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LETTER TO THE EDITOR

Mechanical energy dissipation phenomena in 1–2–4 yttrium superconductors

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Abstract. The results of measurements of the internal friction and Young's modulus in yttrium 1–2–4 superconducting ceramics are reported. The internal friction maxima found in the temperature range from 30 K to 100 K are of relaxation nature. The activation energy and relaxation time of these phenomena have been estimated. The association of the Cu–O chain relaxation with one of the internal friction phenomena is briefly discussed.

We would like to present the first results of measurements of the internal friction in $YBa_2Cu_4O_8$ ceramic superconductors.

The 1–2–4 and 1–2–3 crystal structures are closely related. The main difference is that each 1–2–4 unit cell contains two Cu–O chains instead of one, as in the 1–2–3 unit cell. This leads to a much larger c lattice parameter and smaller orthorhombicity (c = 27.20 Å, e = 0.8% in the 1–2–4 phase and c = 11.68 Å, e = 1.8% in the 1–2–3 phase) [1, 15].

In the last four years, many papers on the anelastic effect in the 1–2–3 superconductors have been published (e.g. [2–5]). A number of relaxation phenomena have been observed in orthorhombic and tetragonal materials. It seemed interesting to us to study the properties of the 1–2–4 compound and to observe the possible changes in the mechanical energy spectra which may be induced by the second Cu–O chain.

The 1–2–4 samples (A) were synthesized by the low-pressure technique. Details of sample preparation are reported elsewhere [6, 7]. The x-ray diffractograms of the material studied showed a single 1–2–4 phase. The transition temperature, determined on the basis of resistive and magnetic shielding measurements, was 76 K.

The measurements of anelastic effects were conducted by the vibrating-reed technique. The measurement frequency was in the range of 95–660 Hz. The detailed description of the experimental methods is published elsewhere [5].

The 1–2–4 samples are much softer than the 1–2–3 ceramics. On the basis of our measurements we cannot determine the exact value of Young's modulus; however, we can observe its evolution with temperature. The results of Young's modulus measurements obtained for the 1–2–4 ceramics were similar to those of the 1–2–3 superconductors [5, 8, 9] and did not show any anomalous features.

Figure 1 presents the results of internal friction measurements versus temperature obtained for the pure 1–2–4 ceramics. Also shown in figure 1, for comparison, is the

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internal friction spectrum in the 1–2–3 superconductor [5]. The similarity between the two curves is apparent. No significant differences, either in the position of the peaks or in their height, can be observed. A small maximum seen at 54 K in the 1–2–4 spectrum seems to be the only difference between the curves. However, our further investigations, carried out with the two-phase material, indicated that this phenomenon is not intrinsic to the 1–2–4 structure [7].

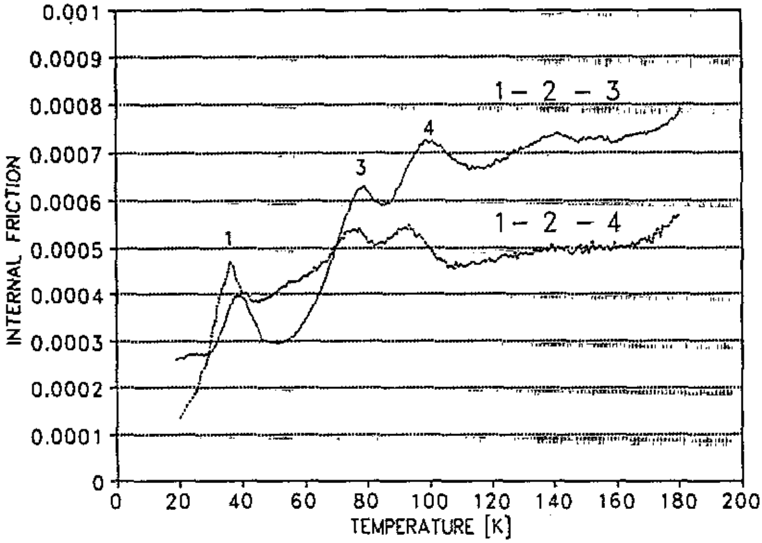

Figure 1. Temperature dependence of the internal friction (Q^{-1}) in the 1–2–4 and 1–2–3 superconductors. The spectra were taken with vibration frequencies of 246 and 212 Hz, respectively.

All the internal friction phenomena observed in the temperature range from 30 K to 140 K are of relaxation nature. The numbers ascribed to particular processes are consistent with those used for describing the 1–2–3 internal friction maxima [5, 10, 12]. The small frequency range available in our experiments prevented us from determining the exact values of the activation energy and relaxation time characteristic for the relaxation phenomena existing in the 1–2–4 ceramics. The quantities displayed in table 1 show the range of their possible values. For comparison, we also present the relaxation parameters of the internal friction maxima found in the 1–2–3 specimens [10, 11]. As one can see, the additional Cu–O chain does not affect the parameters significantly. The small variation of activation energy can be caused by the difference between the unit cell parameters of the 1–2–3 and 1–2–4 superconductors.

So far, process 4 has been interpreted as being due to hops of oxygen atoms between two minima of energy in distorted Cu–O–Cu chains. Such minima exist in the orthorhombic structure of the 1–2–3 material [10, 12, 13]. The neutron diffraction studies show that the zigzag arrangement of copper–oxygen chains does not exist in the 1–2–4 structure [15–17]. If this is indeed the case, one would expect that the process related to the zigzag relaxation should vanish. This leads to a contradiction with the experimental data since no significant change in the peak magnitude has been observed; and might mean that the above interpretation of process 4 would have to be reexamined. We believe that it is rather unlikely that process 4 is due to different mechanisms in the 1–2–3 and 1–2–4 superconductors.

Table 1. The activation energy E_A and relaxation time τ_0 of dissipation energy processes in the 1–2–4 and 1–2–3 superconductors.

Material	1–2–4		1–2–3	
Process No	E_A (eV)	log τ_0	E_A (eV)	log τ_0
1	0.07–0.1	< -13	0.07	-13
3	0.11–0.14	-13	0.16	-12.5
4	0.13–0.15	—	0.2	-13.5

We propose that the interpretation of other relaxation phenomena (the peaks 1 and 3, and the peak existing in the spectra for tetragonal 1–2–3 structure) should be reconsidered as well. Their small activation energy seems to exclude an atom or point defect migration from one lattice position to another [14, 18]. We suggest that some peaks are due to the relaxation of the 'off-symmetry' configurations [14]. More detailed discussion will be published elsewhere [7].

In conclusion, we report the results of internal friction measurements for the 1–2–4 yttrium superconductor. Its internal friction spectra are very much similar to those of the 1–2–3 superconductor. The second Cu–O chain present in the 1–2–4 unit cell does not give rise to new relaxation phenomena in the temperature range from 20 to 300 K.

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