Enhancement of Superconductivity by a Parallel Magnetic Field in Two Dimensional Superconductors

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We report the observation of *enhancement* of superconductivity by a parallel magnetic field in two-dimensional superconducting systems:ultrathin amorphous Pb films (a-Pb) and the 2D electron gas at the interface of $LaAlO_3$ and $SrTiO_3$.The experiments were performed in a dilution refrigerator capable of *in situ* film growth,magnetic impurity deposition and sample rotation.The mean-field T_C in both a-Pb films and the $LaAlO_3/SrTiO_3$ heterostructures is increased by a parallel field as high as 8T,while a perpendicular field of 20 Gauss causes a suppression of T_C.In the Pb films,the T_C enhancement exhibits a non-monotonic dependence on the film thickness,and reaches 13.5% in 8T parallel field for certain film thickness.As paramagnetic Cr impurities were incrementally deposited onto a pure a-Pb film showing field-enhancement of T_C,the magnitude of the T_C enhancement is progressively suppressed and eventually eliminated.Our results are contradictory to the mechanism based on the polarization of paramagnetic impurities.Systematic dependencies of this effect on film thickness, magnetic impurity density, and spin-orbit interaction will be presented.The results suggest that the effect is due to an intrinsic enhancement of superconductivity by a parallel magnetic field,rather than alleviation of a destructive effect.