Effects of Er on the Epitaxial Graphene on SiC(0001)

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Introduction: *Erbium is easy to react with silicon to form $ErSi_2$ even at room temperature, so Er atoms can combine with Si atoms on the surface of 4H-SiC (0001) to promote graphitization of silicon carbide surface, which make it possible to produce high-quality graphene at lower temperature. On the other hand, rare-earth metal atoms can regulate electron band structure of epitaxial graphene by means of intercalation or defect induction. Here we study the influence of Er growth on the epitaxial growth of graphene on SiC(0001) using STM.*

Experimental methods

Omicron UHV STM system@ RT------

base pressure better than 2.0×10^{-10} *mbar*

STM data processing system — Matrix 3.1

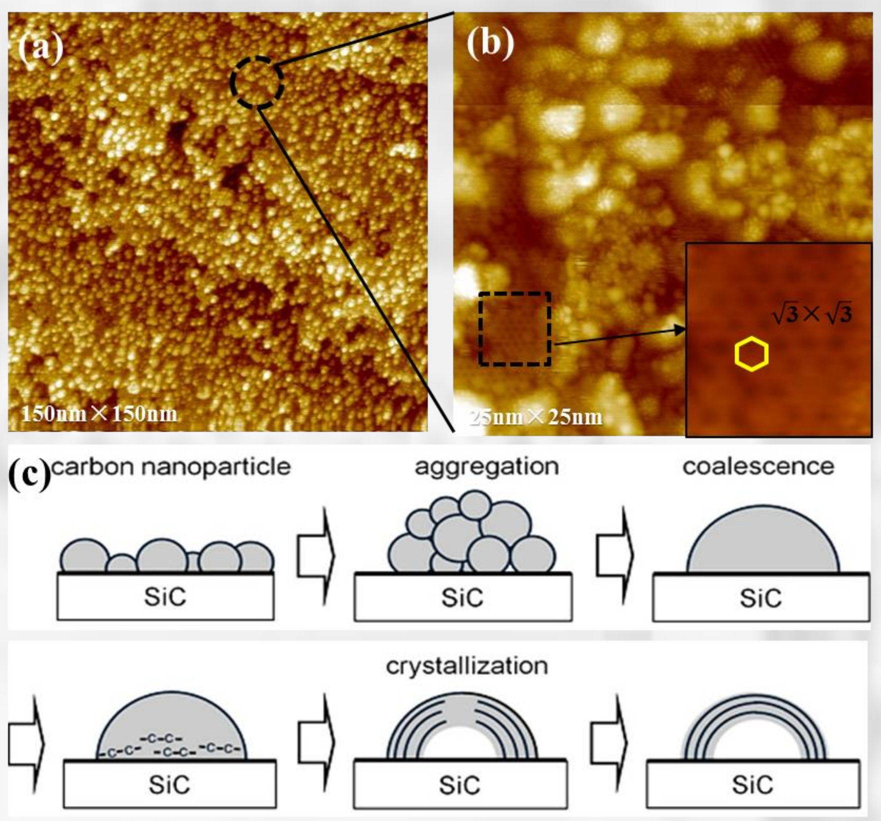
Substrate and methods------

4H-SiC(0001), with N doping density of $10^{18\text{-}19}$ cm^{-3}

degassed at 950℃ for 30min, annealed at 1100 ℃ for 26 min

