Observation of the spontaneous vortex phase in the weakly ferromagnetic superconductor ErNi$_2$B$_2$C: A penetration depth study

EE MIN ELBERT CHIA, TUSON PARK, Los Alamos National Laboratory, MYRON SALAMON, University of Illinois at Urbana-Champaign, HEON-JUNG KIM, SUNG-IK LEE, Pohang University of Science and Technology — The coexistence of weak ferromagnetism and superconductivity in ErNi$_2$B$_2$C suggests the possibility of a spontaneous vortex phase (SVP) in which vortices appear in the absence of an external field. We report evidence for the long-sought SVP from the in-plane magnetic penetration depth $\Delta\lambda(T)$ of high-quality single crystals of ErNi$_2$B$_2$C, using a high-precision tunnel-diode based, self-inductive technique at 21 MHz. In addition to a slight depression of superconductivity at the Néel temperature $T_N = 6.0$ K and at the weak ferromagnetic onset at $T_{WFM} = 2.3$ K, $\Delta\lambda(T)$ rises to a maximum at $T_m = 0.45$ K before dropping sharply down to $\sim 0.1$ K. We assign the 0.45 K-maximum to the proliferation of spontaneous vortices. A model proposed by Koshelev and Vinokur explains the increasing $\Delta\lambda(T)$ as the vortex density increases, and its subsequent decrease below $T_m$ as defect pinning suppresses vortex hopping.