THE EFFECT OF THE INTRAGRANULAR IRREVERSIBLE MAGNETIZATION ON MACROSCOPIC PROPERTIES OF THE CERAMIC HIGH -T_c SUPERCONDUCTORS

V.P.Khavronin, S.L.Ginzburg, I.D.Luzyanin, G.Yu.Logvinova

In the ceramic high-T_c superconductors for the fields below the lower critical field of the grains themselves, h_{c1gr}, macroscopic superconductive properties (transport currents, magnetic shielding, etc.) are governed by intergranular critical current density $j_c(H)$. In the fields of $h > h_{c1gr}$, intragranular magnetization becomes irreversible and since $J_{cgr}(h) >> j_c(h)$ always, under certain conditions this irreversible magnetization can strongly affect the macroscopic electric and magnetic properties of the superconductor. Thus, the occurring situation in principle differs from the situation for conventional superconductors. This difference consists in the two points. First, in a granular superconductor magnetic field h_{dip} generated by intragranular magnetization can be much higher than the fields h_1 out of intergranular shielding currents. Secondly, intragranular magnetization is a new source of the irreversibility. As a result, many new interesting phenomena occur, i.e. hysteresis of critical current, an inversion of the hysteresis loop, etc.

In order to describe these phenomena the generalized critical state theory was proposed. Within the framework of this theory a number of the phenomena was investigated which are determined by the three combined factors, i.e., first, the presence of intragranular irreversible magnetization; secondly, demagnetizing factor value being finite; thirdly, the sample being doubly- connected (hollow cylinder is taken for this purpose in our experiments). Finite sizes of the sample are essential because h_{dip} equals zero in the asymptotic case of an infinite sample and therefore all the phenomena related to flux trapping into grains disappear. The choice of the doubly-connected sample is determined by the fact that, in this case, the sign of the dipole field d_{dip} in the cylinder hole is opposite to the sigh of the field generated by shielding supercurrents h_1 and, as a result, three different types of hysteresis loop can be observed as an amplitude of the DC field changes, i.e. the purely diamagnetic loop, the loop with the interesection of its ascending and descending branches, and the purely paramagnetic loop. On the other hand, the diamagnetic shielding outside the cylinder disappeared, but here the dipole field is not zero. Therefore outside the cylinder the hysteresis loop has the paramagnetic character.

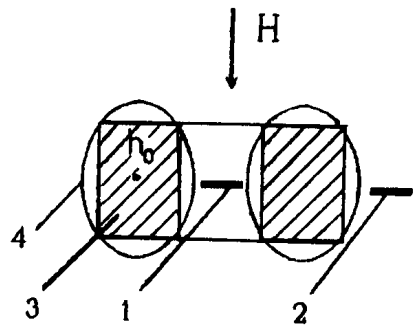

Fig.1. Chart of experiment. *1,2* — Hall probe, *3* — sample, *4*— measuring coil

Experimentally these phenomena were studied both from the behaviour of nonlinear dynamical susceptibility in DC magnetic fields perpendicular to axial AC one and from the measurements of DC field in the centre and outside a hollow cylinder (see fig.1). Taken as an object of the studies were the 1—2—3 and Bi-based ceramics.