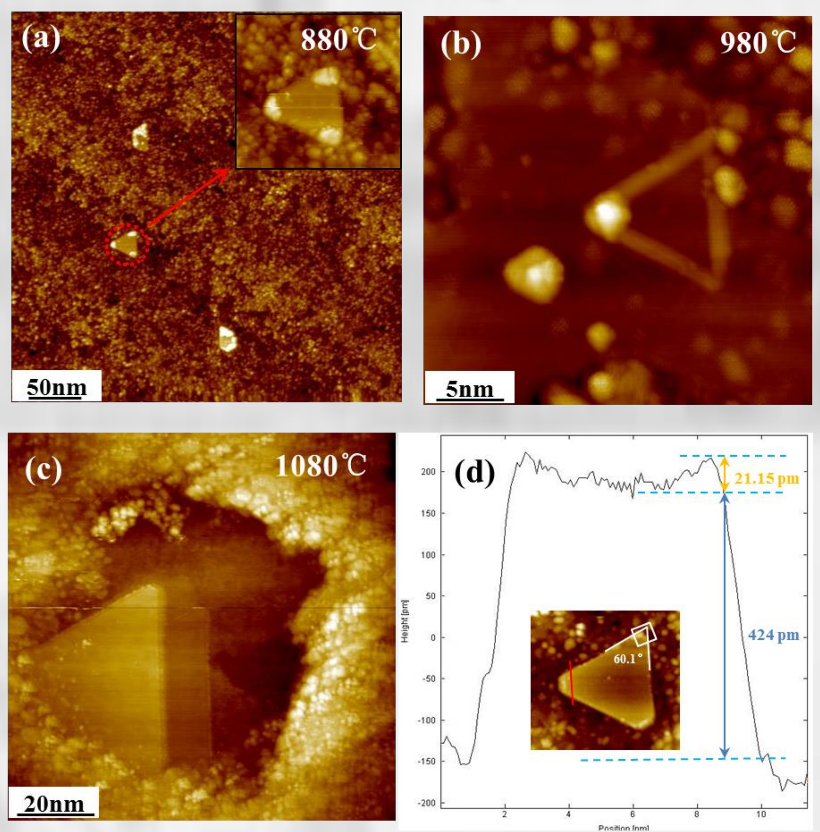
then Er was deposited for 4min (rate ≈ 0.06nm/min) and annealed at 900℃, 1000℃, 1100℃, 1200℃ and 1300℃ for 10 min, respectively.

Clean surface of SiC



Ref: T Maruyama *et al*., Diam. Relat. Mater. **20**, 1325 (2011)

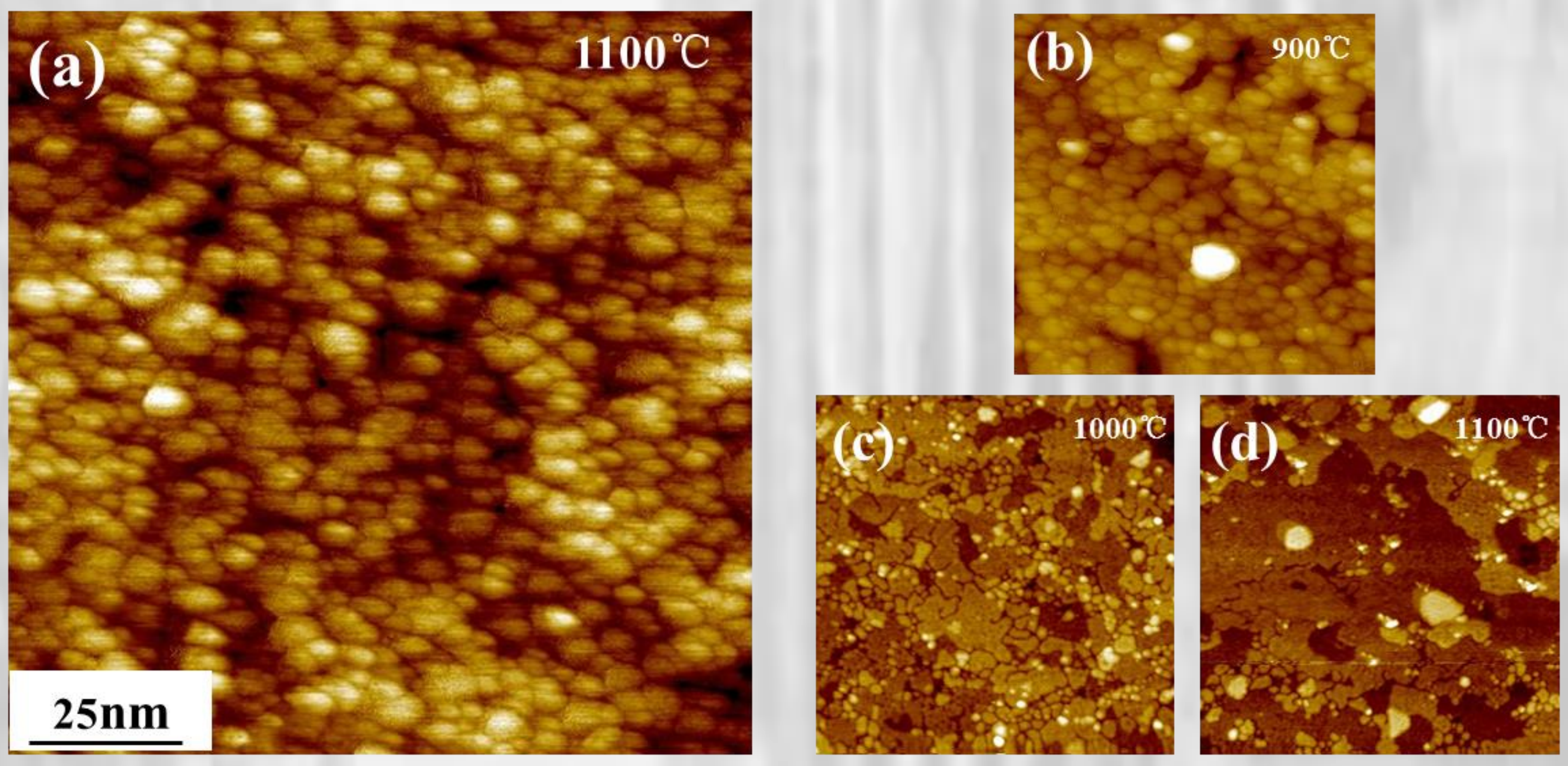
(a) The heating temperature is 1100 °C. (b) The $\sqrt{3}\times\sqrt{3}$ unit cell is outlined. Sample bias =-1.6V. (c) Schematic model of the carbon nanocap formation process during surface decomposition of SiC.



