chem2Dmat
August 31 - September 03, 2021 • Bologna, Italy
European Conference on Chemistry of Two-Dimensional Materials

Rb-functionalized epitaxial graphene on SiC(0001)

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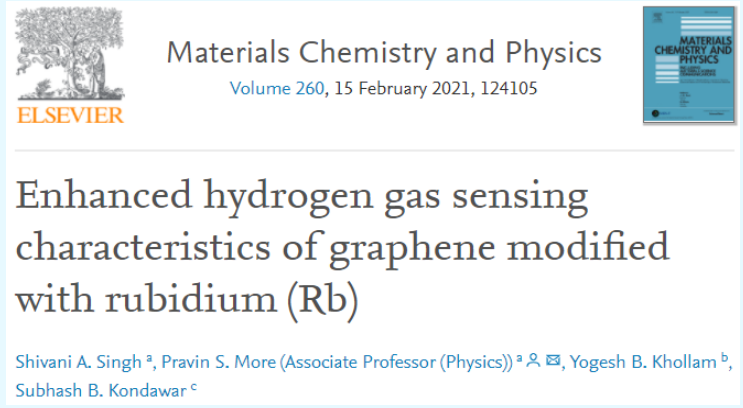
NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy

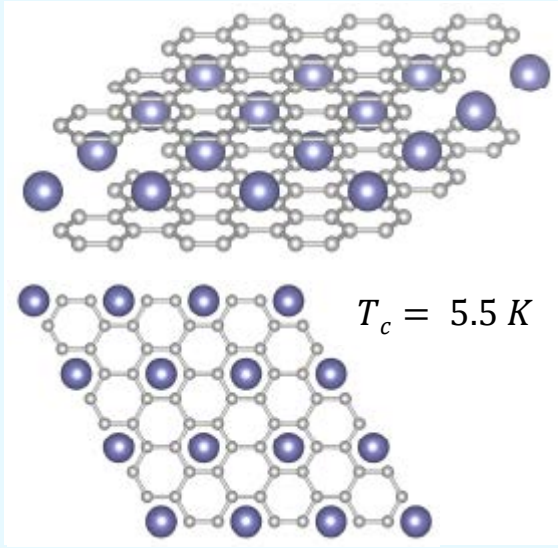
Rb on Graphene - Motivation

Gas Sensing



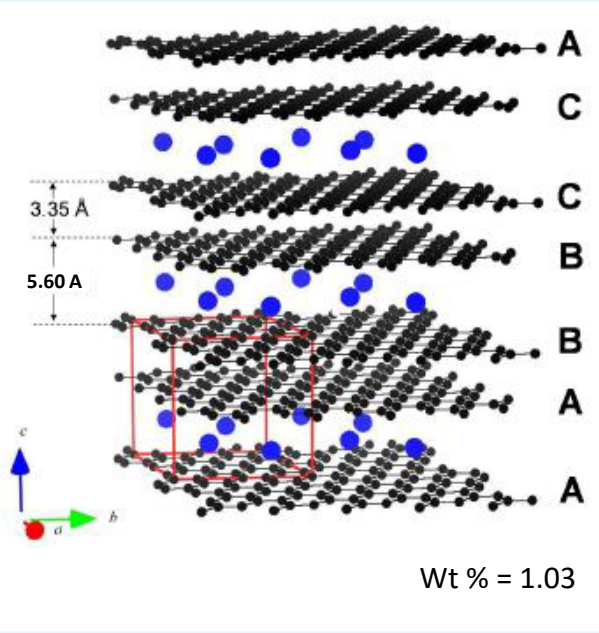
Singh et al.,
Mat. Chem. Phys. 260 (2021) 124105

Superconductivity



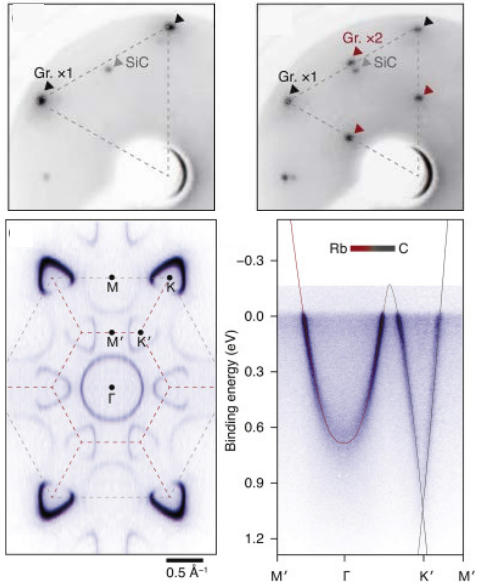
Durajski et al.,
Phys. Chem. Chem. Phys. 21 (2019) 5925-5931

