Drag Coupling Between a Thin Al Film and a Two-Dimensional Electron Gas Near the Superconducting Transition

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We are studying the coupling between thermally excited vortices in a thin superconducting film and electrons in a two-dimensional electron gas. The specific system we use to study this consists of the two layers in a drag measurement geometry. We make this measurement by passing current through a superconducting layer and measuring the voltage induced in the two-dimensional electron gas (or vice versa).

Despite apparent simplicity of this setup, previous experiments in which a normal metal layer was used in place of the 2DEG have revealed anomalous results.[1] Our device, shown in Fig 1, was fabricated using standard photo-lithography techniques, the 2DEG is etched in to a 1mmx40μm wire and a thin layer (100-200Å) of Al is evaporated directly on top of this wire. As we are using an electron gas we are able to vary the number of electrons in the system by gating and depleting the bottom layer, via a negative voltage applied to the Al film.

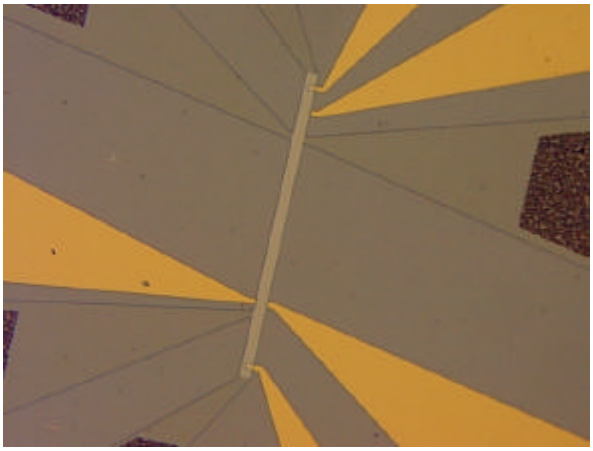

Figure 1 GaAs/AlGaAs 2DEG etched into wire with ohmic contacts, with an Al wire patterned directly on top. The Al and 2DEG have separate electrical contacts.

We have studied two devices fabricated in this fashion, which have very different properties. The first sample had a thin, low resistance Al film, 20 Ω/sq, 650Å away from the 2DEG. The second sample had a thin, high resistance Al film, 1k Ω/sq, 1000Å away from the 2DEG. The second sample showed wider region of superconducting transition. The samples were measured using low frequency lock-in measurements. Both of the samples showed no evidence of an induced drag voltage down to the 10nV level, showing a drag resistance of less than 10^{-4} Ω for the first samples and less than 10^{-3} Ω for the latter. The out of phase signal was

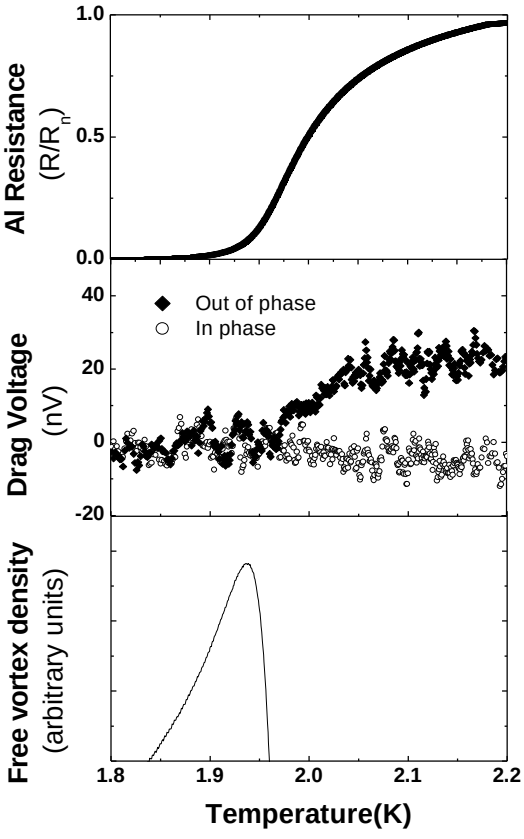

Figure 2 (a) Temperature dependence the Al film resistance (b) Drag voltage measured in the 2DEG with 1μA injected in the Al (c) Thermally induced free vortex density calculated from the Kosterlitz-Thouless transition in the Al film.

consistent with a capacitive model. A typical trace is shown in Figure 2 along with the free vortex density, calculated from the superconducting transition, this peak indicates the region in which vortex-electron interaction would be expected. We found varying the carrier density and the application of low magnetic field left our results unchanged. Additionally we measured the opposite configuration, when current is passed through the 2DEG and voltage measured in the Al. We will present this data and also compare these values to the effects expected to in a simple picture in which the main source of interaction is via eddy currents generated by vortex motion.

1. N. Giordano and J. D. Monnier, Phys. Rev. B 50, 9363 (1994); X.K. Huang, G. Bazan, G.H. Bernstein, Phys. Rev. Lett. 74, 4051 (1995)