STM studies of Er-intercalated epitaxial graphene

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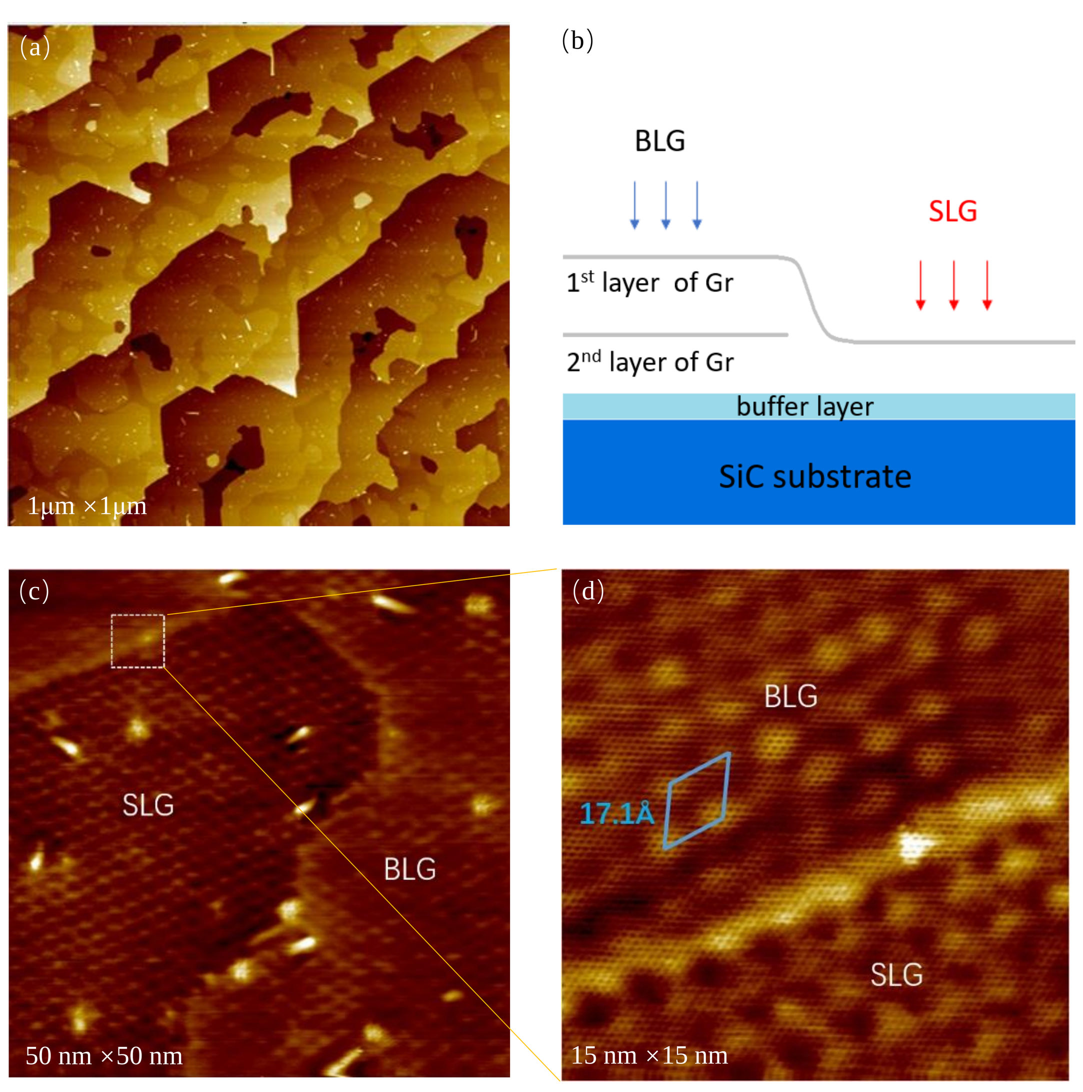
Introduction

Thermal decomposition of SiC is one of the most promising routes to produce large-scale graphene. Graphene on SiC substrate can be directly applied in semiconductor device without the need of any transfer. However, the coupling between epitaxial graphene and SiC substrate reduces the carrier mobility of graphene and limits its application. Intercalation is a feasible way to decouple graphene from substrate.