(a) ~ (c) The triangular crystal facets are also observed at different annealing temperatures. (d) The line profile of crystal plane height along the solid red line.

The surface was cleaned by direct heating of the SiC with an electric current, and obvious $\sqrt{3}\times\sqrt{3}$ reconstruction was observed. During the cleaning process, a new crystal face was found in the existing research result. Its formation mechanism remains to be studied.

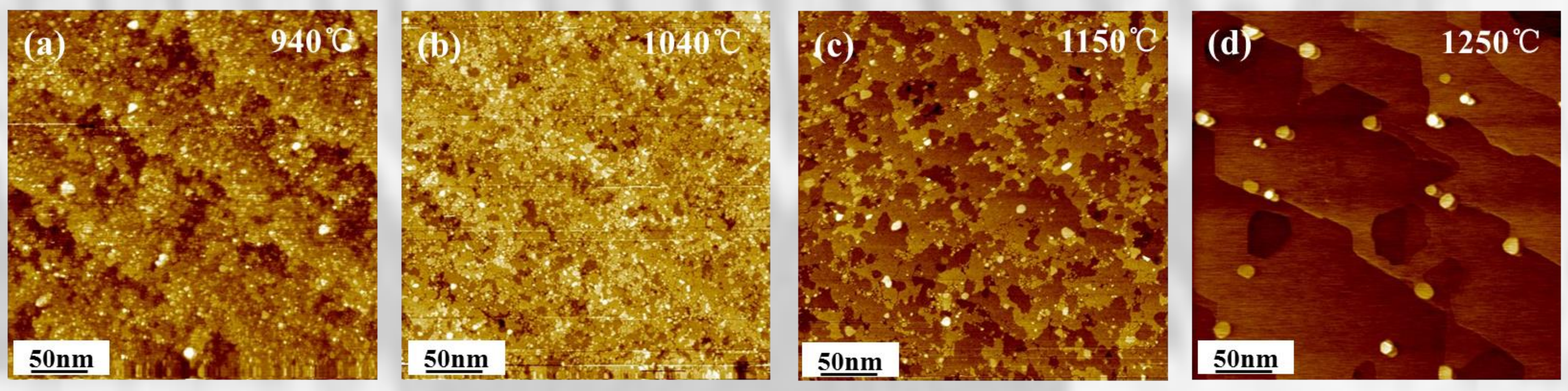
Effect of Er on graphitization of SiC



(a) shows the STM image of SiC annealed at 1100℃ without Er; (b) ~ (d) show the terrace morphologies after annealing at 900/1000/1100℃ with Er growth, respectively

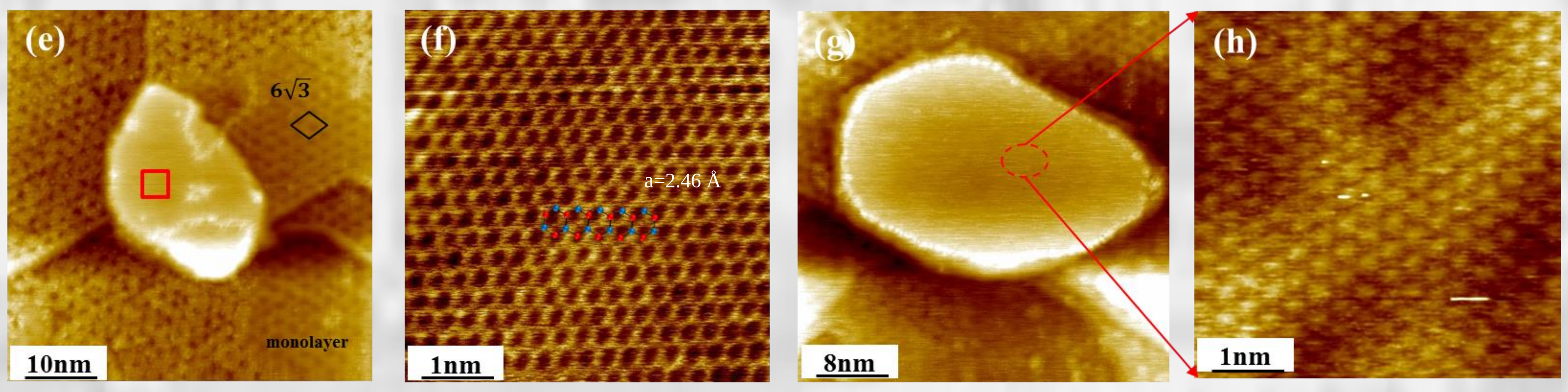
Terrace → planar and complete.
The graphitization of SiC → improved even at lower temperature.

Evolution of Er/SiC morphology



(a) ~ (d) shows STM images of the evolution process with different annealing temperature of 4H-SiC(0001) with 0.24nm Er deposited at room temperature.

