High Quality Graphene Formation on Improved 3C-SiC Epilayer

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With its excellent electronic, mechanical, photonic properties and 2D nature, graphene is believed to be able to push the semiconductor industry into the beyond-CMOS era. Among all the synthesis methods, the Graphene-On-Silicon (GOS) technology is attractive thanks to its low production cost, high scalability, and easiness for NEMS elaboration. More specifically, this graphene is formed by thermally decomposing thin 3C-SiC epilayer grown on Si substrate. However, the graphene formed from the GOS suffers from mediocre quality. Aiming at the betterment of this process, we investigate the influence of the SiC layer quality on graphene. In this study, we compare graphene growth on SiC epilayers grown by different epitaxial growth techniques (MBE&CVD). The properties of the SiC films are characterized before graphitization using XRD, AFM, SEM and LEED to reveal the difference in the film quality. Then we apply the same graphitization process to both layers and confirm the formation of graphene using LEED. The graphene quality is measured by the intensity ratio between D band and G band (I_d/I_g) of the Raman spectrum. As a result, we have found out that the morphology of the SiC surface plays a crucial role in the graphene formation. And we have obtained a much higher graphene quality using CMP treated SiC epilayer. Additionally, the cooling speed after graphitization is also studied and proven to influence the graphene quality.

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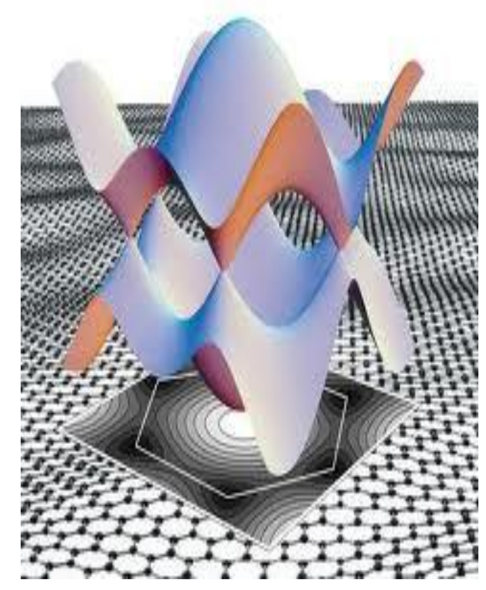
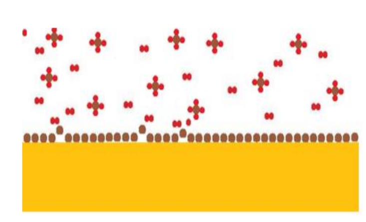
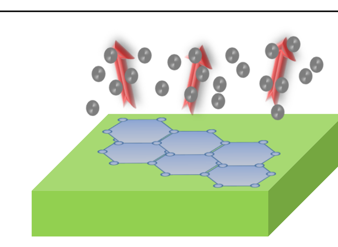
I. Introduction

I.1 What is Graphene?

