Aktuelle Fragen der Nanophysik

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Characterizing Inhomogeneity, Anisotropy, and Transients in 2D Materials


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2D Materials have entered mainstream research as a platform for novel, atomically-thin electronic devices. As more compounds of higher quality are added to the lexicon of 2D materials, the need for improved characterization methods increases. For example, some 2D materials have an anisotropic crystal structure whose orientation needs to be determined to identify the high mobility direction. Here an all-electrical method is introduced for determining the crystal axes of inherently anisotropic 2D materials, such as black phosphorus [1]. In other samples, the inability of 2D materials to screen disorder often results in hysteresis when nearby unscreened traps release and then re-trap charge. It is shown that by cooling the 2D system under back-gate bias, the charge state of the traps can be frozen in, and at low temperatures one sample can achieve a host of different charge-trap states which all collapse on a common characteristic curve, whereby dominant scattering regimes are clearly revealed [2]. Finally, 2D materials can develop inhomogeneous conductivity due to proximity effects transferred by irregularities the neighboring substrate or by imperfect processing. A resistance tomography method is introduced, to show how a local conductivity map of the internal sample area can be determined from purely electrical measurements with ohmic contacts at the periphery [3]. The resolution of the tomographic map goes as C(C-3)/2, where C is the number of contacts, so that 8 contacts results in a 2D area resolution containing 20 pixels, and 15 contacts results in a resolution of 90 pixels.

[1] Lintao Peng, Spencer A. Wells, Christopher R. Ryder, Mark C. Hersam, and M. Grayson, "All-electrical determination of crystal orientation in anisotropic two-dimensional materials," Phys. Rev. Lett. **120**, 086801 (2018).
[2] Chulin Wang, Lintao Peng, Spencer A Wells, Jeffrey D. Cain, Yi-Kai Huang, Lawrence A. Rhoads, Vinayak P. Dravid, Mark C. Hersam, & Matthew A. Grayson. "Field-effect conductivity scaling for two-dimensional materials with tunable impurity density." 2D Mater. **9**, 031002 (2022).
[3] Claire Onsager, Chulin Wang, Charles Costakis, Can Aygen, Lauren Lang, Suzan van der Lee, Matthew A. Grayson. "Sensitivity Analysis for Optimizing Electrical Impedance Tomography Protocols." *arXiv*:2111.01397 (2021).