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Quantized conductance of graphene constrictions patterned by atomic force microscope-based lithography

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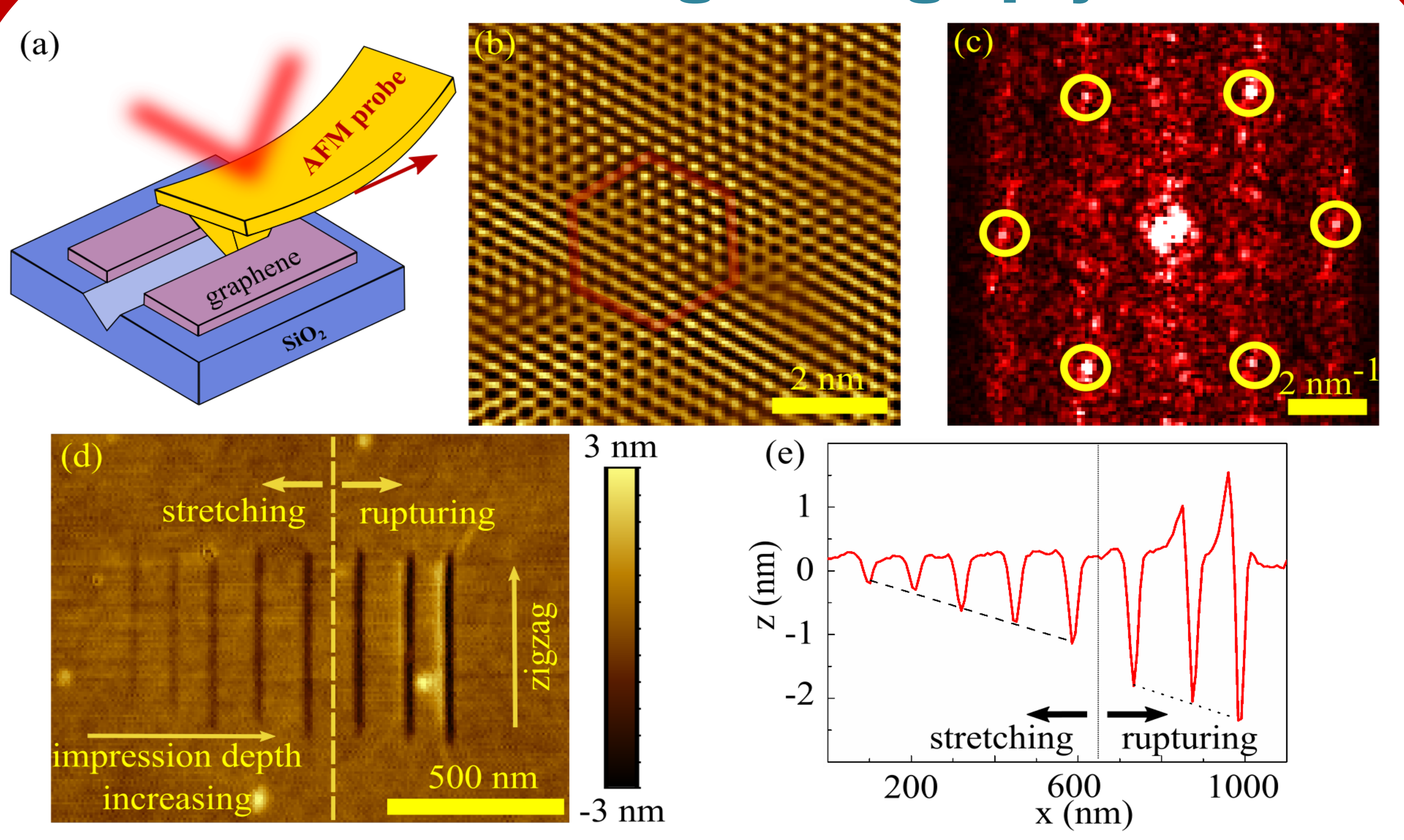
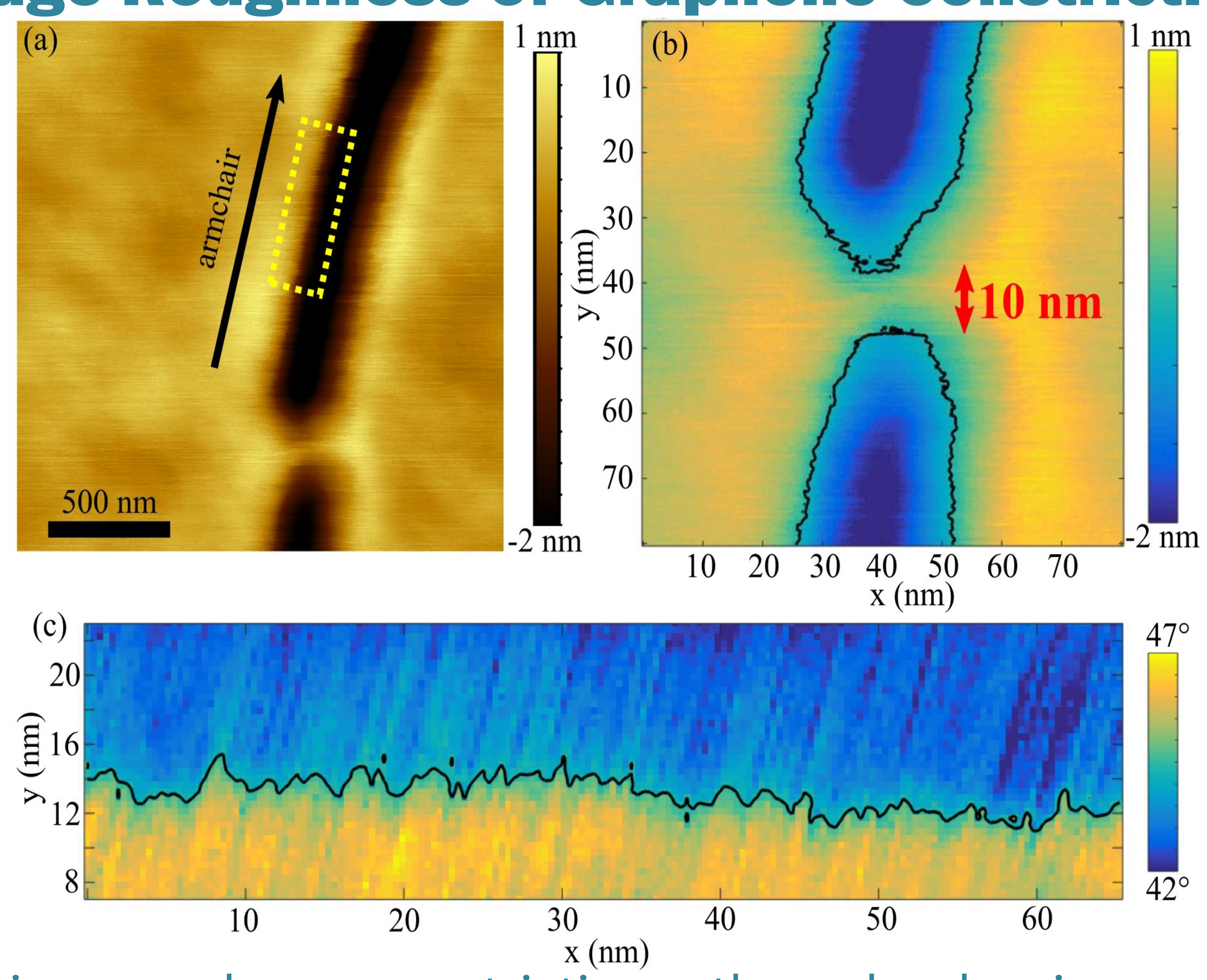
The observation of well-defined conductance plateaus through graphene nanoconstrictions so far has only been accessible in the highest quality suspended or h-BN encapsulated devices. Here, we demonstrate a novel AFM-based nanopatterning technique for defining graphene constrictions with high precision (down to 10 nm width) and reduced edge-roughness (+/- 1 nm). The patterning process is based on mechanical cleavage of graphene, along its high symmetry crystallographic directions. Narrow graphene constrictions with improved edge quality enable an unprecedentedly robust QPC operation, allowing the observation of conductance quantization down to low conductance quanta even on standard SiO_2/Si substrates, and temperatures up to 40 K.

