Structure-Property Relationship in Amorphous Monolayer Carbon

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Abstract

Correlating atomic configurations—specifically, degree of disorder (DOD)—of an amorphous solid with properties is a long-standing riddle in materials science and condensed matter physics, owing to difficulties in determining precise atomic positions in 3D structures. To this end, 2D systems provide insight to the puzzle by allowing straightforward imaging of all atoms[1,2]. Direct imaging of amorphous monolayer carbon (AMC) grown by laser-assisted depositions has resolved atomic configurations, supporting the modern crystallite view of vitreous solids over random network theory[3]. Nevertheless, a causal link between atomic-scale structures and macroscopic properties remains elusive. Here we report facile tuning of DOD and electrical conductivity in AMC films by varying growth temperatures[4]. Specifically, the pyrolysis threshold temperature is the key to growing variable-range-hopping conductive AMC with medium-range order (MRO), whereas increasing the temperature by 25 °C results in AMC losing MRO and becoming electrically insulating, with an increase in sheet resistance of 10^9 times. Beyond visualizing highly distorted nanocrystallites embedded in a continuous random network, atomic-resolution electron microscopy shows the absence/presence of MRO and temperature-dependent densities of nanocrystallites, two order parameters proposed to fully describe DOD. Numerical calculations establish the conductivity diagram as a function of these two parameters, directly linking microstructures to electrical properties. Our work represents an important step towards understanding the structure–property relationship of amorphous materials at the fundamental level and paves the way to electronic devices using 2D amorphous materials.

References

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[2] Hong, S. et al. *Nature* **582** (2020), 511–514.
[3] Toh, C. T. et al. *Nature* **577** (2020), 199–203.
[4] Tian, H. et al. *Nature* **615** (2023), 56–61.

Figures

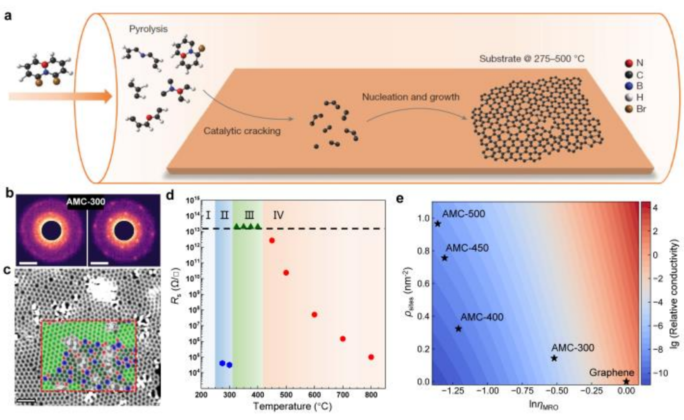

Figure 1: Structure-property relationship in AMC.