Atom-resolved study of CVD graphene on Rh substrates and its intriguing properties by STM/STS

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Abstract:

Chemical vapor deposition (CVD) is the most popular method to prepare large-scale and highly uniform graphene films on metal substrates. However, the atomic-scale structure, the stacking order, as well as the defect states was seldom reported due to the corrugated nature of the polycrystalline metal substrates.[1-3] We tried to address this issue by using Rh foils and Rh(111) as substrates, and explore the different graphene growth behaviors mainly by virtue of scanning tunneling microscopy/ spectroscopy (STM/STS) characterizations.[4, 5] Interestingly, a templated growth of singlecrystalline graphene by the Rh(111) lattice is obtained under (ultrahigh vacuum chemical vapor deposition) UHV-CVD conditions at 600 °C, which is characterized with the formation of a uniform graphene moiré. In comparison, monolayer and randomly stacked few-layer graphene is achieved under the atmosphere pressure chemical vapor deposition (APCVD) condition at 1000 °C, *via* different quenching processes on both Rh foils and Rh(111) (Figure 1). On the basis of evidences hereinbefore, we proposed a surface catalysis and a segregation mechanism for graphene growth at 600 °C and 1000 °C, respectively. Moreover, randomly stacked bilayer or few layer graphene usually exhibit various moiré patterns, on which angel-dependent van hove singularities (VHSs) was observed by STM/STS.[6] In addition, since the distinguished thermal expansion coefficient of graphene and Rh foils, high-density wrinkles and ripples are formed on graphene.[5] Along a wrinkle, states condensed into well-defined pseudo-Landau levels, which mimic the quantization of massive chiral fermions in a magnetic field of about 100 T.[7] We propose that this work is expected to contribute greatly to understand the growth mechanism, the atomic scale structures, as well as the intriguing physical properties like VHSs and high-temperature zero-field quantum valley Hall effect of graphene on polycrystalline metal substrates.

References

[1] Y.F. Zhang, T. Gao, Y.B. Gao, S.B. Xie, Q.Q. Ji, K. Yan, H.L. Peng and Z.F. Liu, ACS Nano, **5,** (2011), 4014.

[2] T. Gao, S.B. Xie, Y.B. Gao, M.X. Liu, Y.B. Chen, Y.F. Zhang and Z.F. Liu, ACS Nano, **5**, (2011), 9194.

[3] Y.F. Zhang, T. Gao, S.B. Xie, B.Y. Dai, L, Fu, Y.B. Gao, Y.B. Chen, M.X. Liu and Z.F. Liu, Nano Research, **5**, (2012), 402.

[4] M.X. Liu, Y.B. Gao, Y.F. Zhang, Y. Zhang, D.L. Ma, Q.Q. Ji, T. Gao, Y.B. Chen, and Z.F. Liu, Small, **9**, (2013), 1360.

[5] M.X. Liu, Y.F. Zhang, Y.B. Chen, Y.B. Gao, T. Gao, D.L. Ma, Q.Q. Ji, Y. Zhang, C. Li, and Z.F. Liu., ACS Nano, **6**, (2012), 10581.

[6] W. Yan§, M.X. Liu§, R.F. Dou, L. Meng, L. Feng, Z.D. Chu, Y.F. Zhang, Z.F. Liu, J.C. Nie, L. He., Physical Review Letters, **109**, (2012), 126801.
[7] W. Yan, W. Y. He, Z. F. Chu, M. X. Liu, L. Meng, R. F. Dou, Y. F. Zhang, Z. F. Liu, C. J. Nie and L. He, Nature Communications, **4**, (2013), 2159.

Figures

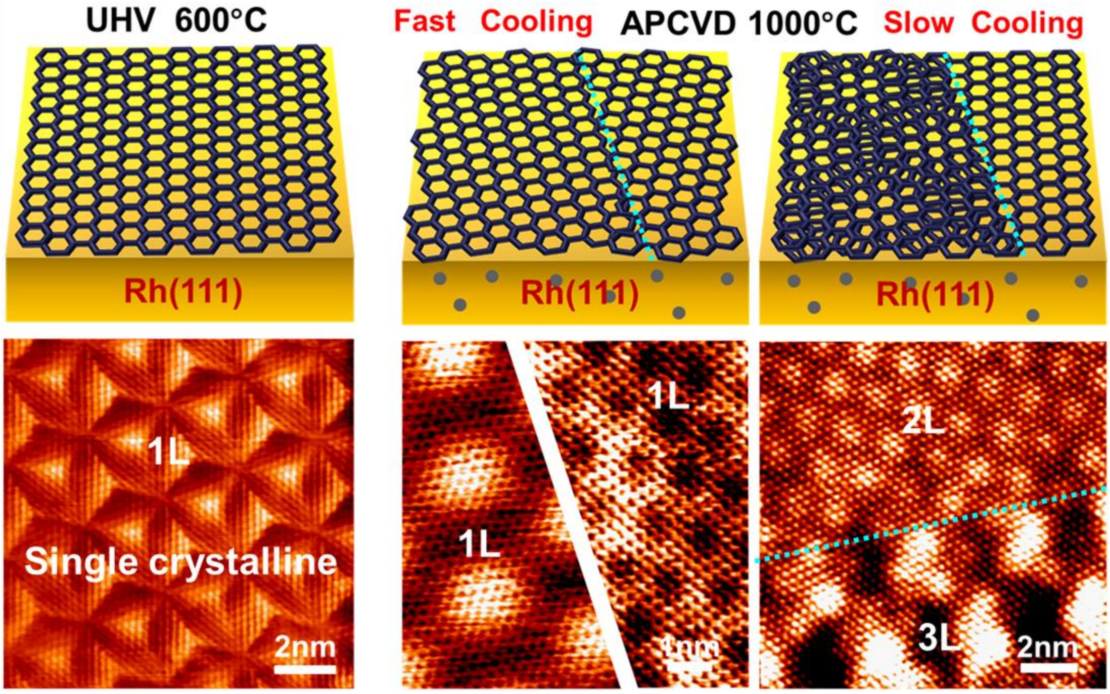

Figure 1. Singlecrystalline and polycrystalline graphene were obtained on Rh(111) under UHV and APCVD conditions at different growth temperature, respectively.