Summary of Dissertation

“Superconductivity in systems with broken inversion symmetry.”

The goal of presented thesis is to describe superconductivity in crystals without the inversion center, wherein an antisymmetric spin-orbit coupling (ASOC) plays a crucial role. We investigate the properties of the singlet s-wave and triplet p-wave states in the tight binding model on the square lattice using the basis of the spin eigenfunctions which do not diagonalize the Hamiltonian. This approach allows us to discuss a competition between the spin-dependent superconducting pairing interaction and the ASOC induced spin helicity in a two band system. This issue turns out to be of particular importance in the presence of the external magnetic field which enforces a new quantization axis incompatible with that established by the antisymmetric spin-orbit coupling.

We consider the conduction band which is characterized by the band width, the band filling and possible van Hove singularities which also arise due to the spin-orbit coupling. In this respect our approach goes beyond the Fermi gas approach employed in earlier publications. In addition to the band effects we discuss various regimes of the antisymmetric spin-orbit coupling and the pairing strength.

The thesis consists of 7 chapters, two supplements and it is organized as follows. In Introduction we present the most important features of ASOC and its influence on superconductivity i.e. the Fermi surface splitting, the mixed singlet-triplet character of the Cooper pairs, the inter and intraband pairing.

In the second chapter we present the Green's function approach dedicated to superconducting system with the spin-orbit coupling and in the applied perpendicular Zeeman field. The obtained anomalous Green's correspond to the mixed singlet-triplet order parameter. Moreover, in the analysis of the anomalous Green's functions we identify their parts associated with the exotic odd-frequency pairing.

In the third chapter we describe the evolution of the density of states in the presence of the ASOC. This discussion is basic for the interpretation of the influence of the ASOC on the critical temperature in the case of the intraband pairing. Our original results are presented in chapters 4, 5 and 6.

The investigation of the s-wave superconducting state for various regimes of the BCS pairing potential and various band fillings is presented in chapter 4. Specifically, contrary to earlier reports, we indicate that the ASOC has a significant impact on the critical temperature, through the mechanism of changes in the density of states.

The chapter 5 is devoted to the analysis of the critical temperature of various, determined by the symmetry of the lattice, triplet p-wave states which can be realized for a separable pairing potential. In particular we show a significant influence of the ASOC on the critical temperature of the intraband state A_2 through the mechanism of changes in the convolution of the desity of states and the pairing potential parameter. We discuss the spin-orbit coupling effect on the critical temperatures of all p-wave states for representative band fillings and varying pairing strengths.

Finally in the chapter 6, we analyze the effects of the ASOC and the Zeeman magnetic field on the s-wave superconductivity. We discuss a poorly investigated case of the perpendicular field and take into account the discontinuous phase transitions. We indicate the existence of a discontinuous phase transition between phases with high and low values of the superconducting order parameter. We present a complex phase diagram with discontinuous transitions and investigate a competition between the stabilizing and destabilizing effects of ASOC on the singlet superconductivity in the Zeeman field. Moreover, we present the influence of ASOC on the induced odd-frequency pairing in the lowest order approximation.

In the last chapter we summarize our results and emphasize the most important conclusions of our work.