Hydrogen Storage

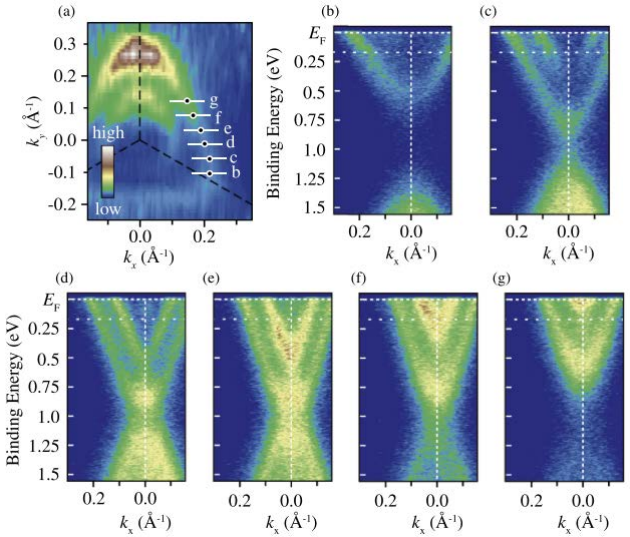


Ahn and Purewal,
Int. J. Hydrog. Energy 39 (2014)

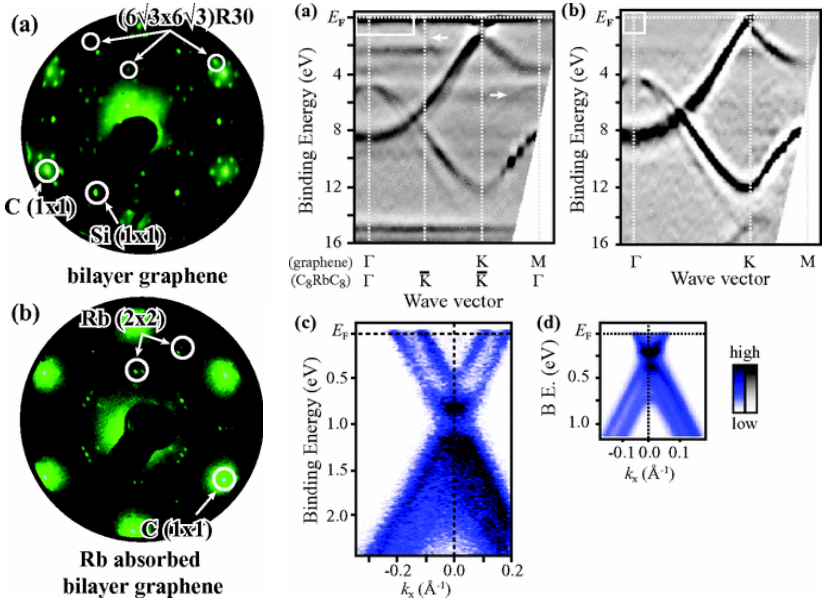
Rb-intercalation



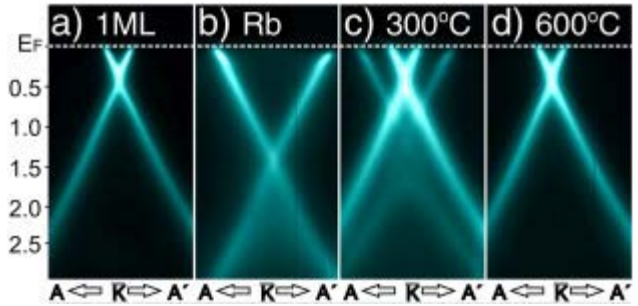
Shin et al.,
Curr. Appl. Phys. 20 (2020) 484-488



