AFM-defined Antidot Arrays with Tunable Potential Profile

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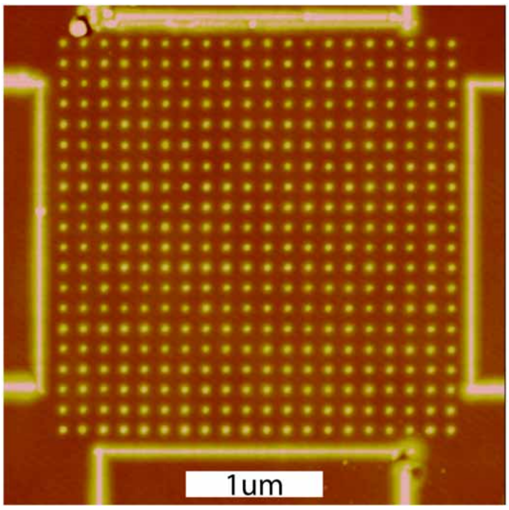
Periodic Arrays of insulating islands in two-dimensional electron systems (2DES), often referred to as antidot lattices [1], display effects including classical commensurability peaks [2], Aharanov-Bohm type oscillations [3] and Aharanov-Altschuler-Spivak oscillations [4]. The quest for an artificial band structure at B=0 is still ongoing. These observations have been analyzed facilitating different theoretical methods [1] and satisfactory agreement with experiment has been achieved. However it has proven difficult to experimentally check the more subtle predictions because many important parameters such as antidot diameter, potential steepness, background mobility, and wavefunction symmetry in z direction are not readily accessible and difficult to tune continuously. Our approach is to study a 20x20 AFM-defined square antidot array with a lattice constant a=150nm with top- and backgate tunability. This allows us to adjust the electron density, antidot diameter, potential steepness, background mobility, and wavefunction symmetry in one and the same array.

The high electronic quality of AFM-defined antidot lattices has been demonstrated [5]. An AFM micrograph of the structure under study is shown in Fig.1. The 2DES is located 34nm below the AFM patterned surface. The topgate was realized by evaporating a TiAu topgate over the entire structure. The backgate consists of highly doped GaAs:Si at a distance of 1.3um from the 2DEG and insulated with layers of ErAs islands [6] from the electron gas. By applying different voltages to the top- and backgate, the position and symmetry of the wavefunction in growth direction can be controlled at constant electron density (Fig.2 and Fig. 3).



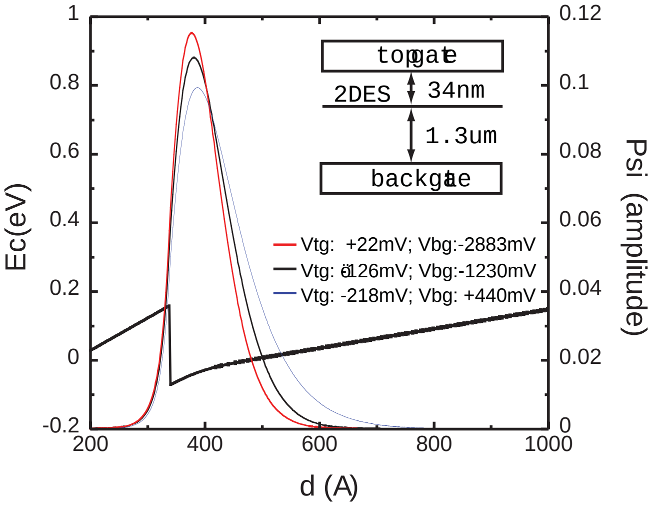


Fig. 1 (left) AFM micrograph of the 20x20 antidot lattice with a=150nm.
Fig. 2 (right) Simulation of the wavefunction shape at constant density with different top- and backgate settings. Inset: schematic illustrating the distances between topgate, 2DEG and backgate.