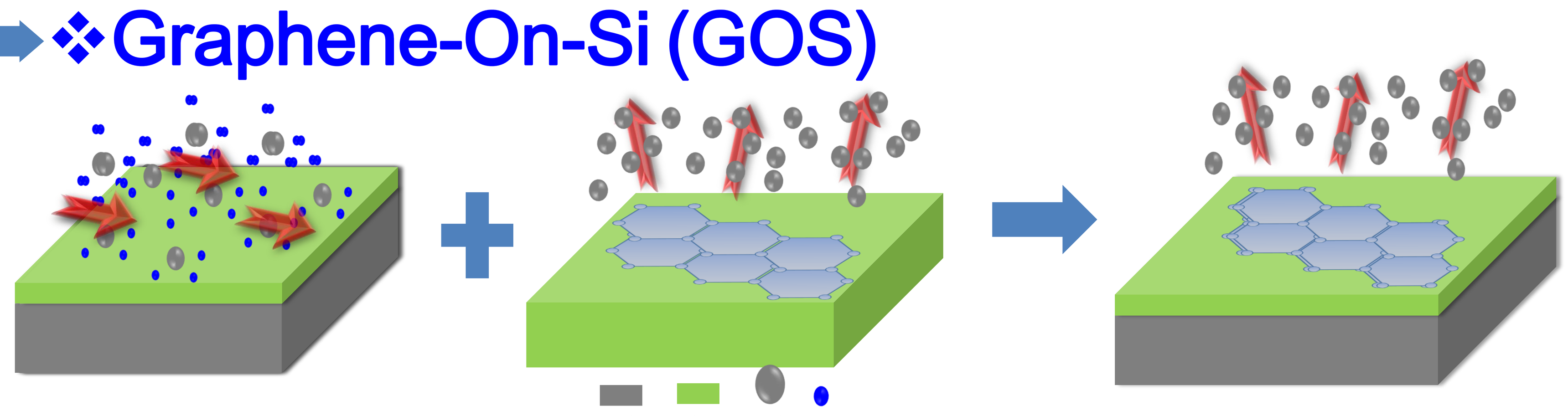


- Atomically thick layer of *sp*² bonded carbon atoms arranged in a honeycomb lattice
- Excellent electronic, mechanical, and photonic properties
- Possible applications include beyond-CMOS technology, ultra fast FET, NEMS sensors, etc.

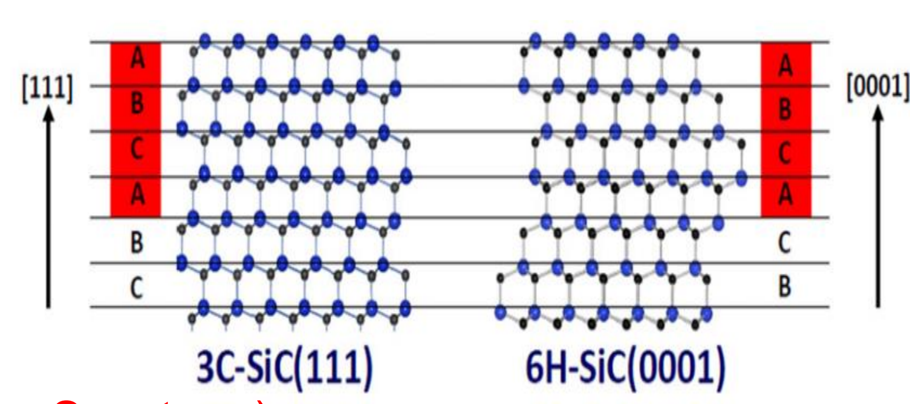
I.2 Methods

	Pros	Cons	Schematic
Exfoliation	•High Quality •Pristine	•Random production •Small flakes •Unable to mass produce	
Chemical Vapor Deposition	•Fairly high quality •Very large scale •Industrial production	•Complex process •Contamination •Expensive	
Epitaxial Growth (4H/6H-SiC)	•Fair Quality •Wafer scale production	•Cost of SiC •Poor availability of large scale production	

❖Graphene-On-Si (GOS)



GOS possible because of the similarity between 3C & 6H

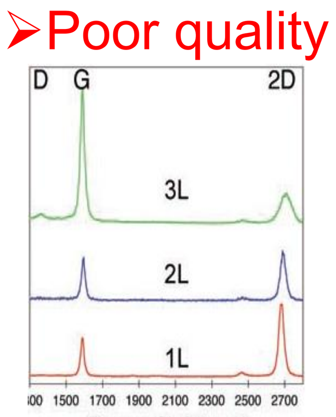


Advantages

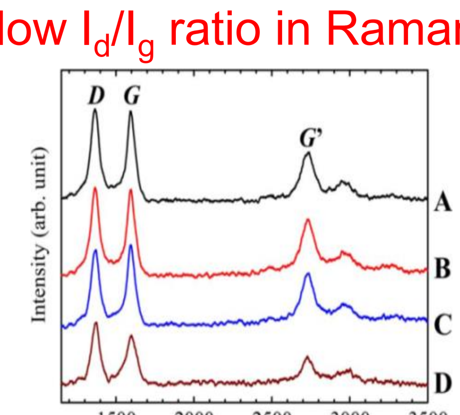
- Cheap, scalable
- Less step-bunching than bulk

Challenges

- Poor quality (low I_d/I_g ratio in Raman Spectrum)



Graphene on bulk SiC



Classic GOS

Why this difference?