Kleeman et al.,
J. Phys. Soc. Jpn. 83 (2014) 124715

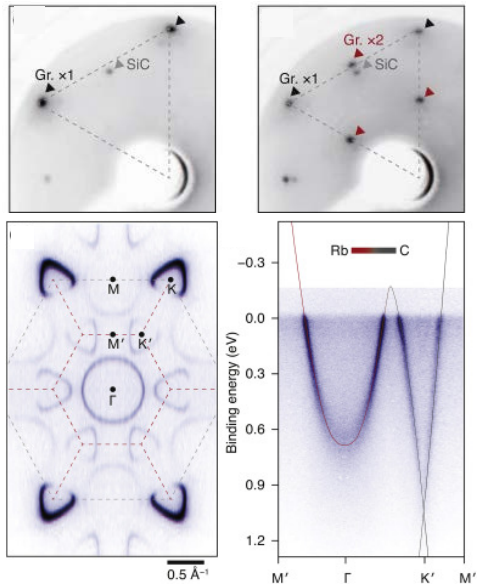


Kleeman et al.,
Phys. Rev. B 87 (2013) 195401

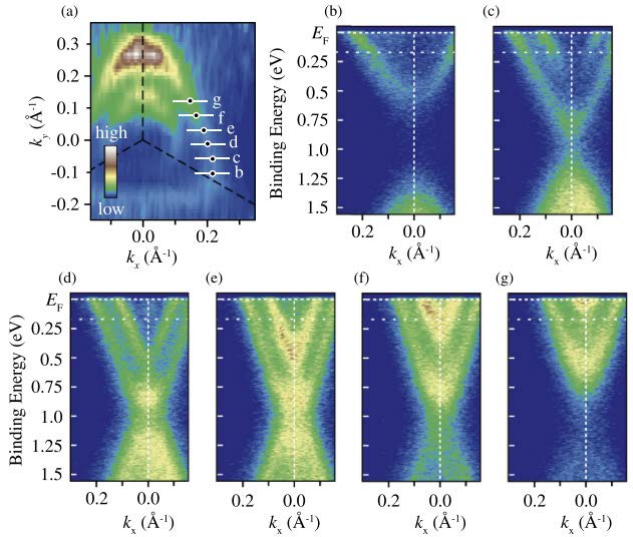


Watcharinyanon et al.,
Surf. Sci. 605 (2011) 1918-1922

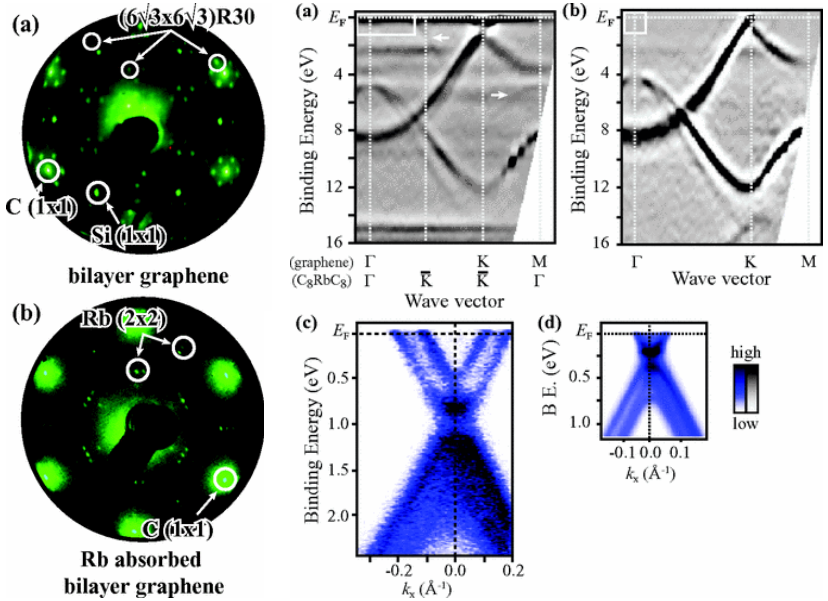
Rb-intercalation



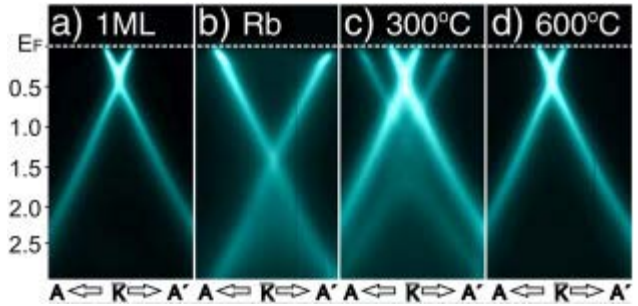
Shin et al.,
Curr. Appl. Phys. 20 (2020) 484-488



Kleeman et al.,
J. Phys. Soc. Jpn. 83 (2014) 124715



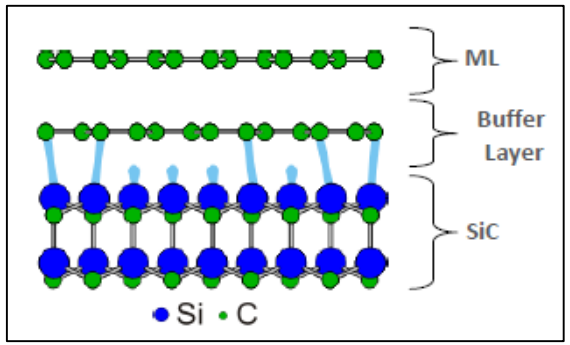
Kleeman et al.,
Phys. Rev. B 87 (2013) 195401



