops almost discontinuously to zero at T_c in accordance with experimental observations /15/ and theoretical predictions /16/.

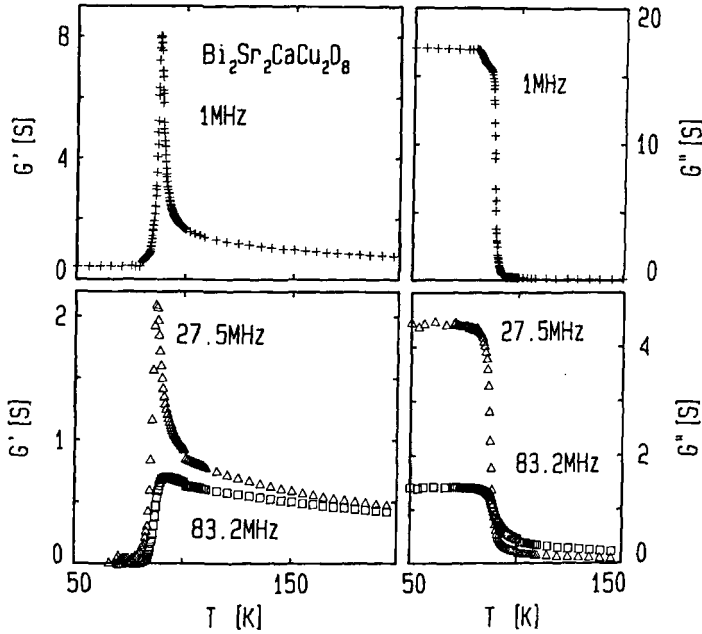


Fig. 1: Real G' (left row) and imaginary part G'' (right row) of the complex admittance in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ vs temperature at different measuring frequencies as indicated.

In Fig. 2 the real part of the conductivity $\sigma'(T)$ in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ is compared to the results obtained in superconducting $\text{YBa}_2\text{Cu}_3\text{O}_7$ thin films. Here σ' was calculated from G using the sample dimensions. In both compounds the conductivities behave rather similar. However, in $\text{YBa}_2\text{Cu}_3\text{O}_7$ the high temperature wing of the peak is much less pronounced indicating that the two-dimensional fluctuation effects are significantly weaker in this compound. Fig. 2 reveals that in both compounds the fluctuation effects below T_c are strongly suppressed. We interpret this effect as being due to the discontinuous increase of the superconducting energy gap at T_c .

In conclusion, the peaks in the temperature dependence of the real part of the conductivity in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ and $\text{YBa}_2\text{Cu}_3\text{O}_7$ reveal the signature of two-dimensional fluctuation effects and no coherence effects show up in $\sigma'(T)$ in both compounds in accordance with the NMR results /7, 8/.

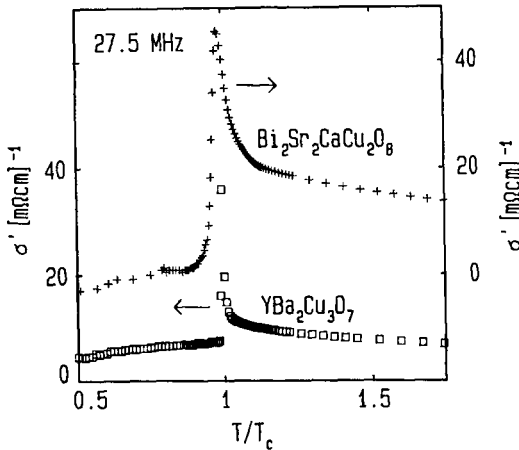


Fig. 2: Real part of the conductivity σ' vs the reduced temperature in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ and in $\text{YBa}_2\text{Cu}_3\text{O}_7$ as measured at 27.5MHz

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