Epitaxially Integrated Patterned Back Gates for Highest-Quality 2DEG Structures in GaAs/AlGaAs

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It is general practice to control the electric field acting on a 2DES within an epitaxially grown heterostructure by surface gates. However, a much more extensive control of the 2DES is achieved by integrating pre-patterned back gates into the wafer [1]. GaAs/AlGaAs heterostructures, synthesized by molecular beam epitaxy, housing a high mobility two-dimensional electron system (2DES) with integrated back gates placed less than one micrometer below a 2DES show an exceptionally high electron mobility of up to $4.0\cdot10^7$ cm^2/Vs [2]. These structures are simultaneously equipped with both a front and a back gate, to tune the density while keeping the electronic wave function centered in the GaAs quantum well. This minimizes the detrimental effect of the interfaces between the quantum well and the AlGaAs setback layers (see Fig. 1). At a density of $3.5\cdot10^{11}$ cm^{-2}, a mobility of $2.9\cdot10^7$ cm^2/Vs was reached, decreasing to $2.5\cdot10^7$ cm^2/Vs when the wave function was pushed into either of the interfaces using appropriate gate voltages. These results demonstrate the advantage of integrating patterned backgates within the epitaxial layer stack without reducing the quality of the 2DES.

The integrated back gate technology is also crucial to investigate the two components of an electronic bilayer system, separated by a narrow tunnel barrier of a few nm of AlAs. Counter flow drag experiments reveal very unusual coupling phenomena [3,4] in such devices realized by placing properly shaped large gates above and underneath a Hallbar structure for fine-tuning the densities of the two layers. An additional series of pinch-off gates below/above each arm of the Hallbar allows to independently control and measure the two layers of the bilayer system in order to study strongly interacting density-balanced 2D layers [4]. If top gates are to be avoided e.g. in a cavity electromagnetic resonator (similar to [5], project is currently ongoing), integrated back gates still allow to control the relative densities of the bilayers.

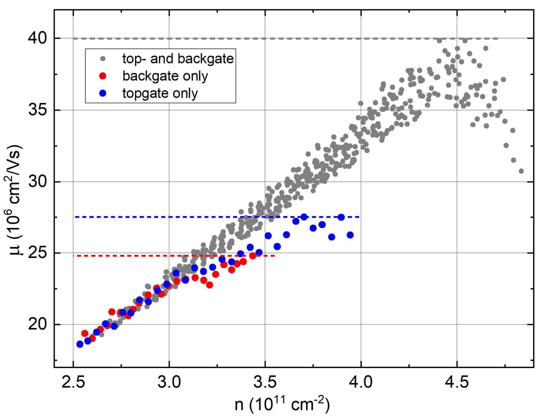

Fig.1. Density vs mobility, tuning with either back- or top gate, and both gates simultaneously.

A set of pinch-off and tuning gates can also be fabricated above and beneath a triple 2DES layer, consisting of a central, high-mobility layer and two ancillary quantum wells. The purpose of the latter is to screen the main 2DES from the Coulomb potential fluctuations stemming from ionized dopants. This remote impurity potential is currently thought to be the dominant limitation for the stability (and thus experimental accessibility) of the notoriously fragile fractional quantized Hall states (FQHS), namely the $\upsilon = 5/2$ state. Without the set of pinch-off gates the ancillary quantum wells would impede the magneto-transport characterization of the 2DES and thereby any efforts to optimize the stability of the FQHS. Results of the project to combine triple layer structures and buried pinch-off gates will be reported.

References

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