1) Surface roughness
2) Low structural quality
3) Excessive Si out-diffusion

I.3 Goal

Form high quality graphene using SiC epilayer improved according to the aspects listed above

II. Experiments

Part 1: Comparison between classic sample with improved sample

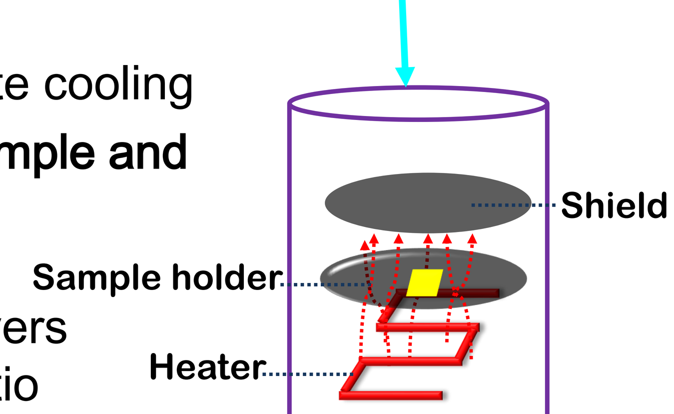
AFM – Surface morphology (atomic structure)
SEM – Electronic image of surface morphology
XRD – Crystalinity (orientation) structural quality

Part 2: Graphitization

Annealing: 1250°C, 60 minutes, 10^{-10} mbar, immediate cooling

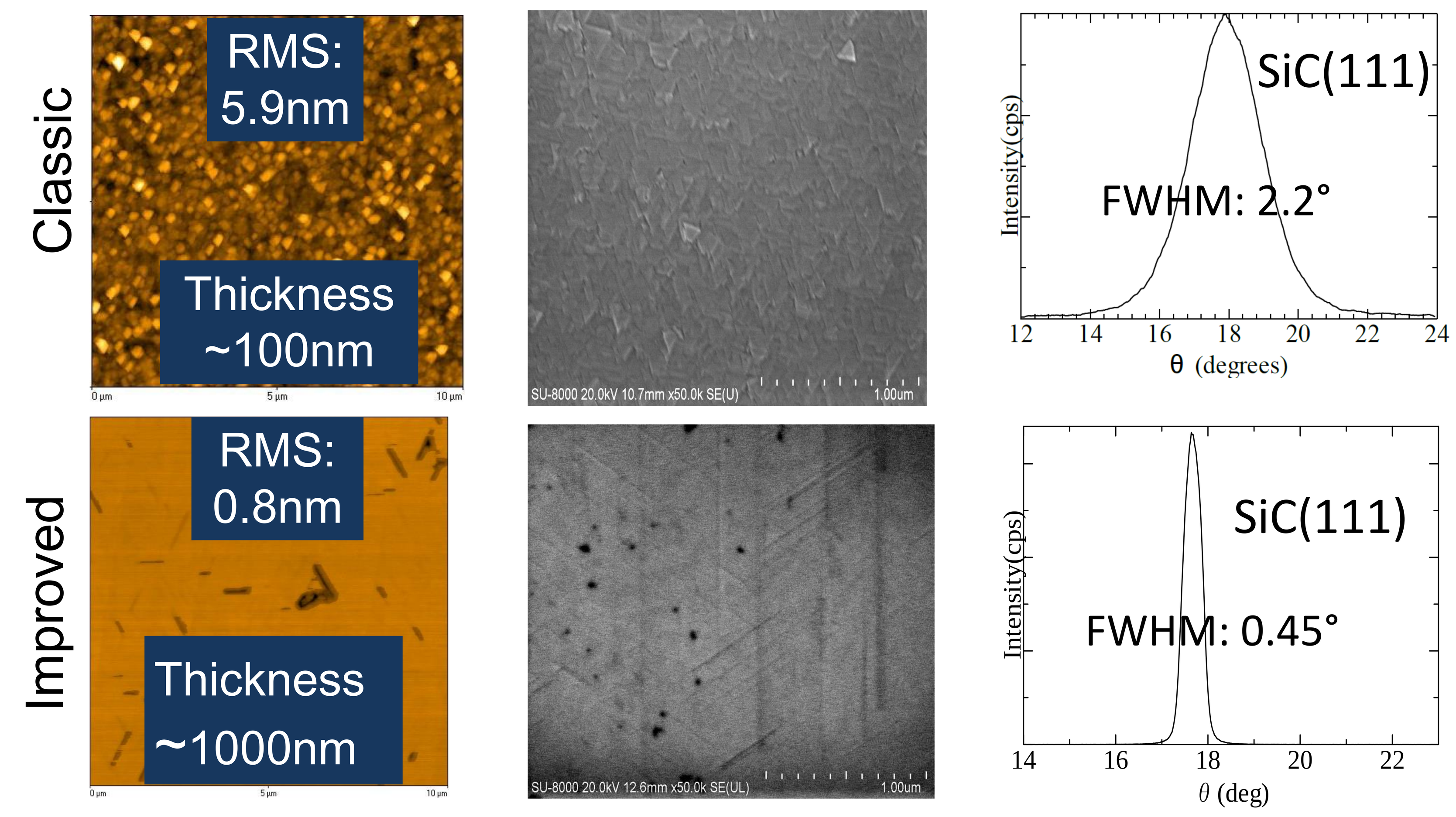
Part 3: Comparison between EG formed on classic sample and EG formed on new improved sample

