# Reentrant Phase and Vortex Dynamics in Bi2212 Single Crystal Studied by Modulate Microwave Absorption

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Reentrant phase has been proposed theoretically for two dimensional high temperature superconducting system by Fisher and Nelson. In this phase diagram, the reentrant "liquid phase (L−1)" is lying just above Meissner phase, then solid phase and usual liquid phase (L−2) exist with increasing field (H) at a certain temperature (T) below $T_C$. Due to the existence of L−1 phase, the solid phase has a nose−shape. The phase boundary fields between Meissner and L−1, and L−1 and the solid phases, decrease gradually with increasing T. This reentrant phase arises from dilute pancake vortices with weak interaction which are melted by thermal fluctuation. Because L−1 region is very narrow, it is difficult to detect it by usual experimental techniques such as resistance.

We applied modulated microwave absorption (MA) technique on Bi2212 single crystals to investigate the reentrant phase. This technique has a strong merit because the field is always varied by the alternating modulation field, and the H−T phases are essentially related to vortex movements. If it's movable, it's the liquid state, while if it's unmovable, it's the solid state

MA signal intensity (S) was measured on the sample with sweeping the field (Ha) at various T near $T_C$. Microwave power dependence of MA was additionally investigated at a low T.

At sufficiently low T as 77.3 K, MA spectrum (S−Ha) shows only a first sharp peak near zero field and it is very flat beyond this peak. At some higher T, a dip appears just above the first peak, besides a second broad peak appears at very high Ha. This broad peak shifts to lower field with increasing T. At sufficiently high T, the dip and the broad peak merge in the first peak, then the spectrum shows the broadened first peak alone. Above this temperature (85 K), there observed no signal, indicating that the sample goes into normal state. The first peak, dip, broad peak and following monotonous decay, well correspond to Meissner, L−1, solid and L−2 phases with increasing Ha, respectively. The dip (L−1 phase) and the broad peak (solid phase) shift to the lower field with increasing T according to the reentrant phase diagram. From the experimental results, we obtained quantitative reentrant phase diagram. It can exactly reproduce the proposed characteristic diagram by Blatter. Additionally, the same MA measurement was done with varying the microwave power (Pm) at the low T as 77.3 K. At sufficiently low Pm, the spectrum only shows the first peak. With increasing Pm, the dip and broad peak gradually appear, and they are shifted to the lower field. This phenomenon is caused by rises of actual sample−temperature (Ts) due to lager microwave power absorption. From the two results, we can obtain the temperature rise vs Pm quantitatively. It is raised by 4 K at 100 mW. Vortex interactions among Abrikosov and Josephson vortices, and microwave−induced vortices, are discussed.