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Magnetotransport in 2D system in parallel and tilted magnetic fields

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Abstract. Study of the magnetoresistivity $\varrho(B)$ has been performed on GaAs-GaAlAs heterostructures in the magnetic field parallel to the 2D plane or tilted by a small angle α from this plane. The influence of relative orientation of the magnetic field and the current through the sample has been also investigated. The results are discussed in the terms of different models proposed recently. It is suggested that also quantum correction e.g. the weak localization should be taken into account to explain observed results.

Introduction

The magnetotransport properties of 2DEG system confined in a narrow quantum well have attracted attention for many years namely for the configuration with magnetic field **B** perpendicular to the confinement plane. It is interesting, however, to study also the case with **B** parallel to the 2DEG plane or tilted by a small angle from it. Such investigation has been done recently by Leadley et al [1] for transport current **I** perpendicular to **B**. They have offered an explanation of their results in terms of nonsymetrical distortion of Fermi surface [2] formed by the combined influence of triangular confining potential well and parallel magnetic field. Recently another model has been presented [3] that takes into account the third dimension playing decisive role in the behavior of the magnetoresistance of 2D systems in the presence of parallel component of magnetic field.

Experiment

The samples under study were prepared from $GaAs-Ga_{1-x}Al_xAs$ heterostructures grown by MBE. The carrier densities at liquid He temperature for the two measured samples have been found to be $5.5 \times 10^{15} m^{-2}$ and $3.5 \times 10^{15} m^{-2}$, respectively, the corresponding mobilities have been $30.4 m^2/Vs$ and $21.5 m^2/Vs$, respectively. The relatively small carrier densities ensure that only one subband is occupied and intersubband scattering and/or depopulation effect can be excluded.

Results and discussion

The effect of magnetic field tilted by a few degrees from the direction parallel to the plane of the 2DEG was studied for two different configurations: perpendicular ($B \perp I$) and parallel ($B \parallel I$) ones. The result can be seen in Fig. 1 for different values of magnetic field B as a function of the component $B_\perp$ perpendicular to the 2DEG plane . For magnetic fields B greater then 1.5 T a sharp dip has been found arround $B_\perp = 0$ with the depth proportional to B in accordance with the measurements of Leadley et al [1] for the perpendicular configuration. For smaller B, however, the dips disappear and broad maxima have been observed around $B_\perp = 0$. At higher values of $B_\perp$ a decrease of resistivity has been detected even for all values of B. The results are qualitatively the same for both configurations.The magnetoresistance for different tilt angles is shown in Fig.2. The positive magnetoresistivity observed for zero angle has changed with increasing angle (i.e. increasing $B_\perp$) to negative one both for lowest and highest fields B.

It does not seem to be possible to explain qualitatively such a complicated behaviour of $\varrho(\alpha, B)$ on the bases of the two above mentioned models only. It can hardly be supposed that a simple two type carrier model based on the distorted Fermi surface could describe results for small B and/or high $B_\perp$. On the other hand the calculation taking into account the third dimension shows that for parallel configuration ($B\|I$) the magnetoresistance should be proportional to $B_\perp^2$ [4]. Such results can however be due to less realistic assumption of harmonic confining potential.

Our results seem to support the idea that quantum corrections i.e. weak localization and electron-electron interaction should also be considered. One can suppose that observed dependences stem from a combinated influence of parallel and perpendicular components of aplied magnetic field. While $B_\|$ gives positive magnetoresistance due to the magnetic field dependence of the relaxation time, $B_\perp$, reducing the weak localization [5-7], leads to a negative magnetoresistance for small $B_\perp$. In small magnetic fields the term due to $B_\perp$ should prevail and maxima can be observed in $\varrho(\alpha)$ dependences. At high $B_\perp$ negative contribution due to the shortening of cyclotron radius with respect to the mean free parth [8] should again reduce the observed magnetoresistance.

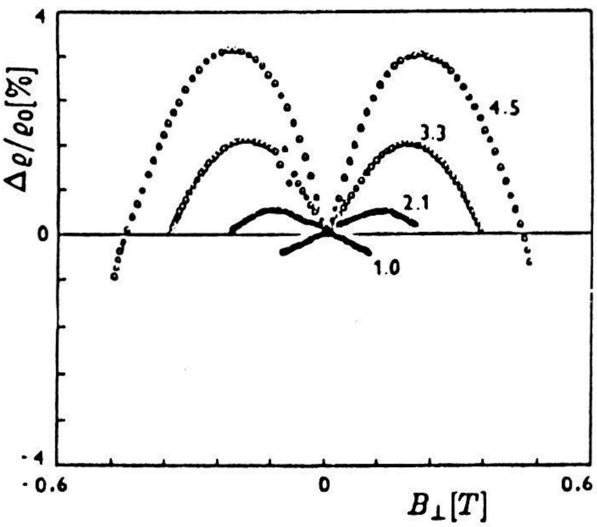

Fig.1 : *Relative magnetoresistance $\Delta\varrho/\varrho_0$ as a function of $B_\perp$ for different applied magnetic fields $B[T]$ ($B\|I$)*

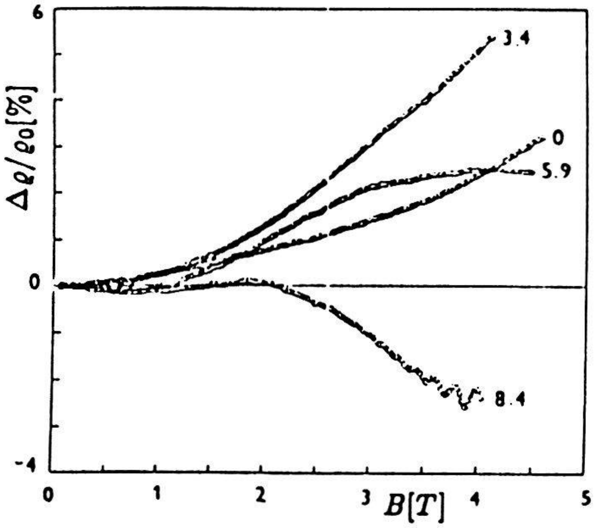

Fig.2 : *Relative magnetoresistance $\Delta\varrho/\varrho_0$ as a function of B for different tilt angles $\alpha[deg]$ ($B\|I$)*

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