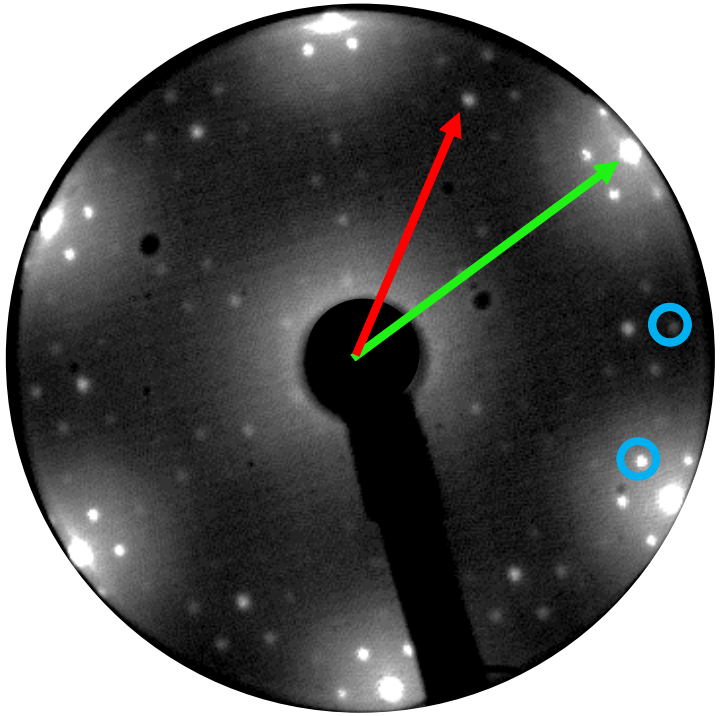
Watcharinyanon et al.,
Surf. Sci. 605 (2011) 1918-1922

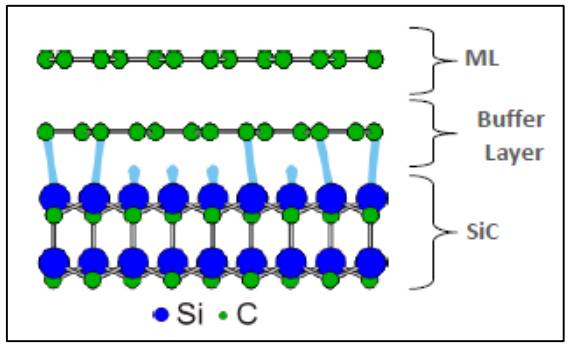
Only LEED, PES
No microscopy studies

Epitaxial Graphene on SiC(0001)



Epitaxial Graphene on SiC(0001)





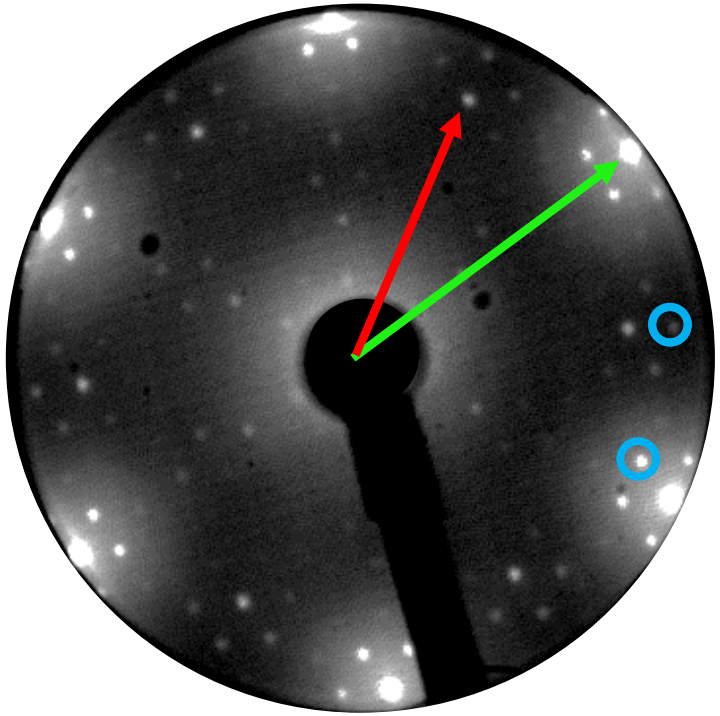
Graphene

SiC

Moirè $(6\sqrt{3})$

LEED

Epitaxial Graphene on SiC(0001)

