Quantum Hall Effect in Black Phosphorus Two-dimensional Electron Gas

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Introduction

Black phosphorus field-effect transistor (FET) has recently emerged as a new elemental two-dimensional (2D) system with high carrier mobilities[1-3]. A gate electric field induces a two-dimensional hole gas (2DHG) or electron gas (2DEG) in black phosphorus. Previously, we have observed the quantum Hall effect in BP 2DHG (ref. 4). In a new set of experiments performed at NHMFL this year, we observed, for the first time, the quantum Hall effect in BP 2DEG (ref. 5).

Experimental.

We used pre-patterned graphite as a local gate to define the 2DEG in a selected region inside of the black phosphorus flake; the area surrounding the 2DEG was in the meantime tuned into an intrinsic insulating state with a Si back gate (Fig. 1 inset). The electrostatically defined smooth edge of the 2DEG leads to much improved quantum transport in the quantum Hall regime. The transport measurements were performed in high magnetic fields in Cell 12 and Cell 15.

Results and Discussion

The pre-patterned graphite gate enables us to define electrostatically the 2DEG in the flake, and we observe, for the first time, well-quantized Hall plateaus in black phosphorus 2DEG. Fig. 1 displays the magnetoresistance R_{xx} and Hall resistance R_{xy} as a function of gate voltage V_g at V_{si} = +5 V under B = 35 T and T = 0.3 K. The quantized Hall plateaus are accompanied by vanishing magnetoresistance R_{xx} – both being hallmarks of the quantum Hall effect. As V_{si} deviates from the +5V, R_{xx} at filling factors ν = 1 and ν = 2 becomes finite (data now shown). The result highlights the importance of the gates-defined edge.

Conclusions

We fabricated black phosphorus FETs with pre-patterned graphite local gates that electrostatically define the 2DEG and its edge. Such a device structure enabled us to observe the quantum Hall effect on electron-doped black phosphorus FETs.

Acknowledgements

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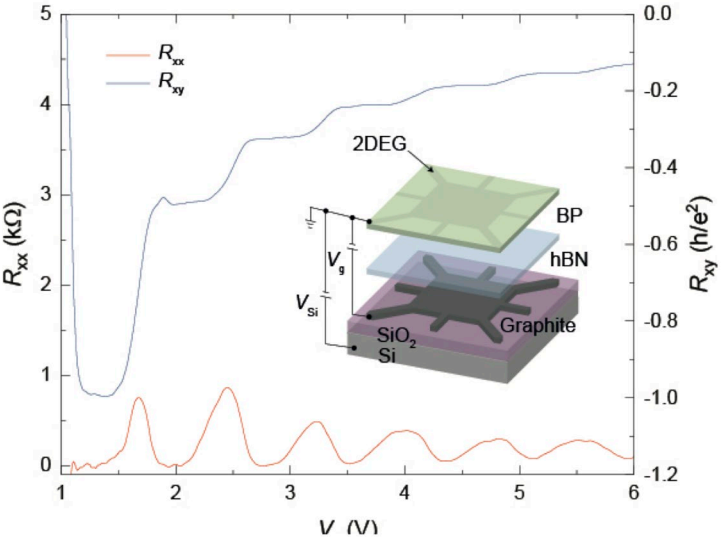

Fig.1 Quantum Hall effect in electron-doped black phosphorus field-effect transistor. Data collected at B = 35 T and T = 0.3 K (left).

References

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