Unusual insulating phase at low temperature in disordered thin superconducting films

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Abstract

We have made systematic studies [Okuma *et al.*, Phys.Rev.**B58** (1998), in press; Solid State Commun.**106**, 529 (1998)] for both the zero-field and field-driven S-I transitions in a series of 4-nm-thick films of amorphous (*a*-) Mo_xSi_{1-x} at temperatures T down to 0.05 K and fields B up to 15 T. For superconducting films, we have observed an anomalous peak in the magnetoresistance $R(B)$ and a subsequent decrease in $R(B)$ with increasing B at low temperatures in fields higher than the critical field B_{xxC}. In contrast, the magnetoresistance for insulating films is always monotonic and positive irrespective of the temperature, consistent with the two-dimensional (2D) weak-localization theory for fermions in the presence of strong spin-orbit interaction. These results indicate that the localized Cooper pairs may exist even on the insulating side of the field-driven S-I transition ($B > B_{xxC}$) in the limit of $T \to 0$. This region is essentially similar to the unusual field (insulating) region $B_{xyC} > B > B_{xxC}$ found in thin *a*-InO_x [Paalanen *et al.*, Phys.Rev.Lett.**69**, 1604 (1992)] and In films [Okuma *et al.*, Phys.Rev.**B56**, 410 (1997); *ibid.* **51**, 15415 (1995)], where B_{xyC} is the critical field determined from the Hall resistance. From these results we propose the possibility that these unusual insulating regions observed in different 2D superconductors may correspond to the Bose-glass insulator.