Numerical Simulation of Contactless Methods for Measuring $j_C$-Distribution of High-Temperature Superconducting Thin Film

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The critical current density $j_C$ is one of the most important parameters of high-temperature superconductors (HTS). Although the standard four-probe method has been widely used for measuring $j_C$, it requires the heat-treat process of a HTS sample. This process may lead to the degradation of the HTS characteristics. For this reason, a contactless method has been desired for measuring the critical current density.

As the contactless measurement method of the critical current density $j_C$, Claassen et al. proposed the inductive method [1]. While an ac current $I(t) = I_0 \sin 2\pi ft$ is applied in an $N$-turn coil placed just above a HTS thin film, they measured the harmonic voltage induced in the coil. As a result, they found that the third-harmonic voltage suddenly develops when the coil current $I_0$ exceeds the threshold current $I_T$. In addition, they showed that $j_C$ can be calculated from $I_T$. On the other hand, Ohshima et al. have proposed the permanent magnet method [2]. While moving a permanent magnet up and down above a HTS film, they measured the electromagnetic force acting on the film. As a result, they found that the maximum repulsive force $F_M$ is roughly proportional to $j_C$. This result implies that $j_C$ can be estimated from the measured value of $F_M$.

A numerical code has been developed for determining the time evolution of the shielding current density in a HTS thin film. By using the code, two kinds of the contactless methods are investigated numerically. The results of computations show that, in the inductive magnet, the third-harmonic voltage suddenly develops above a certain limit of the coil current $I_0$. This tendency qualitatively agrees with Claassen’s experimental results. In addition, it is found that, even if the center of the magnet is located at the film edge, the maximum repulsive force $F_M$ is almost proportional the critical current density $j_C$ in the permanent magnet method (see Fig. 1). This means that the $j_C$-distribution can be determined from these relationships between $j_C$ and $F_M$.