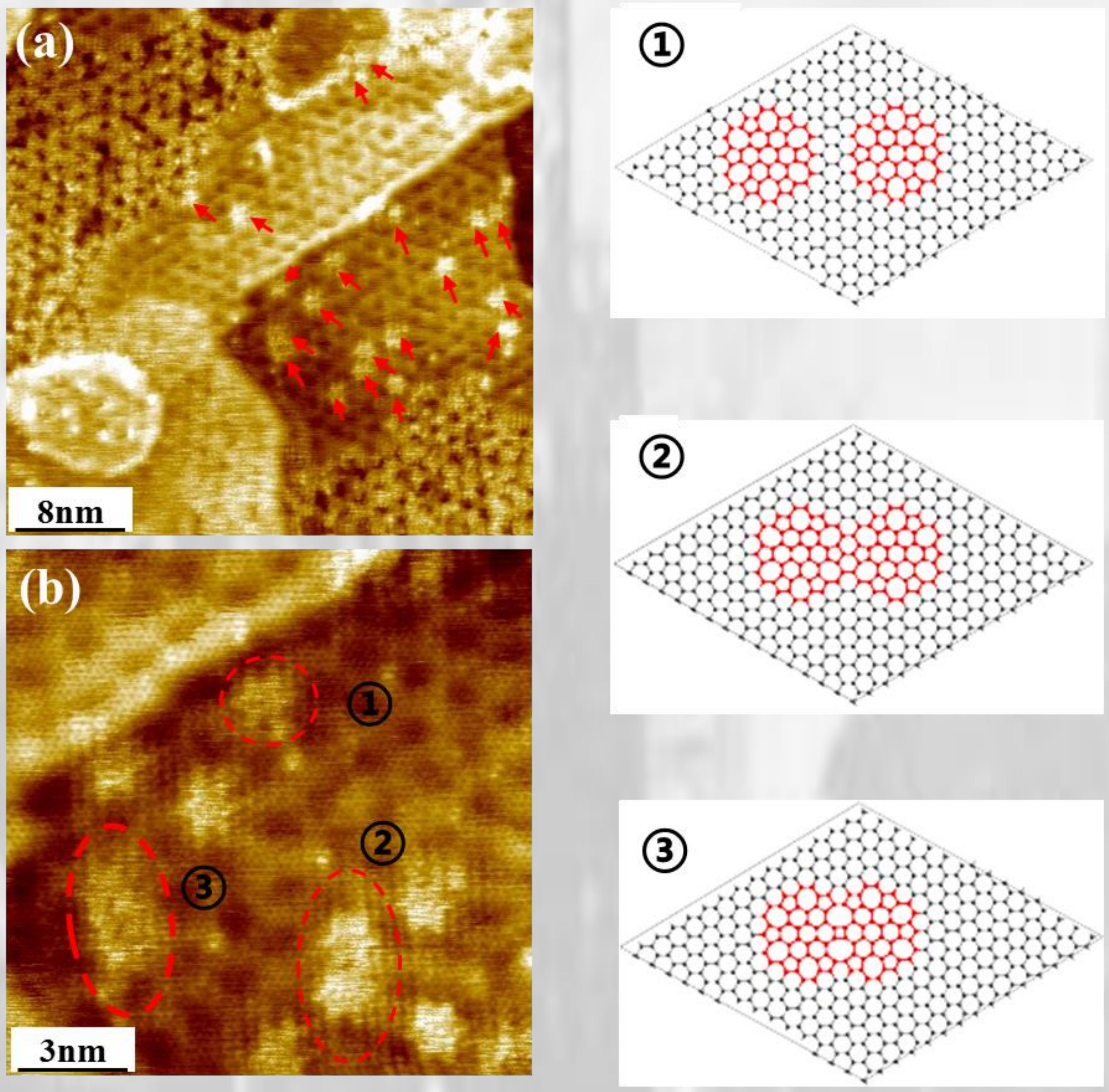
⟶ With raising annealing temperature, the terrace tends to be flat. Many nanoislands appear on the surface with 10 – 30nm in diameter.



(e) & (g) show two kinds of nanoislands on the graphitized terrace of 4H-SiC(0001); (f) & (h) are atomic resolved STM images of the nanoisland in (e) and (g), respectively. The distance between the two spots in (h) is about 0.3nm.

The surface of the nanoisland (e) is covered by graphene. The island in (f) is supposed to be $ErSi_2$ island, which needs to be verified in the future.

Evolution of flower defects



The annealing treatments for graphitization were performed at 1300℃.

→ Many flower defects can be found in epitaxial graphene, as well as the white-dot defects. Compared with graphene without Er deposition, the density of flower defects increases significantly, and the dynamic evolution of conjoined-twin defects can be observed in the image at the same time.

Conclusion

- Er deposition on the surface improves the graphitization degree of SiC substrate.
- The chemical reaction between Er and Si atoms at low temperature makes the carbon atoms in SiC substrate more likely to aggregate and crystallize during annealing.
- More defects can be induced on the epitaxial graphene after Er growth, especially flower defects, which are expected to modify the electronic and mechanical properties of epitaxial graphene.

References:

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