Manifestation of homogeneous superconductivity in single-crystalline (100) boron-doped diamond film near Superconductor-Insulator transition

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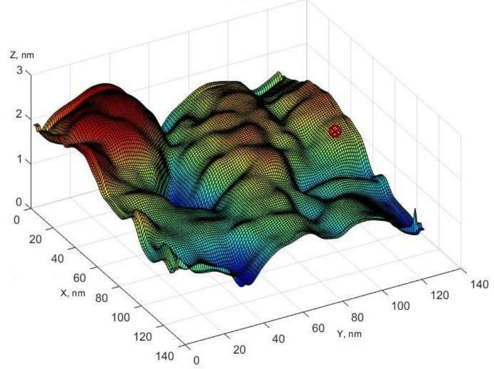
The transition from a superconductor to an insulator in boron-doped diamond can be realized by reducing the concentration of charge carriers in two ways: either by directly reducing the boron concentration [1, 2], or by altering the orientation of crystal growth. The latter owes to the fact that the concentration of Hall carriers can exceed the actual doping concentration due to the distortion of the Fermi surface [3].

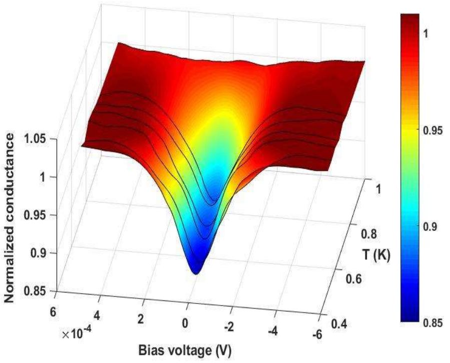
Here we present a scanning tunneling microscopy/spectroscopy (STM/S) study of superconductivity in a single-crystalline boron-doped (100) diamond film prepared by Chemical vapor deposition with a low doping level of $\boldsymbol{n = 3\times10^{20}\ cm^{-3}}$. Homogeneous superconductivity with parameters $\boldsymbol{\Delta(0) = 0.13\ meV}$, $\boldsymbol{T_C = 0.85\ K}$, and $\boldsymbol{H_{C2}}$ between **1.5-1.6 T** was observed even at the boron concentration limit for SIT.

STM/S measurements

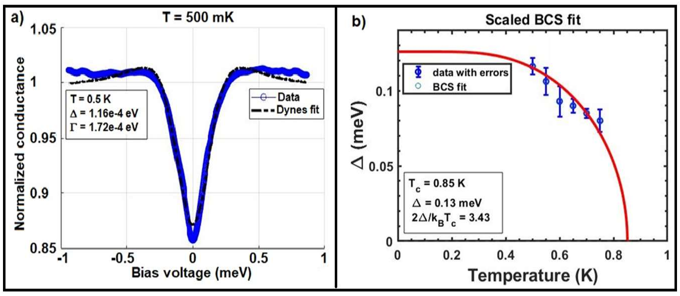


Topography of the sample, 140 nm X 140 nm

Temperature dependence of energy gap

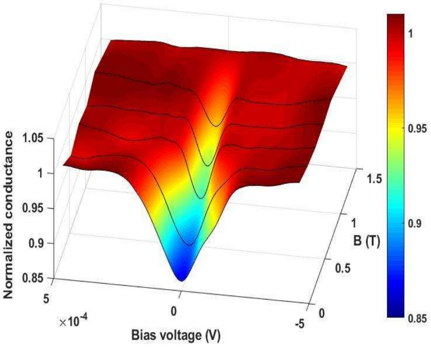


Normalized differential conductance vs. Bias voltage at temperature range 0.5-1 K, measured at ⊗ in topography image. It can be seen that the energy gap disappears at 0.75-1 K.



a) Dynes fit [4] of differential conductance (dashes line) at 0.5 K gives parameters Δ (0.5) = 0.116 meV and Γ = 0.172 meV.
b) BCS fit of energy gap gives Δ (0) = 0.13 meV, T_C =0.85 K and weak coupling coefficient $2\Delta/k_BT_C$ = 3.43.

H_{C2} from measurements and theoretical calculations



Normalized differential conductance vs. Bias voltage at parallel magnetic field in range of 0-1.5 T and T= 0.5 K, measured at ⊗ in topography image. At 1.5 T normalized differential conductance has flat line equal to 1.

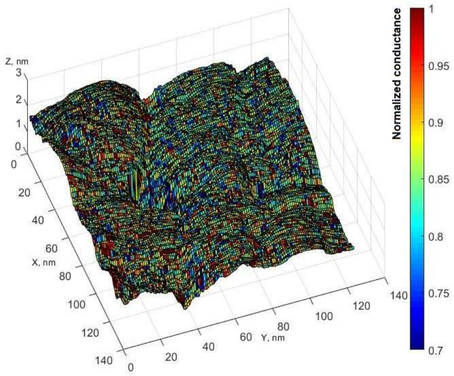
$\mu_0 H_{C2}(0) = \Delta(0)/\mu_B\sqrt{2}$, were μ_B is the Bohr magneton and $\Delta(0)$ is the energy gap at 0 K (from theoretical calculations is equal 0.13 meV).

$H_{C2}(0) =$ *1.59 T at 0 K*

$H_{c2}(0) = \frac{\Phi_0}{2\pi\xi^2}$, ξ = 14.4 nm were Φ_0 is the flux quantum and ξ is the coherent length

ξ from [5] for singlecrystalline diamonds is 15 nm.

The Current-Imaging-Tunneling-Spectroscopy measurements



Current-Imaging-Tunneling-Spectroscopy map of Zero-Bias-Conductance in topography at 0.5 K and 0 T shows homogeneous superconductivity with similar normalized conductance at zero bias voltage, equal 0.75-0.85.

Conclusions

In the work, we investigated local superconductivity in boron-doped monocrystalline diamond with a boron concentration at the SIT boundary n = 3×10^{20} cm^{-3}:

1. From STM/S measurements at temperature range 0.5-1 K, we got superconducting critical parameters T_C = 0.85 K, Δ (0) = 0.13 meV, and a coupling coefficient of $2\Delta/k_BT_C$ = 3.43.
2. The upper critical field of 1.5 T (T = 0.5 K) was obtained also.
3. Using the so-called CITS measurements, a homogeneous distribution of superconductivity in the sample was determined.

Acknowledgements:

We acknowledge
VEGA 2/0091/24 and VEGA 2/0073/24
for financial support.

References:

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