AFM Cleavage Lithography



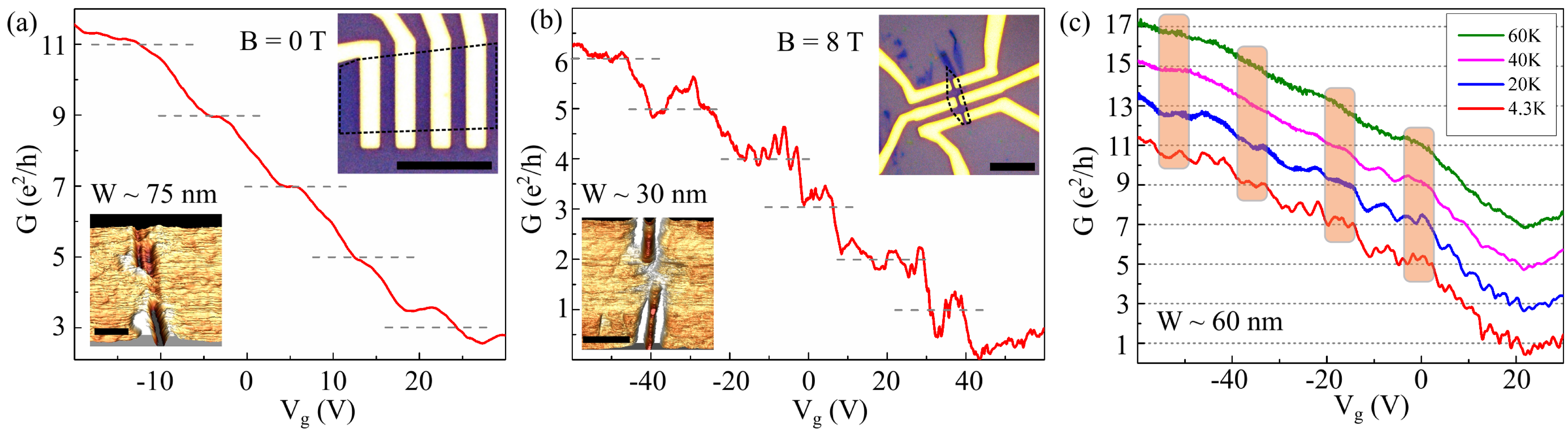
We have utilized the capability of AFM to determine the crystallographic orientations of the graphene lattice before patterning. This made it possible to cleave graphene sheets along their high symmetry directions. After reaching a critical indentation depth, the chances of graphene rupture increase dramatically. Despite the smooth edges, on a series of test lines the two regions can be distinguished.

Edge Roughness of Graphene Constrictions



Defining graphene constrictions through cleaving graphene sheets by AFM along their high symmetry directions, enables us to fabricate graphene nanoconstrictions down to 10 nm width and with reduced edge roughness of +/- 1 nm. The quality of the edges is preserved, since constriction edges never come into contact with resist material or wet chemistry.

Robust Quantum Point Operation



Narrow graphene constrictions with high quality edges display robust QPC behavior manifesting in well-defined zero-field conductance quantization plateaus down to a few conductance quanta, even on SiO_2/Si substrates, and temperatures up to 40K. In zero magnetic field, evenly spaced conductance plateaus could be detected, roughly spaced by 2 e^2/h attributed to the lifting of the valley degeneracy, while the application of magnetic field resulted in plateaus spaced by e^2/h, indicating the lifting of both valley and spin degeneracy.

Conclusions

Here we report on quantum confinement through graphene constrictions on silica substrates, in the form of even-spaced plateau-like features, roughly spaced by $2e^2$/h even in zero magnetic field. Instead of reactive ion etching, using our novel atomic force microscope-based nanopatterning technique can enable the fabrication of higher quality graphene quantum point contacts, lifting the highly demanding requirements for the device quality.

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REFERENCES

P. Kun et al. Robust quantum point operation of narrow graphene constrictions patterned by AFM cleavage lithography, arXiv:2010.04066

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