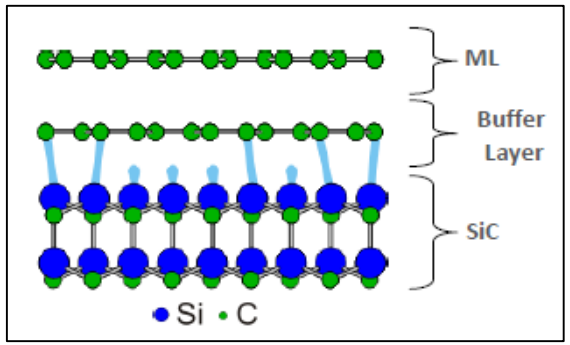


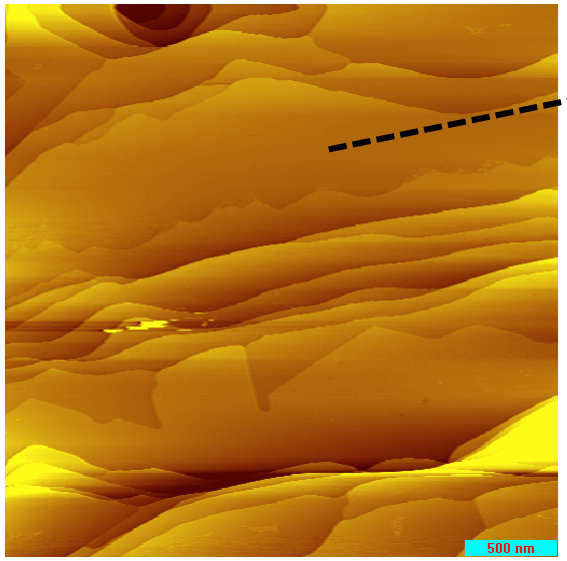
Graphene

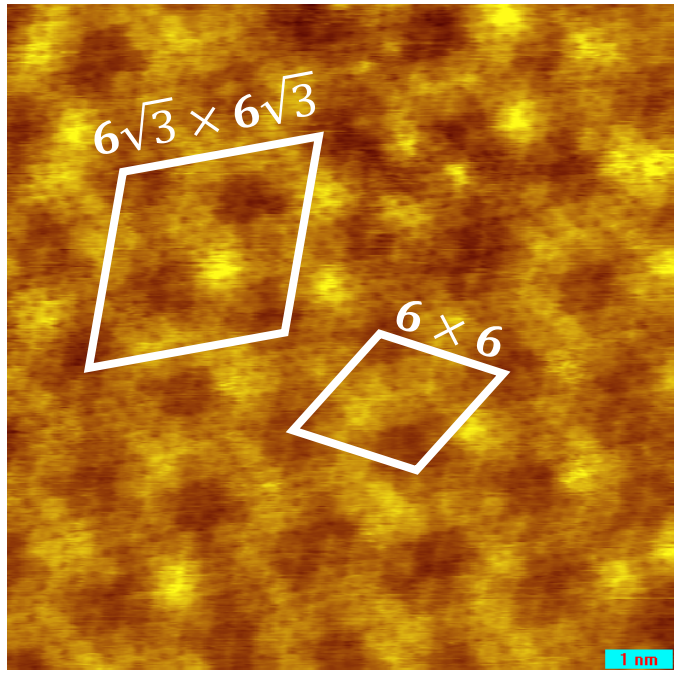
SiC

Moirè $(6\sqrt{3})$

LEED





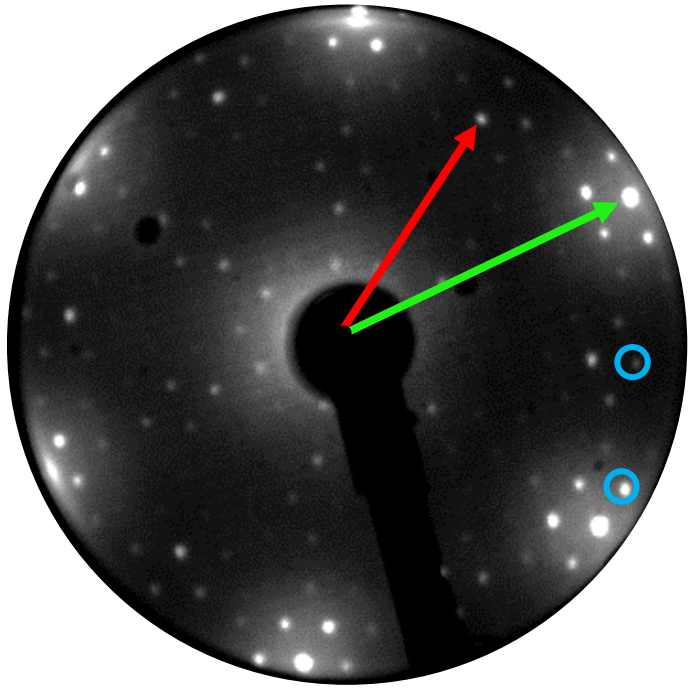


STM

Rubidium on EG/SiC(0001)

LEED

Graphene SiC Moirè ($6\sqrt{3}$)



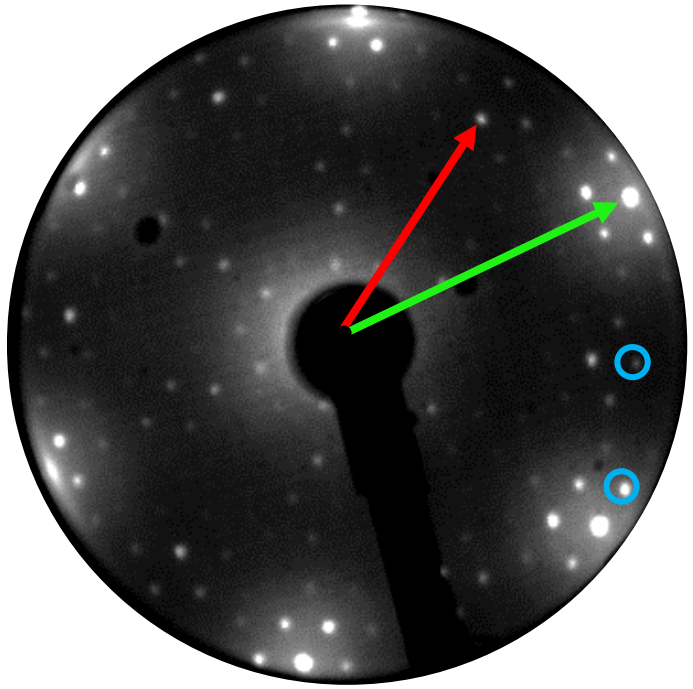
0 min Rb

$6\sqrt{3} \times 6\sqrt{3}\ R30°$

Rubidium on EG/SiC(0001)