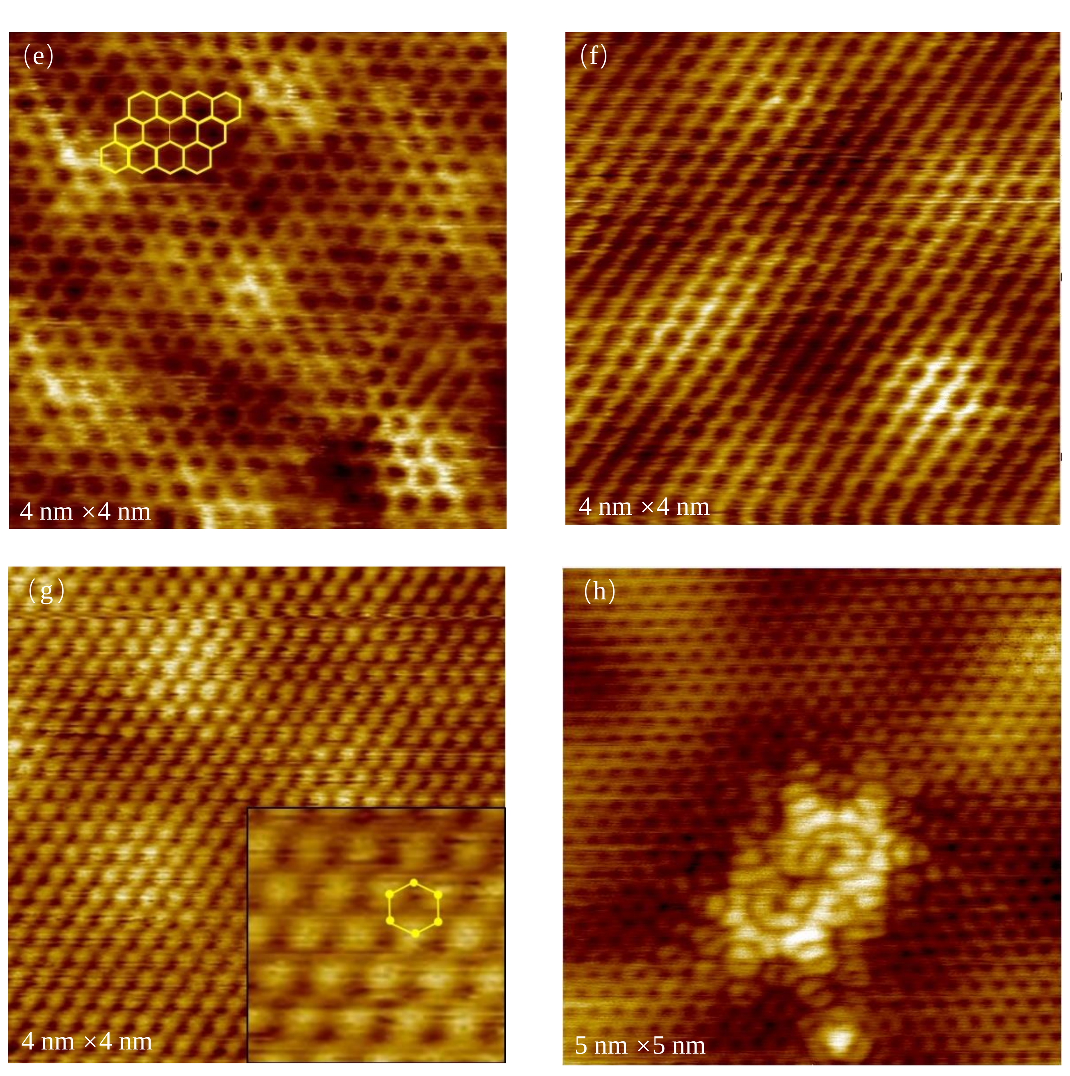
Method

Our experiment was done in UHV system (pressure~10^{-10} mbar). High quality large-scale graphene on 4H-SiC(0001) was obtained by flash heating (HT: above 1300℃; LT: 650℃±50℃). After imaging, Er atoms were evaporated onto sample at room temperature. Er-decorated graphene was annealed above 800℃ to intercalate Er atoms under the graphene layer. Omicron UHV STM