LEED – Confirms graphene formation
XPS– Analyze surface chemistry & number of EG layers
Raman – Measure graphene quality using the I_d/I_g ratio

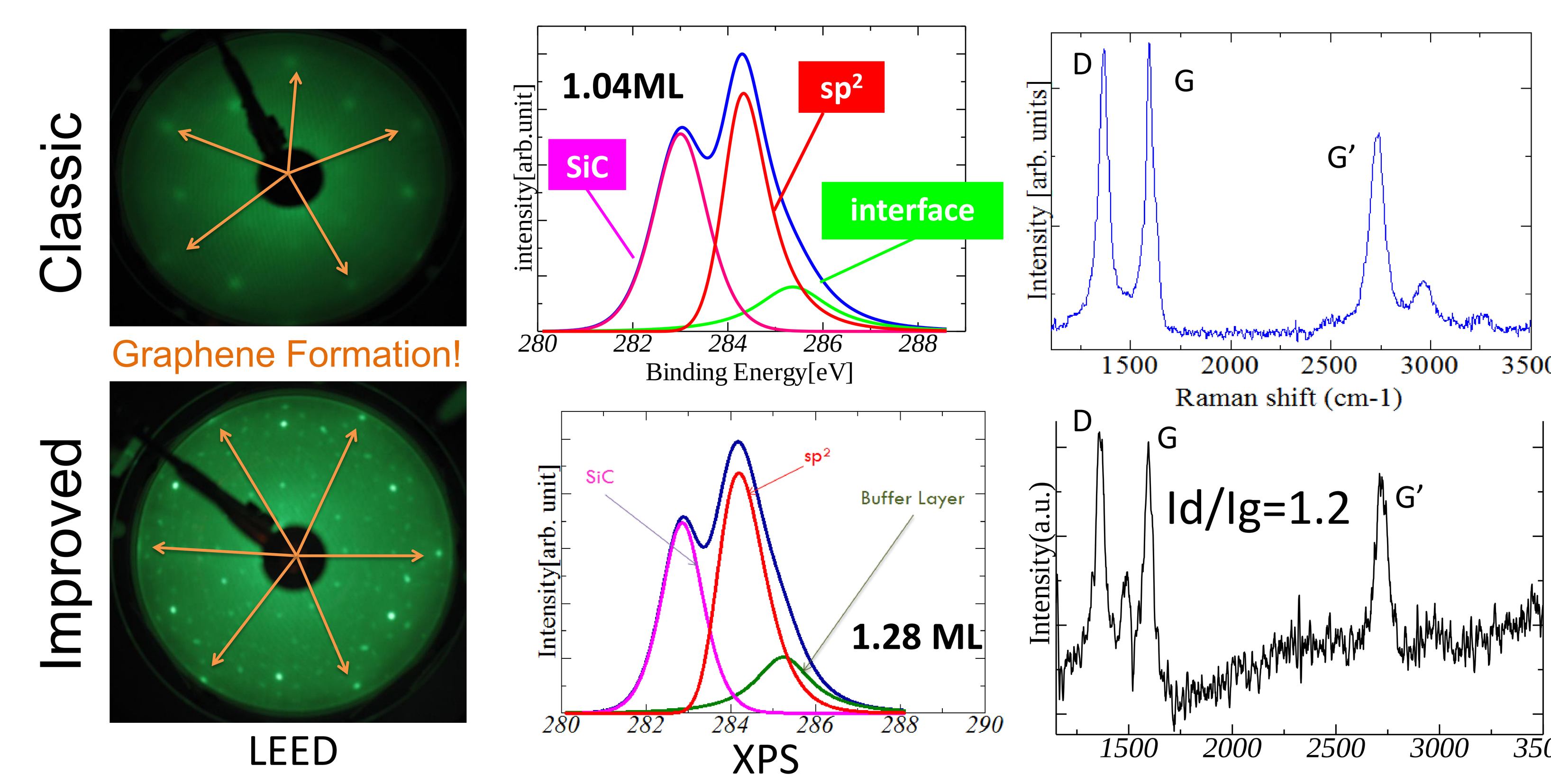


III. Results and Discussion

III.1 Pre-Graphitization



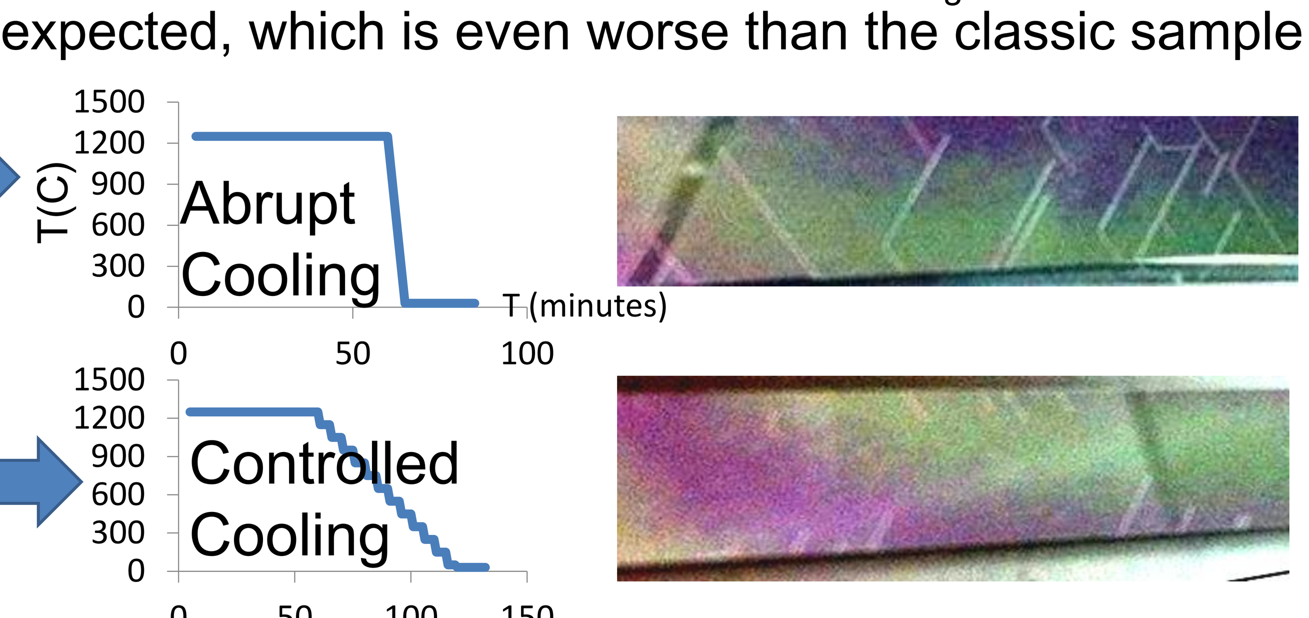
III.2 Post-Graphitization Characterization



