Transport properties of the two-dimensional electron gas in modulation doped CdTe quantum well structures

V. Kolkovsky[1], Z. Adamus[1], M. Wiater[1], A. Sulich[1], G. Karczewski[1] A. Kazakov[2], L.P. Rokhinson[2] and T. Wojtowicz[1]

[1]*Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland*

[2]*Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907, USA*

Recent progress in fabrication of high mobility 2DEG in CdTe quantum well (QW) in our laboratory allowed not only to achieve highest mobility of electrons in wide gap telluride semiconductors, but also to observe fragile fractional quantum Hall effect (FQHE) in this structures [1]. A fundamental asset of high mobility CdTe quantum wells is the possibility to incorporate magnetic ions to form diluted magnetic semiconductors QWs, which offer potential applications in the fields of spintronics and quantum computing [2,3]. It is presumed that incorporation of paramagnetic manganese (Mn) ions into a modulation doped CdTe quantum well will provide a strong enough s-d coupling to 2DEG, but without any considerable reduction of the mean free path or broadening of the quantum levels. Additionally, it is expected that the electron-electron correlation effects in CdTe are stronger as compared to GaAs, the material in which the record 2DEG mobility of 3.5×10^7 cm^2/Vs was observed [4].

Here, we report on the studies of scattering mechanisms, which limit the mobility of the 2D electron gas in CdTe QWs. To the best of our knowledge, no results of such studies have yet been published. To this end, the evolution of the mobility of 2DEG as function of the electron concentration, spacer width and temperature was analyzed. The experimental results were compared with theoretical calculations. All the structures studied here were grown by molecular beam epitaxy and contained a single, 30 nm wide CdTe quantum well, remotely doped on one side by iodine donors, and embedded between $Cd_{1-x}Mg_xTe$ barriers (with Mg content x of about 0.26). In order to analyze the mobility of 2DEG as function of spacer width, the series of structures with different spacer layer thickness - from 2.5 nm to 50 nm - were studied. All structures had 60 nm thick cap made of $Cd_{0.74}Mg_{0.26}Te$ that was separating Iodine doped barrier region (supplying electrons to the QW) from the structure surface. The electron concentration in a given structure was varied by gating electric fields in a field-effect transistor configuration. Hall bar devices with golden gates were produced by electron beam lithography, wet etching and lift-off techniques.

Low-temperature studies of Hall- and longitudinal- magnetoresistance revealing well-developed Integer Quantum Hall (IQH) plateaus were performed as a function of gate voltage in temperatures down to 1.4 K and in magnetic fields up to 9 T. Both the change of the slope of low field Hall voltage and the shift of IQH plateaus were used to measure variation of electron concentration. Next-nano software package was used for theoretical simulation of the dependence of electron mobility on temperature, spacer width and 2DEG concentration by taking into account various scattering mechanisms.

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