By stepping the topgate and adjusting the backgate the electron density could be held constant while shifting the 2DEG in real space. Magnetoresistance sweeps at different electron densities were done this way at 9K (Fig.3) and 1.7K. This allows us to monitor the evolution of classical features like commensurability peaks as well as quantum effects like Aharanov-Bohm type oscillations under continuously varying conditions. In particular, we find that the strength and steepness of the antidot potential can be changed by suitable top- and backgate voltages. Around B=0, the magnetoresistance can be tuned from displaying a maximum to a minimum, which presumably is related to the change in wavefunction symmetry and a crossover from weak localization to weak anti-localization. For certain densities and gate voltages we observe pronounced h/2e periodic oscillations, which have so far only been detected in hexagonal antidot lattices [4]. For our samples both h/e and h/2e oscillations are observed, however, for different parameters values and potential profiles.

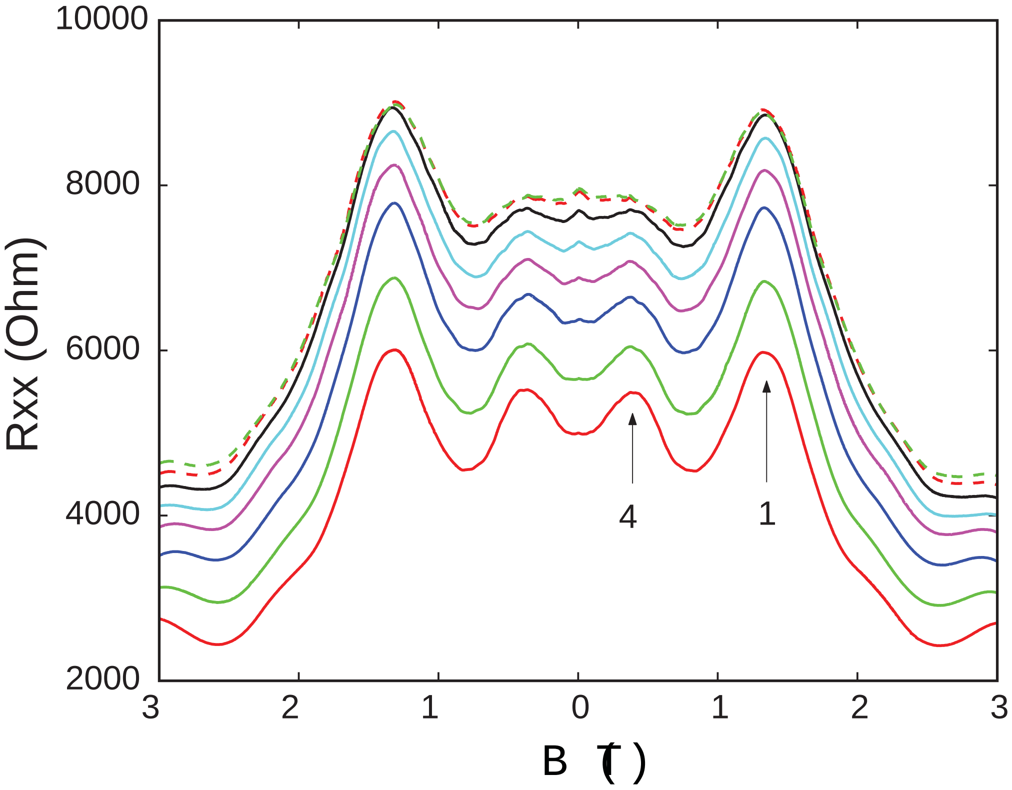


Fig. 3 Magnetoresistance traces taken across the diagonal of the cavity containing the antidot lattice showing commensurability peaks around 1 and 4 antidots. The electron density $n=3.7*10^{-15}\ m^{-2}$ was held constant while the position of the 2DEG was shifted. A pronounced change from a dip to a peak is observed around B=0.

References

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