Er Growth behavior and effect on electronic properties for EG/SiC

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Introduction: *As a two dimensional material holding extraordinary electronic properties, graphene possess a promising future in semiconductor device. Due to its zero-gap band structure, it is necessary to modify the band gap and electronic structure of graphene for specific application. An attractive route is to intercalate atomic species into the graphene/substrate interfaces. Er has higher chemical reactivity than noble metals, which may make them perfect intercalators from the viewpoint of graphene band structure modifications and spintronics researches. Here, we study the growth model of Er on EG/SiC substrate and the effects of Er on graphene band gap, electronic properties and interaction with substrate.*

Experimental methods

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

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

STM data processing system — Matrix 3.1

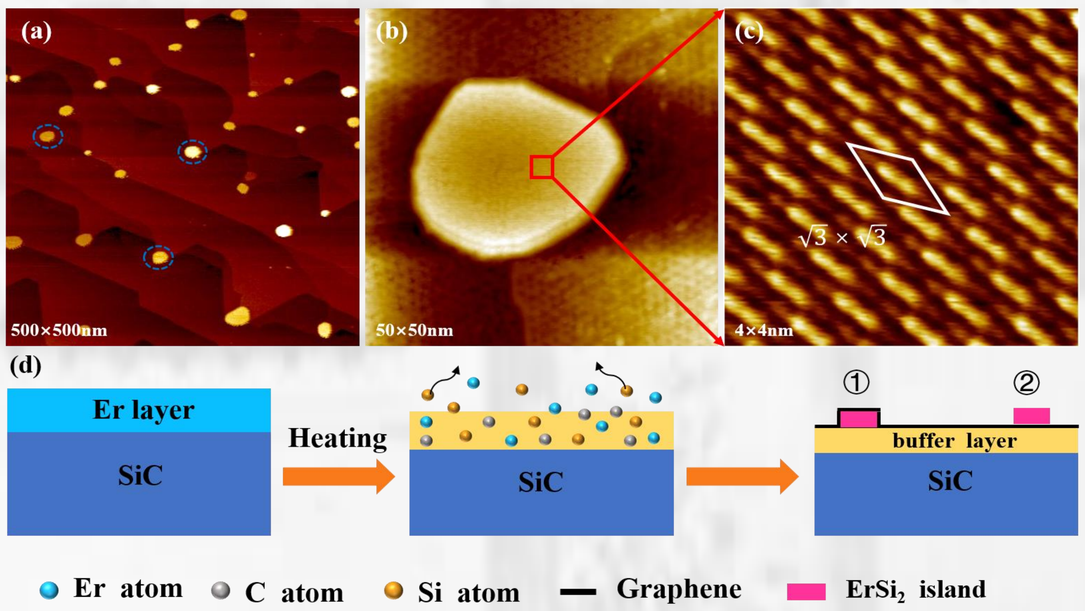
Substrate and methods------

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 4/8min (rate ≈ 0.06nm/min) and annealed at 900℃, 1000℃, 1100℃, 1200℃ and 1300℃ for 10 min, respectively.