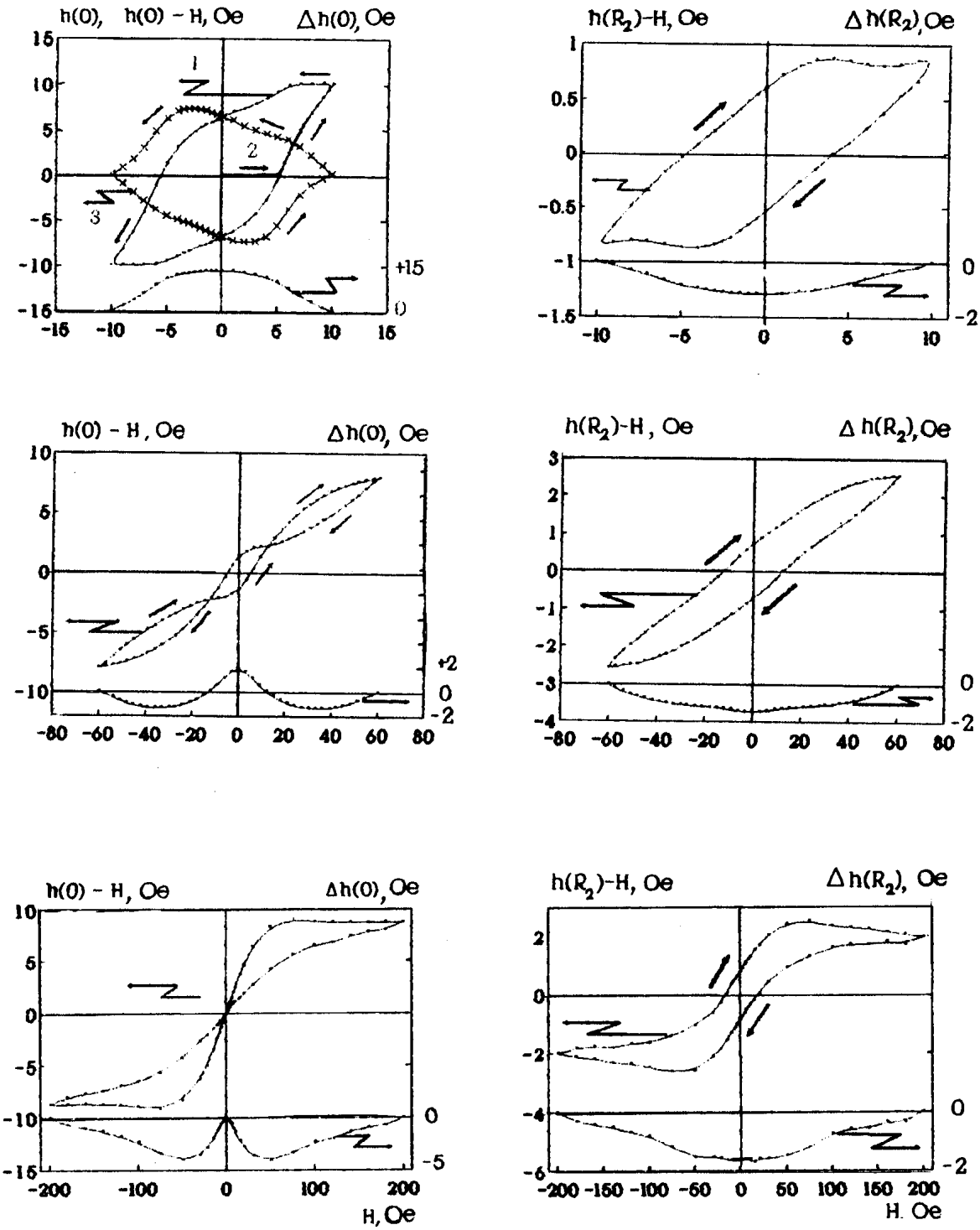

Fig.2. Change of hysteresis loop character in, $h(0)$, and outside, $h(R_2)$, hollow cylinder against applied DC field. Bi-based ceramics, $T = 90.5\ K$ (*a*) *and* (*b*) belong to the situation when $H < h_{c1pr}$: *1* — dependence $h(0)$ against H; *2* — initial branch of hysteresis loop (One can see, *Dc* field does not penetrate into centre of cylinder at $H < 5\ Oe$; *3* — dependence $h(0) - H$ against H. Δh (0) and $\Delta h(R_2)$ are the differences between ascending and descending branches of hysteresis loop, correspondingly. (*c*) and (*d*) - dependencies $h(0)$-H, Δh (0)) and $h(R_2)$ - H, $\Delta h(R_2)$ against H at $H < h_{c1gr}$. (*e*) and (*f*) - at same, at $H >> h_{c1gr}$