system is performed to investigate surface morphology and structure of graphene and intercalated graphene.

Gr/4H-SiC(0001)

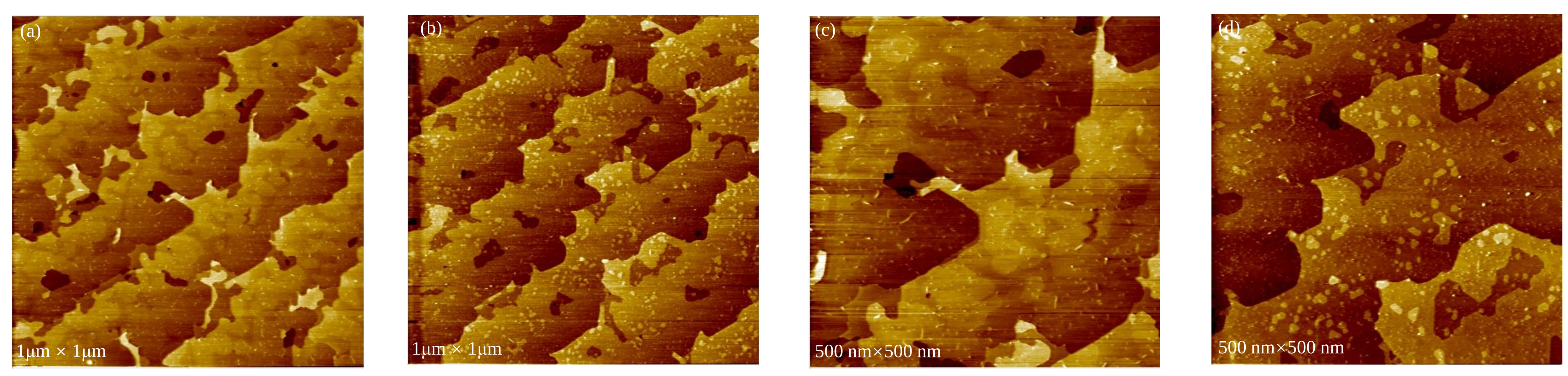


(a),(c)&(d): STM images of Gr/4H-SiC(0001). The period of $(6\sqrt{3}\times 6\sqrt{3})R30°$ reconstruction we observed is 17.1Å, which agrees with others' report. (b): Schematic of bilayer graphene and single layer graphene on SiC substrate.