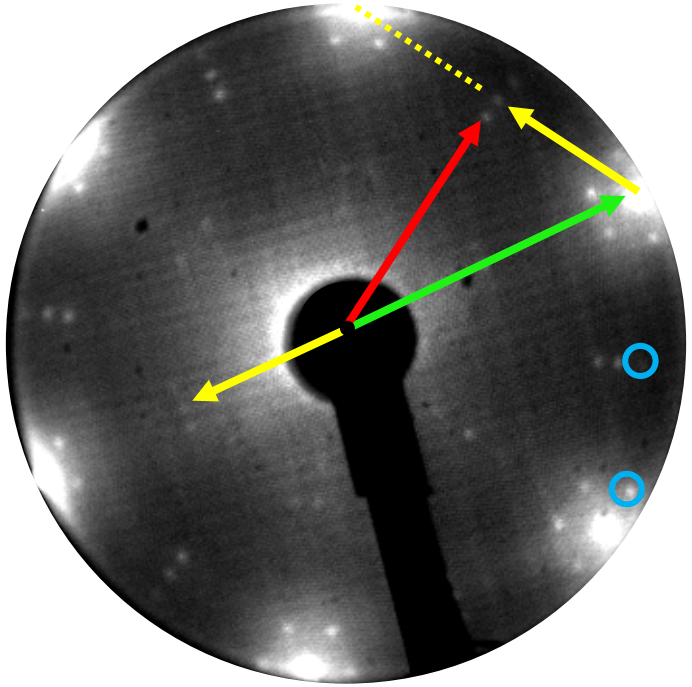
LEED

Graphene SiC Moirè ($6\sqrt{3}$) Rb(2×2)



0 min Rb

$6\sqrt{3} \times 6\sqrt{3}\ R30°$



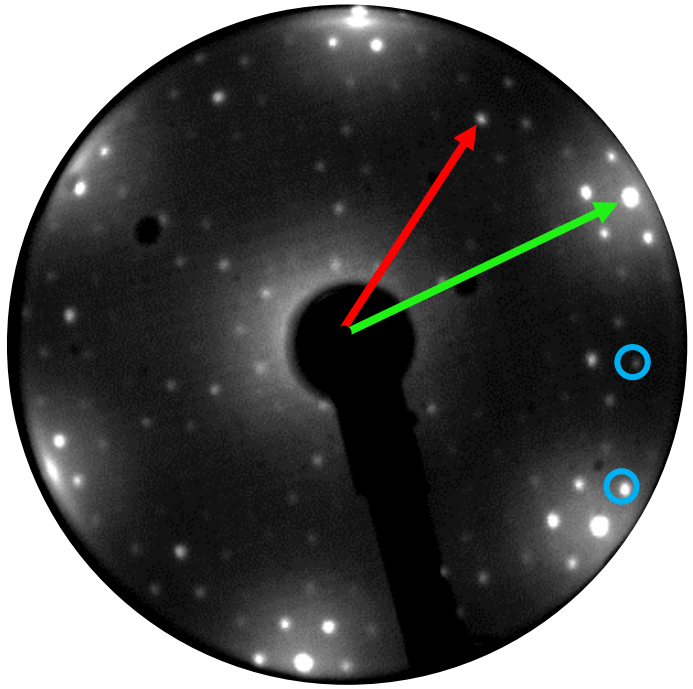
1 min Rb

Rb(2×2)

Rubidium on EG/SiC(0001)

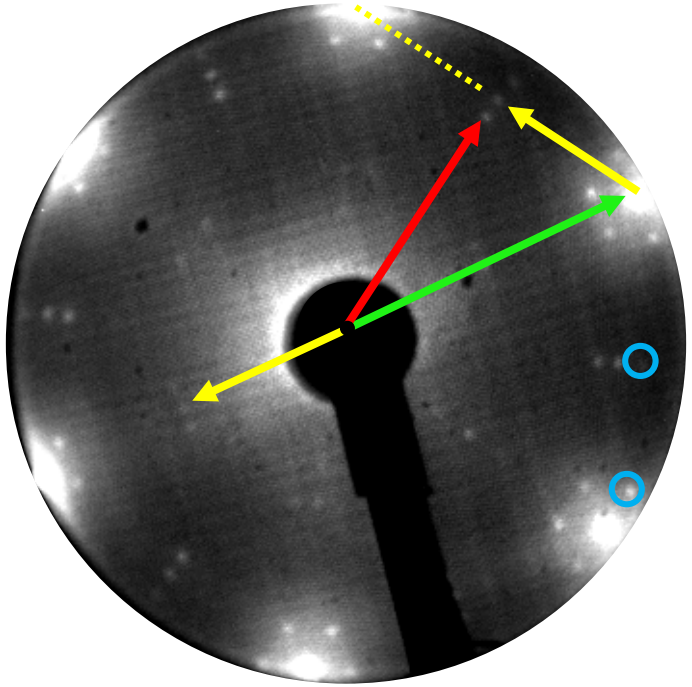
LEED

Graphene SiC Moirè ($6\sqrt{3}$) Rb(2×2)



