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Fluctuation Conductivity in Superconducting MgB_2¶

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Abstract—According to the crystal structure of MgB_2 and band structure calculations, quasi-two-dimensional (2D) boron planes are responsible for the superconductivity. We report on critical-field and resistance measurements of 5.6-μm-thick MgB_2 films grown on a sapphire single-crystal substrate. Resistivity measurements yield a temperature dependence of the fluctuation conductivity above the critical temperature, which agrees with the Aslamazov–Larkin and Maki–Thompson theory of fluctuations in layered superconductors, indicating a quasi-two-dimensional nucleation of superconductivity in MgB_2. © *2002 MAIK "Nauka/Interperiodica".*

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Recent discovery [1] of superconductivity in magnesium diboride (MgB_2) raised questions about the origin and properties of superconductivity in this compound. MgB_2 has a hexagonal crystal structure with boron layers interleaved by magnesium layers. Band structure calculations [2, 3] indicate that electrons at the Fermi level are predominantly derived from boron atoms. MgB_2 can be regarded as a layered compound having sheets of metallic boron with strong covalent intralayer bonding, separated by Mg layers with ionic interlayer B–Mg bonding. The strong B–B bonding induces enhanced electron–phonon interaction, so that the superconductivity in MgB_2 is mainly due to the charge carriers in the boron planes.

Experimental investigations on single crystals and *c*-oriented epitaxial and textured films (see, e.g., the review [4] and references therein) give evidence for a highly anisotropic superconducting gap. Measured critical magnetic fields usually show a pronounced anisotropy for *c*-oriented films and single crystals [4]. Applying the anisotropic Ginzburg–Landau model to these measurements, authors derive an effective mass anisotropy for the charge carriers of $\gamma = \sqrt{m_{ab}/m_c} \approx 0.15–0.3$. Thus, the band structure calculations and experimental measurements strongly suggest that superconductivity nucleates at the quasi-two-dimensional (2D) boron planes and then extends through the magnesium layers by a nanoscale proximity effect forming an anisotropic 3D superconducting state in the material.

In this letter, we present experimental evidence for the quasi-2D nucleation of superconductivity in a 3D magnesium diboride film. To demonstrate this, we measured the temperature dependence of the excess conductivity caused by fluctuations above the critical temperature, T_c. If quasi-2D boron planes are responsible for the superconductivity, then the excess conductivity should exhibit 2D-like behavior, although measured in a 3D sample. We found that the temperature dependence of the excess conductivity agrees with the Aslamazov–Larkin (AL) [5] and Maki–Thompson (MT) [6] theory of superconducting fluctuations in layered superconductors [7].

The MgB_2 films were prepared by DC magnetron sputtering on a single-crystal (100)-oriented sapphire substrate according to the procedure described in [8]. To compensate losses of magnesium due to its oxidation in plasma, a composite target was used which contained MgB_2 and metallic magnesium in approximately equal amounts. A Mg–MgB_2 target was sputtered in a 99.999% purity argon atmosphere at a pressure of 3 Pa. The substrate temperature during sputtering was held at 200°C and than raised to 600°C for several seconds at the final stage. At this final *in situ* annealing, the plasma discharge was not switched off. Next, the films were annealed *ex situ* in a saturated Mg vapor atmosphere for 1 hour at 850°C. X-ray studies revealed a textured (101)-oriented structure of our polycrystalline films. The MgB_2 film thickness was about 5.6 μm. For the resistance and critical field measurements, 1.5-mm-wide stripes were cut by a diamond cutter.

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