Observation of a Vortex Lattice Spinodal and a Bragg Glass in MgB_2

Hyun-Sook Lee[*, a], S. K. Gupta[b], Byeongwon Kang[c], Sung-Ik Lee[a]

[a] *National Creative Research Initiative Center for Superconductivity and Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Republic of Korea*

[b] *Technical Physics & Prototype Engineering Division, Bhabha Atomic Research Centre,Mumbai-400 085, INDIA*

[c] *Department of Physics, Chungbuk National University, Cheongju 361-763, Republic of Korea*

We observed fully disordered (Spinodal) and ordered (Bragg glass) vortex states in a clean and weakly pinned MgB_2 single crystals by using fast transport measurement technique. In this method, critical currents (I_c) for variously prepared vortex states were measured. In order to avoid current-induced phenomena such as a more disordered lattice due to sample edge contamination or a more ordered lattice due to motional ordering, we specially applied ramp pulse current within time scales shorter than vortex reorganization times and could capture the response of the initial vortex state. The measured I_c, responding a degree of disorder of the vortex lattice, showed pronounced different behavior as how to prepare the vortex state (Zero Field Cooling (ZFC), ZFCW (Warm), FC, and FCW). The spinodal point was determined from where the so-called cold-measured critical current of a heated lattice after well ordered (ZFCW) was saturated. Surprisingly, I_c at FC and FCW states presented clear hysteresis with two reversible points, which was not reported in $NbSe_2$ with several μs relaxation time. One reversible point above the peak point was exactly same as the spinodal point obtained with cold-measurement. The other point below the peak point was also consistent with the Bragg glass point measured from the time resolved transport measurements [Phys. Rev. Lett. 96, 017009 (2006)]. Finally, we obtained the field-temperature phase diagram including several vortex states, fully ordered, mixed, and fully disordered vortex states. Interestingly, the spinodal line predicted by Li and Rosenstein, which describes the case of $NbSe_2$, was not in good agreement with our spinodal line of MgB_2. This indicates that a new theory containing the two-gap nature should be developed.

Keywords : MgB_2, vortex state, peak effect, spinodal, Bragg glass