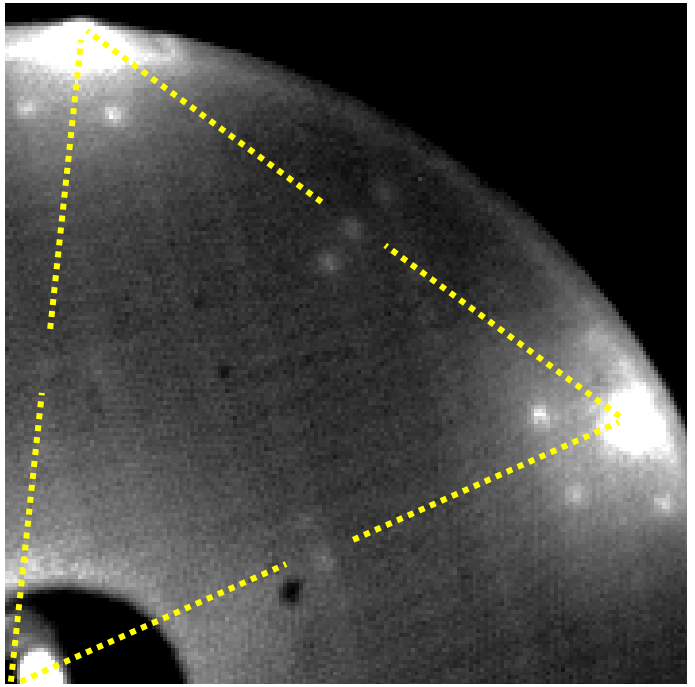
0 min Rb

$6\sqrt{3} \times 6\sqrt{3}\ R30°$



1 min Rb

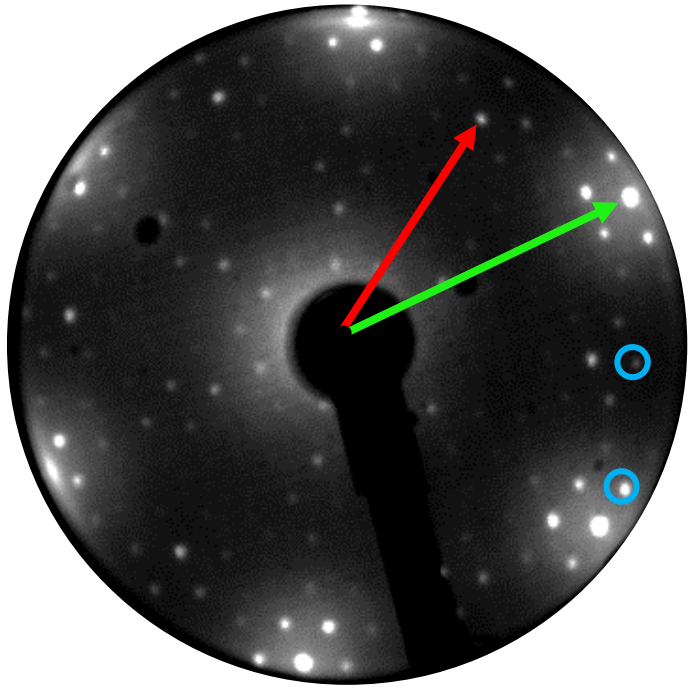
Rb(2×2)



Rubidium on EG/SiC(0001)