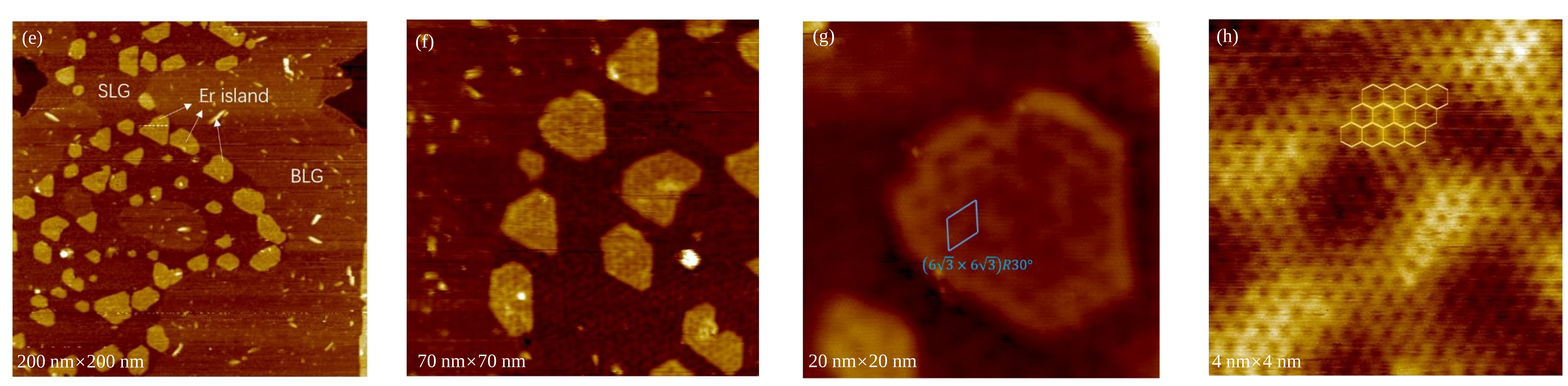


(e): Atomic resolution of single layer graphene, V_s = 0.3V, I = 300pA. The honeycomb structure is observed as the yellow line shows. (f) & (g): Atomic resolution of bilayer graphene in different regions, V_s = 0.3V、- 0.3V, I = 300pA、400pA, respectively. Image (g) shows a triangular lattice rather than a honeycomb arrangement due to Bernal stacking, which causes suppression of the density of state of the A sublattice at low bias, yielding images of only the B sublattice. (h): conjoined-twin defect in graphene, V_s = 0.6V, I = 300pA.

Er/Gr/4H-SiC(0001)

