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Tunneling spectroscopy of fluctuating and localized preformed Coopers pairs in highly disordered superconducting films

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We have performed tunneling spectroscopy on superconducting titanium nitride and indium oxide films in the vicinity of the disorder-driven superconductor-insulator transition (SIT). Tunnelling spectroscopy highlights a rather unusual superconducting state with a pseudogap regime above the critical temperature Tc [1]. We demonstrated that this pseudogap is the signature of short lived Cooper pairs that are preformed above Tc. It evolves at low temperature into an inhomogeneous superconducting system due to spatial fluctuations of the disorder at the mesoscopic scale in both materials [2,3]. However, the SIT in TiN and InO films display different characters. Ultrathin TiN films remain bad metals with dominating two-dimensional thermodynamic fluctuations when disorder is increased. In this case Tc goes to zero at the critical disorder of the SIT, whereas in InO, Tc remains above 1 K on the superconducting side of the SIT. In this latter situation, localization takes over and the preformed Cooper pairs above Tc can locally remain localized at zero temperature. We showed that the absence of BCS coherence peaks at the gap edges in the local one particle density of states is the signature of these localized Cooper pairs. Besides, using our STM, we have continuously analyzed the local conductance between the tunneling regime and the point-contact regime. In the latter, Andreev spectroscopy reveals a new energy scale related to the quantum coherence energy and independent from spatial fluctuations of the pairing energy [4].

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[4] T. Dubouchet, in preparation.