LA-UR- 02-7563

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Submitted to: Annual APS March Meeting 2003, Austin TX

Los Alamos
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Critical Currents, Vortex Dynamics and Microstructure in MgB_2

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One key issue in optimizing critical current density (J_c) in MgB_2 is to determine which structural features are the relevant pinning centers. Likely sources of vortex pinning include grain boundaries and intra-grain defects. Detailed studies of the field (H) and temperature (T) dependence of pinning in microstructurally well-characterized samples are required to clarify this point. In this work we explore the influence of microstructures on the vortex dynamics of MgB_2 bulk samples prepared either at ambient or at high pressure (HIP). Scanning and transmission electron microscopy indicate the presence of several types of defects. Both un-HIPed and HIPed samples contain a large number of intra-grain $Mg(B,O)_2$ precipitates coherent with the matrix, with sizes ranging from 5 nm to 100 nm, which are very well suited to act as pinning centers. The HIP process further improves flux pinning by eliminating the porosity, dispersing the MgO present at the grain boundaries of the un-HIPed samples, and generating dislocations.

We also present a detailed study of the T, H and current density (J) dependence of the normalized time relaxation rate, $S = d\ln J/d\ln t$. The intermediate transition temperature $T_c \sim 39K$ makes MgB_2 attractive for exploring vortex dynamics in a regime of intermediate influence of thermal fluctuations. At low T, we observe a linear S(T), from which we extract a pinning energy U_c that is weakly T dependent and decreases monotonically with H. The extrapolations to T=0 indicate that the quantum creep rate is small. At higher T, the activation energy U(J) shows the divergent behavior at $J \rightarrow 0$ that characterizes the glassy phases. The results are contrasted with the expectations of various collective creep scenarios to extract information on the characteristics of the pinning centers.