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Tomasch Effect and the Effect of Non-Magnetic Impurities on the Superconducting Properties of Nanowires

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Abstract:

In superconducting nanowires, quantum confinement results in an inhomogenerous distribution of the Cooper-pair condensate [1]. By solving the Bogoliubov-de Gennes equations self-consistently, we found that it further triggers the Tomasch effect (TE) [2] and leads to a position-dependent impurity effect [3].

The TE is due to quasiparticle interference as induced by a nonuniform superconducting order parameter, which results in oscillations in the density of states (DOS) at energies above the superconducting gap [4]. The effect on the electronic structure is calculated. We found that the TE results in additional BCS-like Bogoliubov-quasiparticles and BCS-like energy gaps resulting in oscillations of the DOS and in modulated wave patterns in the local density of states for energies above the superconducting gap. We found that their properties are strongly related to the symmetry of the system and the structure of the quantum confined states.

In a bulk superconductor, a single impurity has very little effect on the thermodynamic properties. However, as the dimensionality is reduced, the effect of impurities becomes more significant. We found that: 1) impurities strongly affect the superconducting properties, 2) the effect is impurity position-dependent, and 3) it exhibits opposite behaviour for resonant and off-resonant wire widths. We show that this is

due to the interplay between the shape resonances of the order parameter and the sub-band energy spectrum induced by the lateral quantum confinement. These effects can be used to manipulate the Josephson current, filter electrons by subband and investigate the symmetries of the superconducting subbands.

References

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