INFRARED SPECTRA AND THE GAP IN $YBa_2Cu_3O_{7-\delta}$ FILMS

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The experimental determination of the superconducting gap has long been associated with low-frequency (IR and microwave) spectroscopic methods[1]. Initial attempts to extract the gap value from electromagnetic spectra in high-temperature superconductors have failed because early ceramic and even crystalline samples did not show perfect reflectivity typical of a classic superconductor at frequencies below the gap value. Recently, with improved sample quality, several groups have obtained reflectivity values close to 100 per cent within experimental uncertainty[2-4]. We illustrate this uncertainty in Fig. 1 on the spectrum of a high quality $YBa_2Cu_3O_{7-\delta}$ laser-deposited film (T_c = 91 K, ΔT_c = 0.5 K). The strong suppression of the noise (i.e. forcing the reflectivity to be exactly 1 in the region below the observed downturn and aggressively smoothing the curve above) is imperative in order to extract meaningful results from Kramers - Kronig analysis .

It is tempting to associate the frequency at which $R(\omega)$ starts to deviate from 1 with the superconducting gap value. However, if we look at our results in the context of other data taken on high-reflectivity samples (these are summarized in Table I), we would argue otherwise. From the

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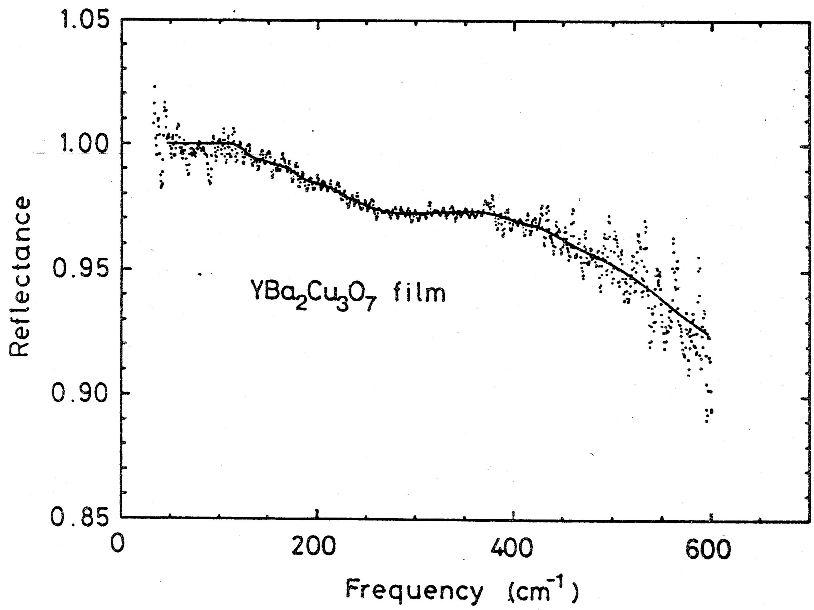

Figure 1. Reflectivity of $YBa_2Cu_3O_{7-\delta}$ film (dots: measured data, solid line: data used for Kramers-Kronig analysis as described in text)

MATERIAL	T_c(K)	ONSET OF ABSORPTION cm^{-1}	ONSET OF ABSORPTION K	REFERENCE
$YBa_2Cu_3O_{7-\delta}$	50	120	170	3
$YBa_2Cu_3O_{7-\delta}$	68	150	210	3
$YBa_2Cu_3O_{7-\delta}$	90	130	180	4
$YBa_2Cu_3O_{7-\delta}$	85-91	120-150	170-210	5
$Bi_2Sr_2CaCu_2O_8$	85	300	420	4
$Bi_2Sr_2CaCu_2O_8$	85	250	350	7

Table I. Comparison of reflectivity downturns (onsets of optical absorption) in different high T_c materials.

table it is apparent that the onset of optical absorption does not scale with T_c in different $YBa_2Cu_3O_{7-\delta}$ samples, but shows a marked difference between $YBa_2Cu_3O_{7-\delta}$ and $Bi_2Sr_2CaCu_2O_8$.

We believe the absorption in the infrared in these materials is not a gap onset but an electronic feature present in both the normal and the superconducting state[6], determined by the chemical structure. The real gap can not be seen in these spectra for the following reasons: in the normal state, both the oscillator strength and the width of the free-electron Drude contribution to the optical conductivity are far smaller than for ordinary metals[4-7]; this, together with the higher T_c and thus presumably higher gap value leads to the fact that in the superconducting state all the free electron oscillator strength condenses into the delta function at zero frequency. This means high-T_c materials are unique also in the respect that they represent <u>the first examples of "clean limit" superconductivity.</u>

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