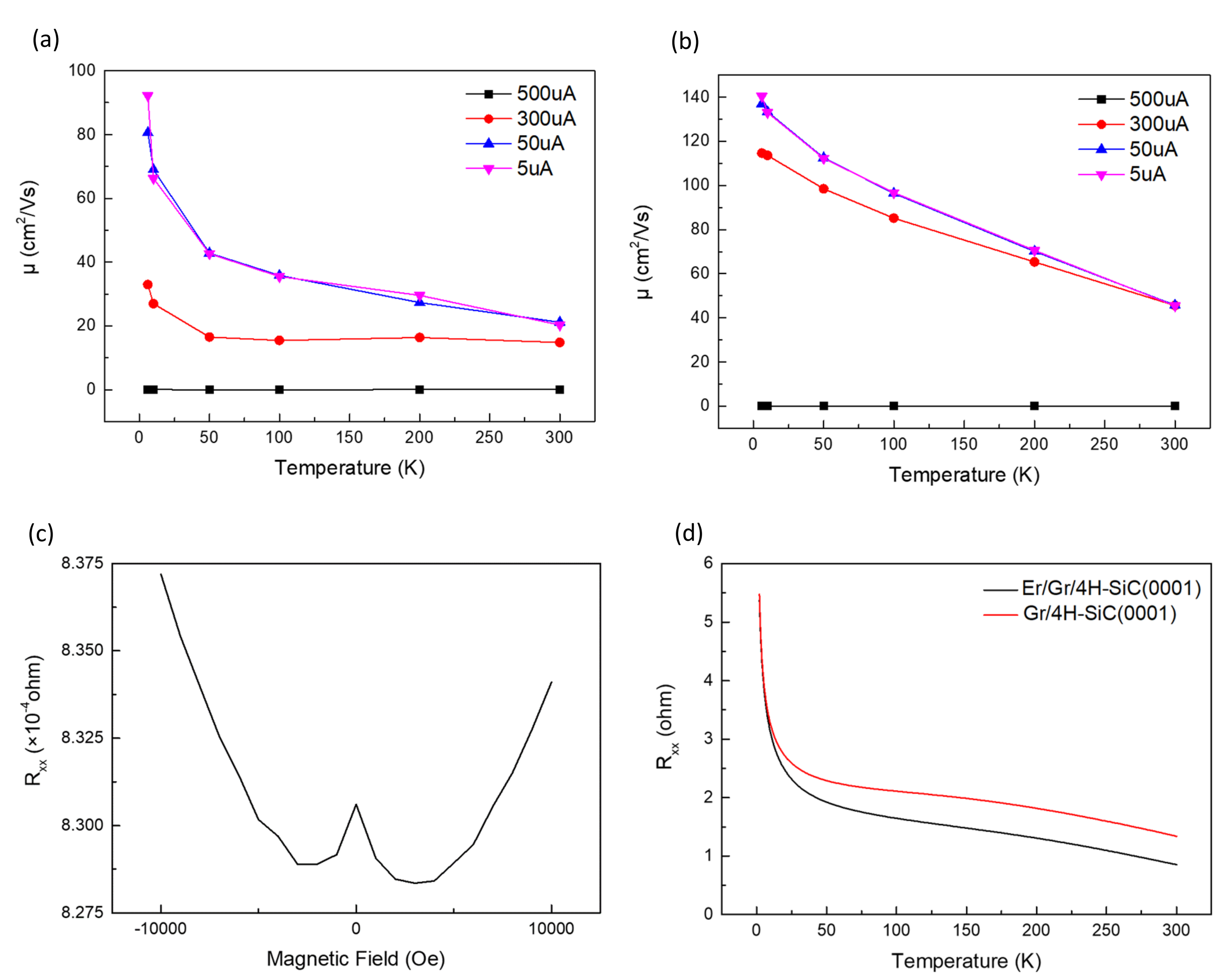


STM images: (a) & (c): Gr/4H-SiC(0001). (b) & (d): Er/Gr/4H-SiC(0001). After Er intercalation, many islands appears on the surface of sample. Obviously, these islands are Er islands which result from Er intercalation. Are these Er islands intercalated under the graphene layer?



(e) - (g): Zoom-in STM images of Er/Gr/4H-SiC(0001). It's interesting that most of Er islands located in single layer graphene region. (h): Atomic resolution of Er island showing in image (g). Obviously, this image shows a honeycomb arrangement, it means the island is covered with graphene layer and Er atoms exactly were intercalated under the graphene layer. According to the clear $(6\sqrt{3}\times 6\sqrt{3})R30°$ reconstruction observed on the Er island (shown in image (g)), we can draw a conclusion that Er atoms were intercalated at the interface between single layer graphene and buffer layer.

Transport Property



(a) &(b): Temperature dependence of μ of Er/Gr/4H-SiC(0001) and Gr/4H-SiC(0001), respectively. It's interesting that, when different excitation currents were used in experiment, different carrier mobility values were observed. It seems that excitation current affects carrier mobility. But there is no longer much difference between carrier mobility in 50 μA and in 5 μA. Furthermore, the R_{xy} data we obtained indicated that, R_H (hall coefficient) of Er/Gr/4H-SiC(0001) is negative, while R_H of Gr/4H-SiC(0001) is positive. It means Er/Gr/4H-SiC(0001) is n-type and Gr/4H-SiC(0001) is p-type. This result is repeated in our experiments but different from others' report.
(c): Weak localization peak observed in MR of Er/Gr/4H-SiC(0001) near B=0. The weak localization peak is also observed in Gr/4H-SiC(0001).
(d): Temperature dependence of R_{xx}. The R_{xx} of Gr/4H-SiC(0001) and Er/Gr/4H-SiC(0001) both decrease with increasing temperature, showing obvious semiconductor characteristics.

Conclusion

High quality large-scale epitaxial graphene on 4H-SiC(0001) was obtained by flash heating, which consists of a mixture of single layer graphene and bilayer graphene. After evaporation and annealing above 800℃, Er-intercalated graphene was obtained. It's interesting that most of Er islands were intercalated in single layer graphene region, and these Er islands actually were intercalated in the interface between single layer graphene and buffer layer. The transport properties of graphene and intercalated graphene were assessed by PPMS device.

References:

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