

DESCRIPTION FOR GENERAL PUBLIC

Without any doubt one of the most intriguing phenomenon in solid state physics is the superconductivity, which was discovered in 1911 by Kamerlingh Onnes during his study on the material properties at low temperatures. At that time, when measuring the electrical resistance of Hg it was observed that the resistance of this material reduces by a few orders of magnitude at low temperatures. Now, we know that the materials in the superconducting state does not exhibit any electrical resistance, thus the current induced in the superconducting circuit will flow in it infinitely long. This amazing property opens a wide range of possibilities, especially in the context of superconducting electronics. Although the superconductivity was discovered at the beginning of 20th century, the full microscopic explanation of this phenomenon was given by John Bardeen, Leon Cooper and John Schrieffer almost 45 years later. This so-called BCS theory assumes that the essence of superconductivity is the creation of pairs of charge carriers, called Cooper pairs. According to the BCS theory, the Cooper pairs consist of the electrons with opposite spins and momentums, in a way that the total momentum of the Cooper pair is equal to zero. Unfortunately, the BCS theory and experiments reported that the critical temperature, below which the material transmits to the superconducting state, is very low (below 10 K) for most metallic materials. This constitutes the serious limitation for these materials in the context of their usage in the current electronics. For this reason, the studies on superconductivity performing in many laboratories over the world have one common objective, namely finding the superconductors with the critical temperature above the room temperature. In this terms, the milestones were discoveries made in 80s which showed that the superconductivity can be observed at the temperature up to 160 K. Moreover, the huge progress in nanotechnology which has been made in the last decade opens the issue of superconductivity in the nanoscale regime. In this respect, it is extremely interesting to answer the question what happens if the size of the sample becomes smaller than the size of the Cooper pairs. Recent experimental studies report that for nanostructures, the critical temperature oscillates as a function of the geometrical parameters reaching the value higher than that observed in the bulk. It opens the issue concerning the possibility of the increase of the critical temperature by reduction of the size to the nanometer scale.

Although the superconductivity at the room temperature has not been discovered until now, the studies on it revealed many interesting superconducting states i.e. FFLO, Rahba FFLO-like or helical state, which are not described by the BCS theory. These unconventional superconducting states are characterized by the non-zero momentum of the Cooper pairs which leads to several fascinating properties. This research project addresses the theoretical study of unconventional superconducting phases in atomically thin nanofilms, in the context of ongoing experiments. The main objective is to analyze the influence of the quantum size effect, occurring in the nanoscale regime, on the properties and stability conditions of the non-zero momentum paired states. The main focus of the analysis is going to be placed on the multiband character of superconductivity in nanofilms and its influence on the considered phases. We expect that the developed multiband model, which takes into account the inter-subband pairing, will allow us to discover and explain many interesting, and still unexplored properties. The realization of all the objectives of the project will be an significant extension of the knowledge about the unconventional superconducting states in metallic nanofilms.