Report on master thesis

Hall effects in non-magnetic systems: classical, quantum and fractional

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Thesis is devoted to theoretical description of the effects of external magnetic fields to electron gas in non-magnetic systems. Weak fields which essentially affect electron dynamics only, as well as high magnetic fields which modify electron energy spectrum, are treated. Known basic formulae are presented and in some cases they are applied to simple model systems.

First chapter is devoted to the effect of weak field. Known semi-classical formulae taken from reference [6] are applied to simple tight binding model on square lattice. Dependencies of the Hall coefficient on electron concentration and temperature are presented and discussed. Essential part is devoted to the alloying effect. Single site approximation of the coherent potential approach taken from references [19,23] is applied to binary substitutions alloy. Number of further approximations to the general concept are used and their effects on evaluated Hall coefficients discussed. Obtained insights might be useful for application to real systems and can help to identify convenient materials for Hall sensors operating under specific conditions.

Remaining two sections are devoted to high magnetic fields which modify electron energy spectrum. Second chapter focuses on single electron approach, i.e. possible effect of the non-ideal screening of the background potential is not taken into account. Magnetic field enters tight binding Hamiltonian multiplying hopping parameter by phase factor given by Peierls substitution. In two-dimensional systems energy spectrum is controlled by the ratio of unit cell area and area per single magnetic flux. Spectrum has the well known form, Hofstadter butterfly. Using commercial software density of states and introduced parameter, discretization metric, were established for square lattice considering super-cell containing 37 $\times$ 200 lattice sites. Obtained results are presented for several ratios of lattice constant and magnetic length and their variation were analyzed in dependence on band energy.

Third chapter is devoted to the situation when single electron approach does not effectively screen background potential. Solving the problem desires to take into account electron-electron interaction representing non-trivial many-body problem. The goal is to establish excitation of the ground states. Single mode approximation as one way to solve the problem is described and applied to the Laughlin state for filling factor 1/3. By the use of commercial software gaps as function of excitation wave mode have been presented not only for Coulomb coupling but also for several other form of coupling interactions.

Thesis has been evidently written in hurry and in some parts not too carefully. There are misprints in the text (sometimes lower-case instead of the upper-case are used and reversely) and in formulae, see e.g. Eqs. (1.5), (1.11) and (3.3). Physical conditions under which presented theories are applicable were not sufficiently described. In the first chapter it is not even mentioned in which way magnetic field enters derivation of the presented Hall coefficient formula below Eq. (1.3): how does B_k^{app} relate to $\sigma_{\alpha\beta k}$? In the second chapter with the title "Integer Quantum Hall Effect" one expects that at least to be mentioned how quantum values can be established. However, this information is missing.

Both missing pieces of information should be explained during thesis defense.

On the other hand the thesis scope is quite wide and the author had to process and understand considerable amount of literature. Presented descriptions show deep understanding of mentioned theories and ability to apply them to model systems. In my opinion this thesis fulfills requirements for award of the master degree and I recommend it for defense.

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