Vortex Dynamics in $Bi_2Sr_2CaCu_2O_8$ Single Crystal with Low Density Columnar Defects Studied by Magnetic Force Microscopy

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We have studied vortex dynamics in $Bi_2Sr_2CaCu_2O_8$ single crystal with low density columnar defects by using a magnetic force microscope. Single crystal $Bi_2Sr_2CaCu_2O_8$ sample was irradiated by 1.3 GeV uranium ion to form artificial pinning centers. The irradiation dose corresponded to a matching field of $B\phi$ = 20 gauss. The radius of an individual vortex is approximately 140 nm, which is close to the penetration depth of this material. Magnetic force microscopy (MFM) images show that intrinsic crystalline defects such as stacking fault dislocations are very effective pinning centers for vortices in addition to the pinning centers due to ion bombardment. Counting the number of vortex, we found that the flux trapped at each pinning center is a single flux. At higher magnetic field, the vortex structure showed an Abrikosov lattice disturbed only by immobile vortices located at pinning centers. When increasing or decreasing the external magnetic field, the spatial distribution of vortices showed a Bean model like behavior.