Raman scattering from the $Bi_2Sr_2CaCu_2O_{8+y}$ superconductor

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The Raman spectrum from 10 to 550 cm^{-1} has been obtained from the $Bi_2Sr_2CaCu_2O_{8+y}$ superconductor. Modes similar to those exhibited by $YBa_2Cu_3O_{7-y}$ are found, as expected from similarities in the crystal structures of the two materials. In addition, several strong low-frequency modes are present, suggestive of a material with loosely coupled substructures consistent with the structural x-ray analysis of $Bi_2Sr_2CaCu_2O_{8+y}$. Meissner analysis shows that the sample used exhibits bulk superconductivity.

Recently Tarascon *et al.*[1] have described the crystal structure of the $Bi_2Sr_2CaCu_2O_{8+y}$ superconductor which has $T_c=85$ K. While the space group[1] of this material differs[2-5] from that of $YBa_2Cu_3O_{7-y}$, the Raman-active plane is common to both; thus, the spectra of the two superconductors can be expected to have strong similarities. This will indeed prove to be the case.

The apparatus used has been described in detail elsewhere[6] and consists of a Raman microprobe apparatus with a spot size of ~ 1 μm. A backscattering geometry is used in all experiments such that the exciting electric vector E_{in} is in the plane of the sample. This exciting radiation is provided by the 4880-Å line of the Ar^+ laser. All data were taken at room temperature.

Micalike crystals of $Bi_2Sr_2CaCu_2O_{8+y}$ for these studies were grown using a flux composed of bismuth and copper oxides in excess of the stoichiometric requirements.[7] A piece was picked off which weighed 70 μg with an estimated 30% error. Figure 1 shows as evidence of bulk superconductivity the Meissner curve for this sample, which was obtained in a field of 10 G. The percent superconductivity is not quoted because sample geometry does not warrant calculation of the appropriate demagnetizing factor. T_c is seen to be 80 K; the broad transition indicates some nonuniformity in the material.

Figure 2 shows the spectrum obtained from this sample from 10 to 550 cm^{-1}. Although the polarization of the electric vector of both the exciting and scattered radiation was varied, no effects on the spectrum were observed. This indicates that there was no long-range single-crystal order within the 1-μm spot size. All spots observed gave the same line spectra; however, signal-to-noise ratio varied as much as a factor of 10 from point to point which we attribute to areas of greater surface roughness.

In $YBa_2Cu_3O_{7-y}$, the Y, Cu(1), and O(4) atoms cannot participate in Raman modes[2-5,8] (identification of atom positions as in Ref. 2). Out-of-phase bond bending[2-5] of O(2)–O(3) gives rise to the 340 cm^{-1} mode; in-phase bond bending of these same oxygens[2-5] accounts for the mode at 447 cm^{-1}. Axial stretching of O(1) leads to the 500 cm^{-1} mode;[2-5] similarly axial stretching of

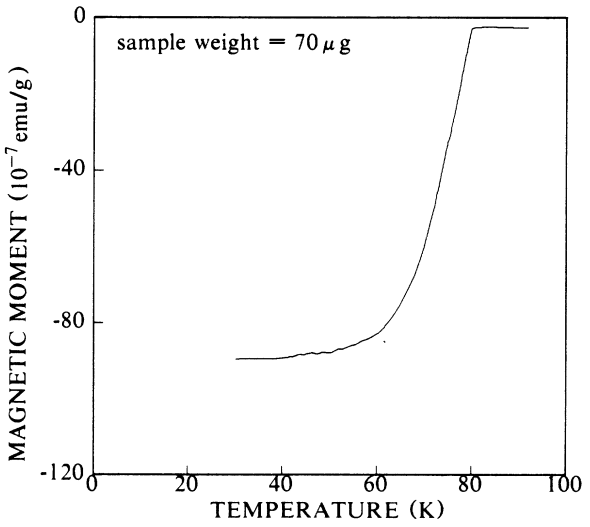

FIG. 1. Magnetization vs temperature for the $Bi_2Sr_2CaCu_2O_{8+y}$ sample used for Raman data. The curve represents cooling in field of 10 G (Meissner).