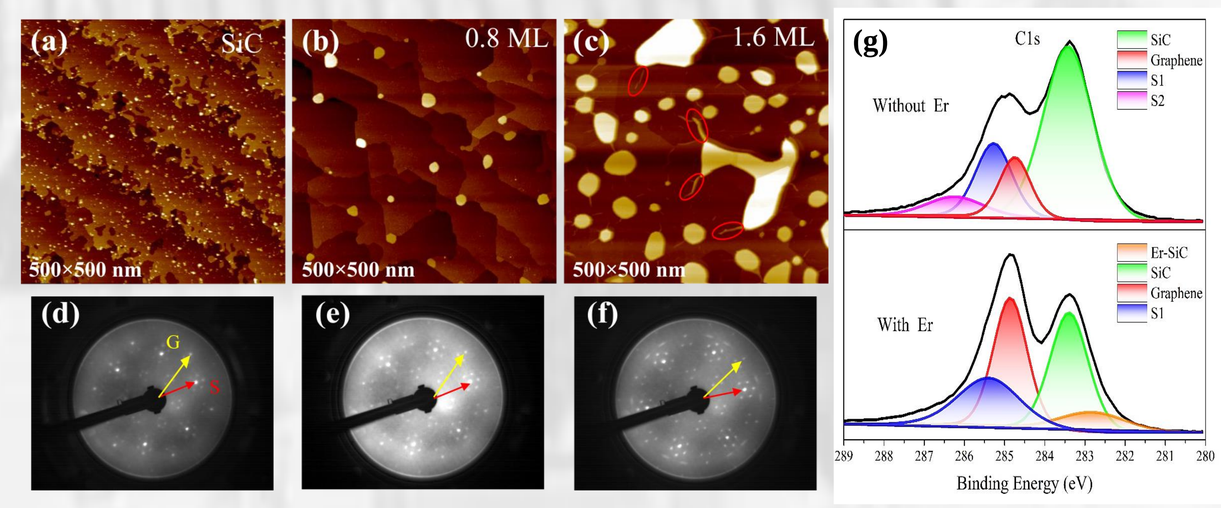
Formation of $ErSi_2$ island



(a) STM images of SiC(0001) surface with 0.8ML Er postannealed at 1300℃ for 10min; (c) show the images at atomic resolution obtained on the top surface of the nano island in (b) ; (b) Schematics of $ErSi_2$ island formation, ① and ② are the two states of the $ErSi_2$ island on the EG/SiC substrate respectively.

The Er pre-deposited on the SiC surface will form AlB_2-type $ErSi_2$ island with hexagonal symmetry after annealed.

Effect of Er on SiC graphitization and chemical bond

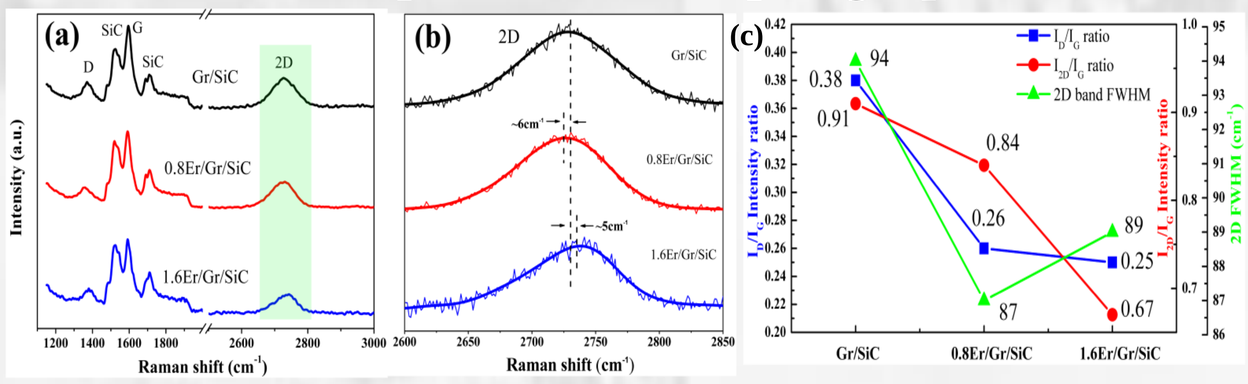


(a) STM image of EG/SiC, and morphology of $ErSi_2$ islands grown on EG/SiC substrate with (b) 0.8ML and (c) 1.6ML Er deposition. (d)-(f) LEED patterns of (a)-(c) samples respectively; (g) XPS C1s spectra of samples with Er and without Er.

