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TDGL Simulation of Critical Current Density introducing *z* axis Anisotropy γ_z

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The relationship between anisotropy strength and critical current densities J_c in small superconducting cube exposed to a transport current and a transverse magnetic field were investigated. The TDGL equations for the superconducting cube was numerically solved by using the Euler method. In this case, the vector potential $\boldsymbol{A}$ depends only on the external magnetic field $\boldsymbol{B}$. We show the three-dimensional dynamics of the quantized magnetic flux lines by plotting the contour surfaces of the superconducting electron density $|\Psi|^2$, where Ψ is the order parameter.

In this study, the parameters using in the original TDGL equations were normalized using the coherence length ξ and the upper critical field B_{c2} and so on for reducing the number of the constants in the TDGL equations.

We considered a superconducting cube of which side length is 10ξ in the vacuum. In addition, 4 columnar pins of diameter ξ were introduced with the distance d of pins as shown in Fig. 1(a). Here, we define the order parameter Ψ as 0 inside of the pins. We give the boundary condition corresponding to the normal component of the electric current density $\boldsymbol{J}$ is zero at the surfaces of the cube. $\boldsymbol{J}$ and $\boldsymbol{B}$ are applied to the y axis and the z axis, respectively. Hence, the vector potential can be given by $(A_x, A_y, A_z)=(0, Bx, 0)$ for the transverse magnetic field. The electric current density and the magnetic field at each time were kept constant at a normalized value.

Fig. 1(b), (c) and (d) shows the flux lines with different γz of columnar pins. Calculations were made with external magnetic field $B = 0.1, 0.2, \ldots, 0.6$, current density $J = 0.01, 0.02, \ldots, 0.30$, and z axis anisotropy strength $\gamma_z = 1, 2, 4, 8$.

Fig. 2 shows the numerical results of J_c - B at the z axis anisotropy strength $\gamma_z = 1, 2, 4, 8$. A large peak appears at $B = 0.4$. This is due to the peak effect. And there is almost no difference due to the strength of the anisotropy. Therefore, it was confirmed that the peak effect works similarly even when the z axis has anisotropy.

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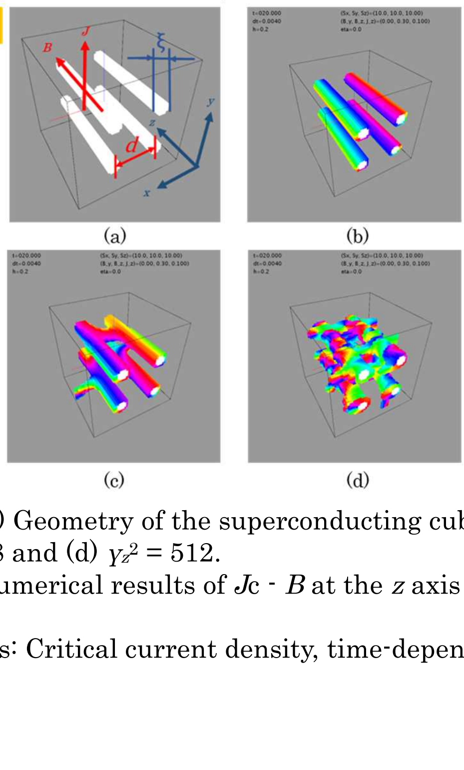

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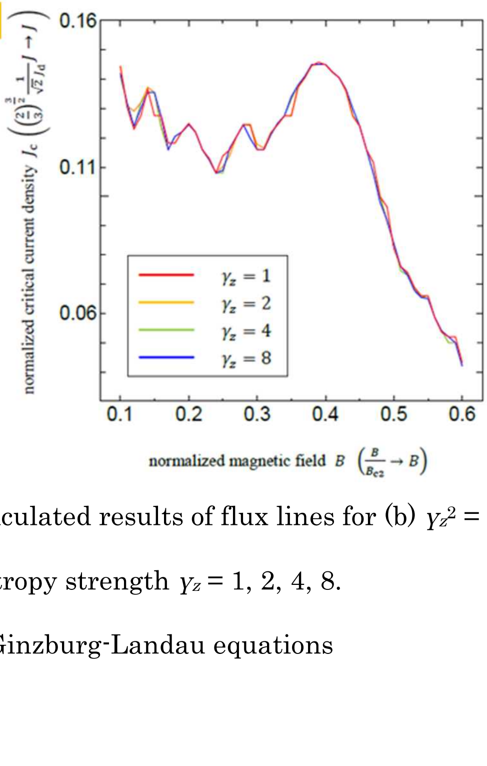

Fig. 1: (a) Geometry of the superconducting cube. Calculated results of flux lines for (b) $\gamma_z^2 = 1$, (c) $\gamma_z^2 = 8$ and (d) $\gamma_z^2 = 512$.
Fig. 2: Numerical results of Jc - B at the z axis anisotropy strength $\gamma_z = 1, 2, 4, 8$.

Keywords: Critical current density, time-dependent Ginzburg-Landau equations