Patterned Back Gates suitable for Ultra-High Quality GaAs/AlGaAs Heterostructure Epitaxy

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Gate patterning is mandatory for meso- and nanoscopic scale devices such as quantum point contacts. While patterned top gates can be realized with relative ease, the implementation of patterned back gates is very demanding. Ideally, the patterned back gate needs to be buried between substrate and heterostructure to attain sufficiently low distance between back gate and 2DEG. Moreover, the quality of the heterostructure epitaxy should not be limited by a patterned substrate. We developed a reliable technique to implement patterned back gates for ultra-high quality 2DEGs suitable for nanoscopic devices.

We found a way [1] to overcome the limitation of prior approaches and define back gate patterns directly on the epitaxial surface of the GaAs substrate using oxygen implantation on silicon doped GaAs substrates to electrically insulate regions (passively written gates). Recently we realized actively written gates by implanting silicon directly on GaAs substrates and subsequent annealing for dopants activation.

The sample fabrication (see Fig. 1) is efficient, reliable and scalable. It starts with standard photolithography on a GaAs wafer using photo resist as a selective absorber for the silicon ion implantation, followed by an "epiready" cleaning process as well as dopants activation in a MOCVD system (optional step depending on the growth temperature in the MBE). The samples then are overgrown with the desired heterostructure. Subsequently, mesa-structures with inherently separated contacts for 2DEG and back gate can be defined. The implantation parameters were optimized to achieve reliable gating as well as a minimal impact of the implantation to the surface quality of the substrate.

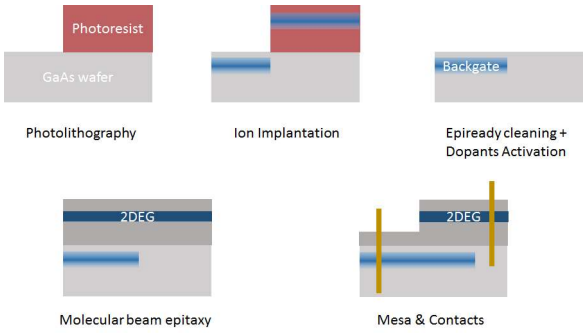

Fig. 1: The five steps to fabricate heterostructures with patterned back gates. Details are given in the text.

Our new patterned back gate technology is especially promising in the following fields (for details on current measurements we refer to abstract "Manipulating the Wavefunction of High-Quality 2DEGs in GaAs/AlGaAs using Advanced Gating Techniques"):

1) Reliable contacting of 2DES and back gate with a wide gate tuning range without risking electrical shorts.
2) Nanoscopic gating via closely spaced 2DES and back gate (~100nm) while retaining high quality heterostructures
3) Extremely high quality 2DEG accessible by pushing the density limits with patterned top and back gates, reaching world record mobilities
4) Sophisticated gating of double layer 2DEG and/or 2DHG systems which must be tuned independently through a top and a back gate.

[1] M.Berl, L.Tiemann, W. Dietsche, H. Karl, and W. Wegscheider, Appl. Phys. Lett. 108, 132102 (2016)

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