⟶ Er concentration ↑ SiC graphitization degree ↑

⟶ Er-Si bond formation and surface band bending

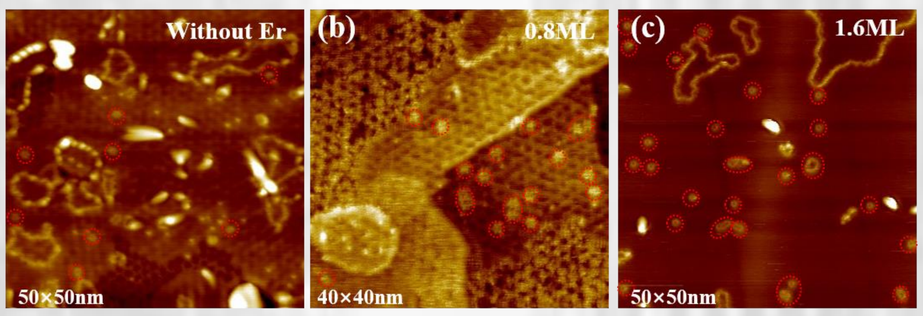
Raman spectra of Er-doped graphene



(a) Raman spectra of EGs, 0.8ML and 1.6ML Er-doped graphene grown on SiC; (b) the enlarged part of the 2D-band region of (a); (c) the blue square, green triangle and red circle represent for I_D/I_G, I_{2D}/I_G and the 2D band FWHM, respectively.

With the increase of Er deposition, the doping and strain effect of graphene are enhanced, and the quality of graphene is continuously improved.

Induction of flower defects



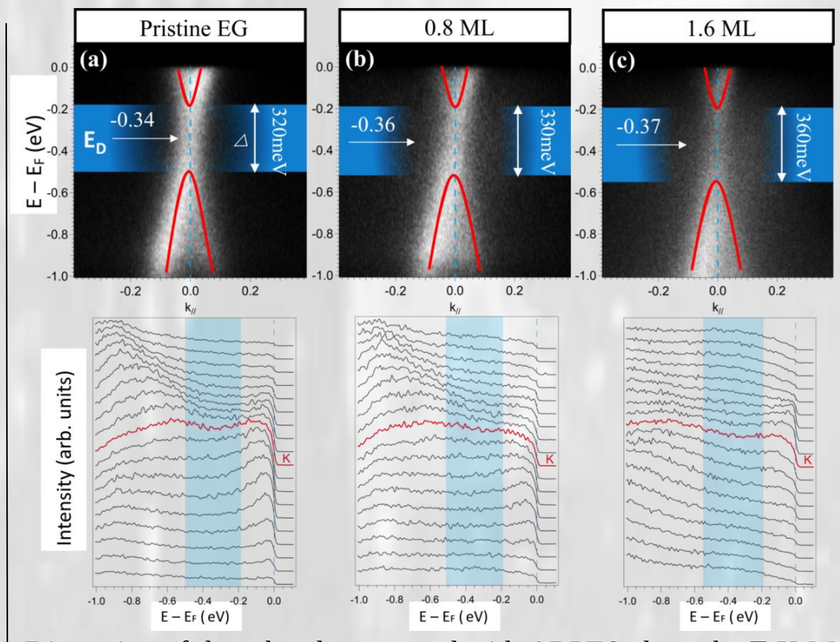
0.28×10^{12} cm^{-2} 1.22×10^{12} cm^{-2} 1.52×10^{12} cm^{-2}

STM images of the distribution of flower defects in graphene at different Er concentrations: (a) 0ML, (b) 0.8ML and (c) 1.6ML.

Er atoms existing on SiC can change the quantity of flower defect in graphene, providing a method for preparing high density flower defects, the mechanism of which awaiting for more research to explore.

Doping type and band gap modulation

- Enhanced n-doping behavior with electron transfer from Er to EG layer;
- Band gap open, △E from 320meV to 360meV;
- Enhanced interaction between graphene and SiC substrate.



Dispersion of the π bands measured with ARPES along the Γ-K-M direction of the graphene Brillouin zone for EG on SiC(0001) surface around the K-point of (a) clean EG, and Er doped EG with increasing Er coverage; (b) 0.8ML, (c) 1.6ML.

Conclusion

- Er forms $ErSi_2$ after post annealed on SiC, flower defect density and SiC graphitization degree increase with Er concentration.
- Doping and strain effect of graphene are enhanced due to Er deposition.
- The graphene band gap opens about 40 meV, and its width is related to Er concentration. Surface charge is modified in the interfacial region due to Er-Si bond formation.

References:

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