Supporting Information for

Bosonic Confinement and Coherence in Disordered Nanodiamond Arrays

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I. Statistical analysis of the grain size distribution of the disordered nanodiamond arrays

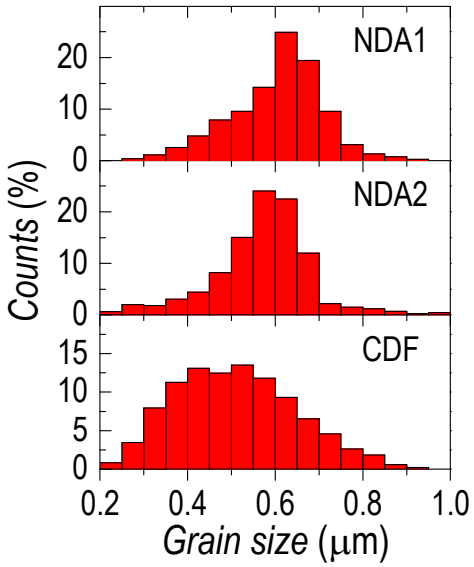

Figure S1. Grain size distributions of the nanodiamond arrays. Statistical analysis of large-area scanning electron micrographs of the arrays yields a mean grain size d of 605 nm, 572 nm and 511 nm for NDA1, NDA2 and CDF, respectively. Even though the same recipe was used for the nanodiamond growth, the arrays still demonstrate variations in d, mainly caused by the difference in the growing environment. Note that in NDA1 and NDA2, the nanodiamonds are free to grow, while in CDF, the nanodiamonds, sitting next to each other in an almost close-packed two-dimensional layer, have their growth constrained in the lateral direction by their neighbors, but not in the upward direction. At first sight, the d variations seem to be big, although it is the ξ_{GL}/d ratio rather than d itself that matters in this research. Taking into account ξ_{GL} = 8.9 nm, we get ξ_{GL}/d = 0.015, 0.016 and 0.017 for NDA1, NDA2 and CDF, respectively, with a negligible deviation.

II. Determination of ξ_{GL} from the $\mu_0 H_{c2}$–T phase boundary of CDF

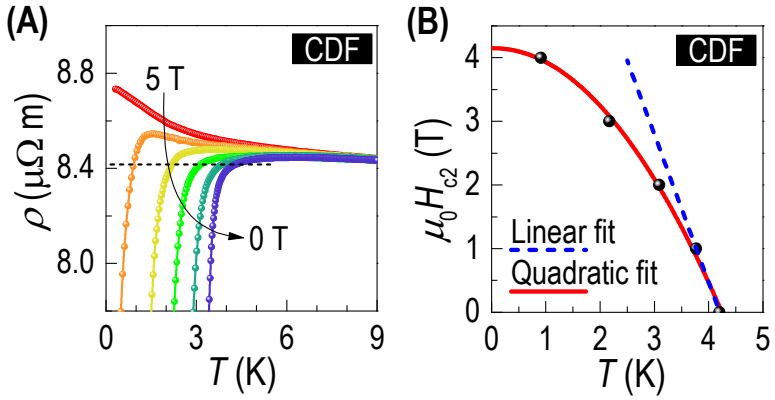

Figure S2. Determination of ξ_{GL} from the $\mu_0 H_{c2}$–T phase boundary of CDF. As the reference sample of our disordered nanodiamond arrays, CDF is used for the determination of characteristic parameters, such as ξ_{GL}. The $\mu_0 H_{c2}$–T phase boundary is extracted from the $\rho(T)$ plots in applied magnetic fields by setting a criterion at $\rho = \rho_{12\ K}$ upon the resistive superconducting transition, as indicated by the dashed line in (a). b) The quadratic fitting yields a zero-temperature upper critical field $\mu_0 H_{c2}(0)$ = 4.15 T. According to the relation $\xi_{GL} = [\Phi/2\pi\mu_0 H_{c2}(0)]^{1/2}$ with Φ being the flux quantum, ξ_{GL} = 8.9 nm is derived. The linear fitting yields dH/dT = -2.325 T K^{-1} at T_c, which, following the standard relationship for a dirty type-II superconductor $\mu_0 H_{c2}(0) = -0.69 T_c (dH/dT)|_{Tc}$, gives rise to $\mu_0 H_{c2}(0)$ = 6.74 T and ξ_{GL} = 7 nm.

III. STM/S measurements on isolated nanodiamonds

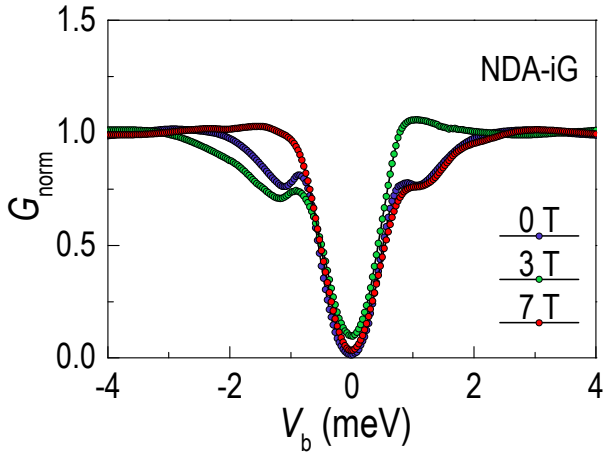

Figure S3. Gapped single quasiparticle density of states up to 7 T, revealing a much higher local upper critical field than the bulk value, and thus suggesting intragrain confinement of Cooper pairs in the isolated nanodiamonds. As remarked by the author of the London theory himself, "*a very small superconductor should have a much higher magnetic threshold value than a bulky one*".[S1] In the extreme case, the orbital motion of the Cooper pairs becomes negligible and the upper critical field is determined by the Zeeman coupling. This mechanism leads to a higher critical magnetic field, the Pauli limiting $\mu_0 H_P$, where $\mu_0 H_P / T_c \sim 1.84$ T/K.[S2] In this limit, the suppression of superconductivity by magnetic field is a first-order transition.[S3] In the case of our isolated nanodiamonds with $T_c \sim 7$ K, the estimated upper critical field $\mu_0 H_P \sim 13$ T, whilst our STM/S data show that the spectra remain fully gapped up to 7T.

REFERENCES

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S3. Herman, F.; Hlubina, R. Microscopic Interpretation of the Dynes Formula for the Tunneling Density of States. *Phys. Rev. B* **2016**, *94*, 144508.