Abstract

Among high-temperature superconductors, RE-123 is one of the most interesting materials to study for its pinning properties, as it is considered to be a strong candidate for practical applications. In single crystal RE-123 superconductors, it has been reported that the critical current density J_c has a broad peak due to the pinning of a low T_c phase in which RE sites are substituted by Ba. Recently, superior performance of higher peak critical current density J_{cp} and irreversibility field B_i has been also reported in NEG-123 bulk superconductors at 77.3 K as compared to Y-123 or Nd-123. However, further improvement is still needed for facilitating applications. To achieve the higher J_{cp} and B_i, it is necessary to understand the flux pinning mechanisms which brings about high J_{cp} and B_i, which is the main objective of this thesis.

The critical current density J_c and the apparent pinning potential in a single crystal Nd-123 superconductor which shows a broad peak effect are investigated by measuring DC magnetization and its relaxation. The reason why the single crystal is investigated is to identify the mechanism of the peak effect without being disturbed by complicated additional pinning by 211 particles and other defects such as nano-lamellas. The behavior of pinning parameters is investigated to discuss the pinning mechanism with aid of the theoretical model of flux creep and flow, and it is concluded that the peak effect of Nd-123 single crystal originates from the order-disorder transition of flux lines. The proof of the order-disorder transition of flux lines is given by the reduction of g^2, the number of flux lines in the flux bundle, which shows that the softening of flux lines occurs due to the transition.

In order to study the pinning mechanism of peak effect and irreversibility field in NEG-123 bulk system, the variations in J_{cp} and B_i with volume fractions of EG-211 and NEG-211 phases were measured for $Nd_{0.33}Eu_{0.38}Gd_{0.28}Ba_2Cu_3O_y$ superconductor. It was found that J_{cp} increases but B_i decreases with increasing volume fraction both of EG-211 and NEG-211 phase and there was no large difference between these phases. This result shows a negative correlation between J_{cp} and B_i, suggesting that the mechanisms which determine J_{cp} and B_i are different. Based on the discussion on these results the following conclusions are obtained:

1. Since the peak effect became pronounced by addition of 211 phase, the change can be attributed to the 211 particles themselves or new defects nucleated by the addition. For the following reasons, it can be concluded that the 211 particles do not contribute for the peak effect: (a) the pinning force of 211 particles based on the pinning mechanisms of the condensation energy interaction decreases monotonically with increasing magnetic field and (b)since the size of 211 particles is much larger than the flux lines spacing, those can not contribute to the order-disorder transition of flux lines.
2. The pinning mechanism of the nano-lamella structures is the usual condensation energy interaction with the pinning strength which decreases monotonically with increasing field. Hence, these defects do not directly contribute to the peak effect. On the other hand, their size is sufficiently small that those can contribute to the peak effect with the aid of the order-disorder transition.
3. Since the irreversibility field is deteriorated by the addition of 211 phase, it can be concluded that the irreversibility field is not determined by the flux pinning of

211 particles. The decrease in B_i with the increasing fraction of 211 phase is considered to be caused by the proximity effect between thin superconducting region and high density of nano-lamellas.

4. The strong correlation between irreversibility field B_i and upper critical field B_{c2} also supports such speculation that the deterioration of B_i occurs due to the degradation of B_{c2} by the proximity effect.