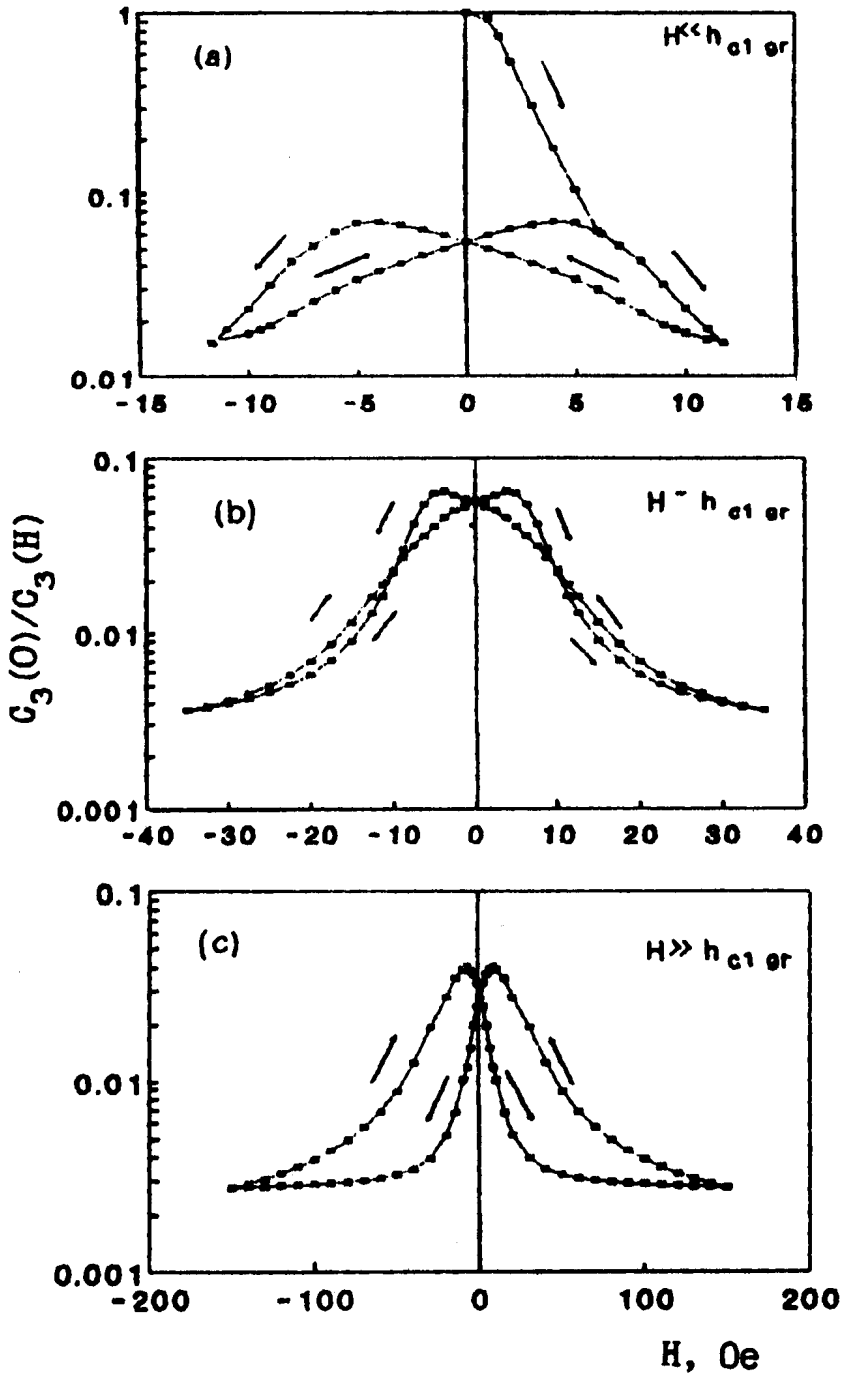

Fig.3. Hysteresis curves for inverse of third harmonics, C_3^{-1}, at various ratios H/h_{c1gr} (f=20 kHz, h_0 = 0.2 Oe).

According to expectation with increasing the apllied Dc field the change of the hysteresis loop character both outside and in a hollow cylinder (fig.2) and of the third harmonics amplitude of magnetization which is the inverse of the transport current density (fig.3) was observed.