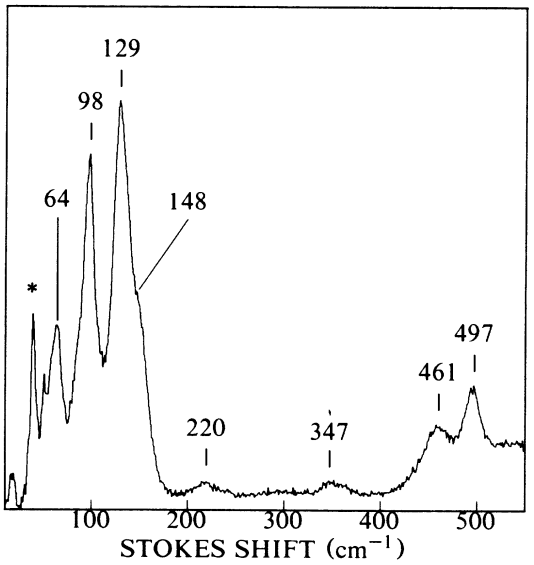

FIG. 2. Raman scattering from $Bi_2Sr_2CaCu_2O_{8+y}$. Asterisk indicates plasma line. Background has been subtracted.

Cu(2) gives the 220 cm^{-1} mode.[2-5] Finally, the 150 cm^{-1} mode derives from symmetric stretching of the Ba planes.[2-5] It is obvious from Fig. 2 that each of the above mentioned $YBa_2Cu_3O_{7-y}$ modes has a counterpart in the $Bi_2Sr_2CaCu_2O_{8+y}$ superconductor. This is to be expected, since the substructure of $Bi_2Sr_2CaCu_2O_{8+y}$ has in-plane Raman-active Cu and O atoms with similar environment to those active in $YBa_2Cu_3O_{7-y}$. The Ba plane is replaced by a Sr plane, which is also Raman active, as determined from group theory used in conjunction with the crystallographic information.

The space group[1] for the $Bi_2Sr_2CaCu_2O_{8+y}$ substructure is $I4/mmm$ (D_{4h}^{17}). On the basis of the Wyckoff notation for equivalent sites,[1] we find[8] that Ca has point-group symmetry D_{4h}, and therefore is not involved in any Raman modes. O(1) has symmetry C_{2v}^{6} and can have Raman modes $A_{1g}(R_{xx}+R_{yy},R_{zz})$, $E_g(R_{xz},R_{yz})$, and $B_{1g}(R_{xx}-R_{yy})$. The remaining atoms [Sr,Bi,Cu,O(2), O(3)] each have symmetry C_{4v}, which gives the A_{1g} and E_g Raman-active modes. If the modes of Fig. 2 which are at 148, 220, 347, 461, and 500 cm^{-1} are analogous to those of $YBa_2Cu_3O_{7-y}$, they can be expected to have A_{1g} symmetry.[2-5]

The strong low-frequency modes at 64, 98, and 129 cm^{-1} are unique to the spectrum of $Bi_2Sr_2CaCu_2O_{8+y}$. It is interesting to note that Fig. 2 resembles spectra of polytype structures[9] where unit-cell substructures are loosely coupled together in layers. The weaker high-frequency modes discussed above come from within the unit cell, while these large low-frequency modes arise from motion between layers. Such a picture is consistent with the fact that, within $Bi_2Sr_2CaCu_2O_{8+y}$, slabs are displaced from one another along the c axis by a distance (Ref. 1) $(\frac{1}{2}a,\frac{1}{2}b)$; this structure gives the sample its micalike character as found in graphite or layered materials. The low-frequency modes might also be due to scattering from long-range fluctuations observed perpendicular to the c axis in the bismuth oxygen plane. Clarification of mode assignments will be made with data from more uniform crystals combined with lattice-dynamic calculations.

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