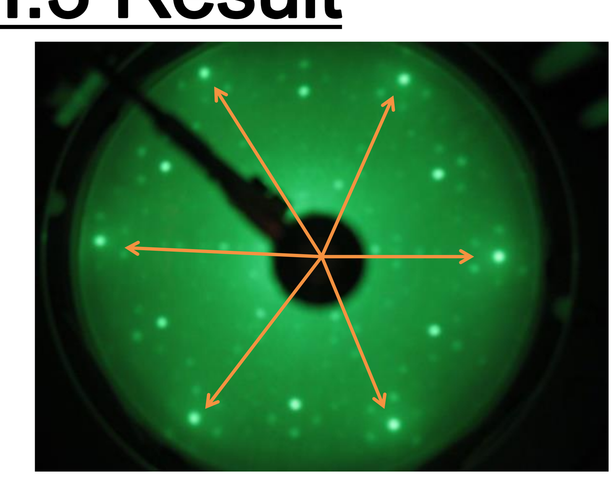
Although the film quality was improved, the I_d/I_g ratio did not turn out as expected, which is even worse than the classic sample

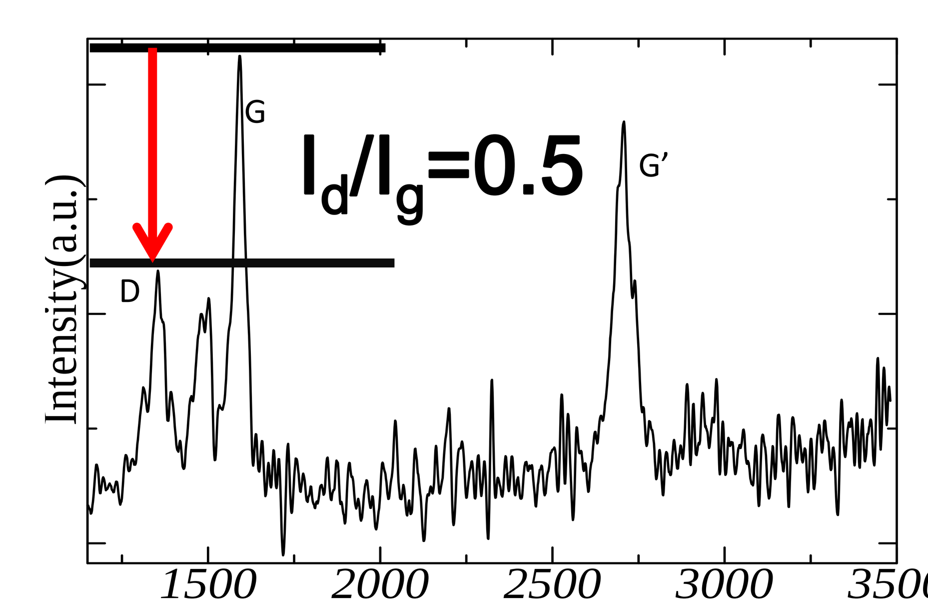
Why?

Solution



III.3 Result





IV. Conclusion

1) Thick SiC
   - Helps seal Si out diffusion
   - Low surface roughness
   - Good structural quality
   - Strain proportional to thickness
2) Strain relaxation (cracks) is most crucial to EG quality, and is directly related to the cooling parameters
3) Upgraded GOS quality is achieved with improved SiC epilayer and the specified cooling process, leading to a 50% reduction in the I_d/I_g ratio!

Acknowledgements

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