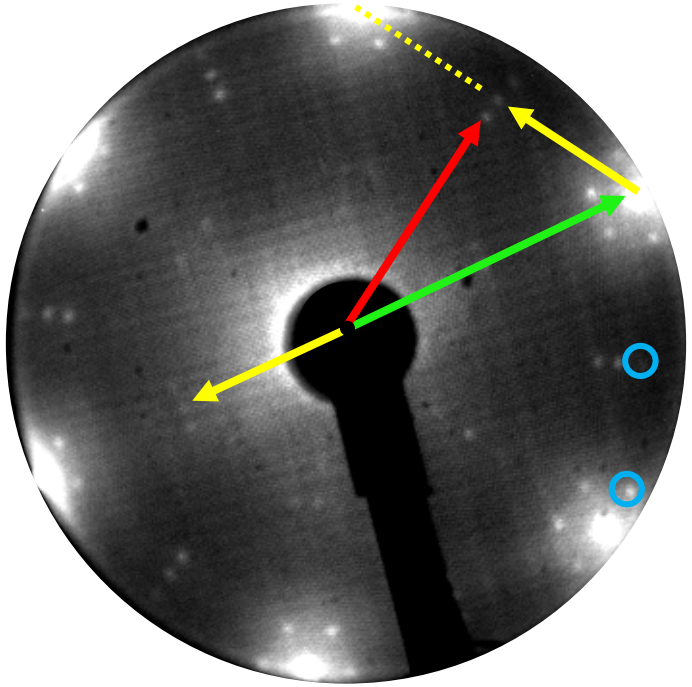
LEED

Graphene SiC Moirè $(6\sqrt{3})$ Rb(2×2) Rb$(\sqrt{3} \times \sqrt{3})R30°$



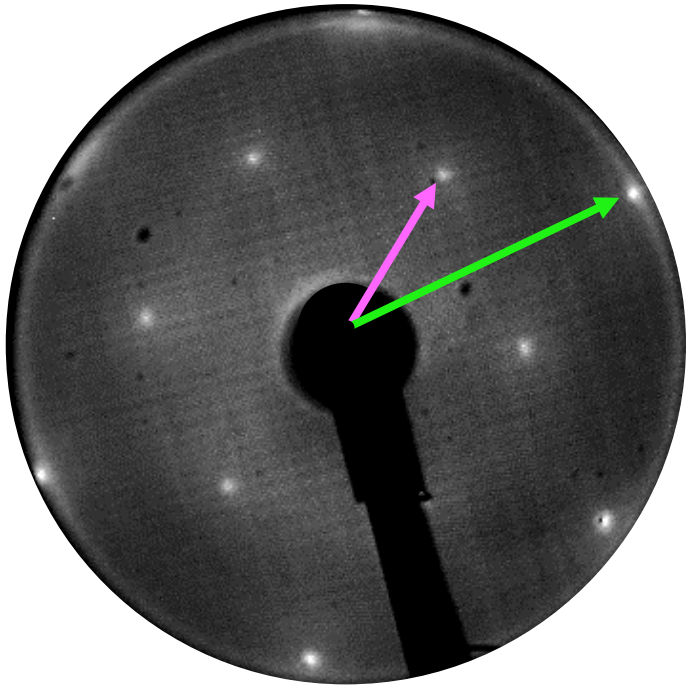
0 min Rb

$6\sqrt{3} \times 6\sqrt{3}\ R30°$



1 min Rb

Rb(2×2)



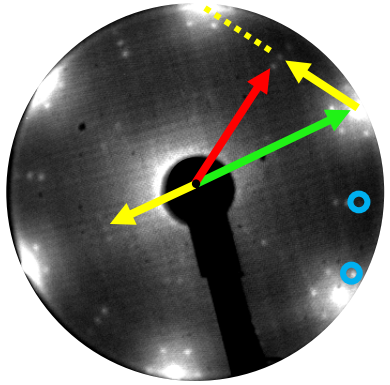
3 min Rb

Rb$(\sqrt{3} \times \sqrt{3})R30°$

Rubidium on EG/SiC(0001)

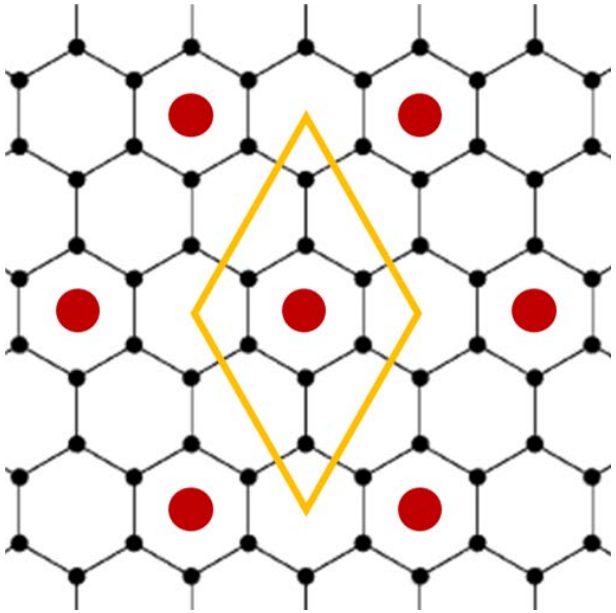
LEED

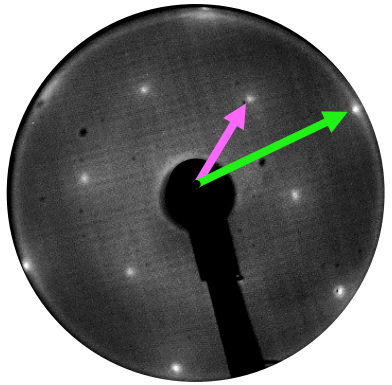
Graphene SiC Moirè $(6\sqrt{3})$ Rb(2×2) Rb$(\sqrt{3} \times \sqrt{3})R30°$



1 min Rb
Rb(2×2)

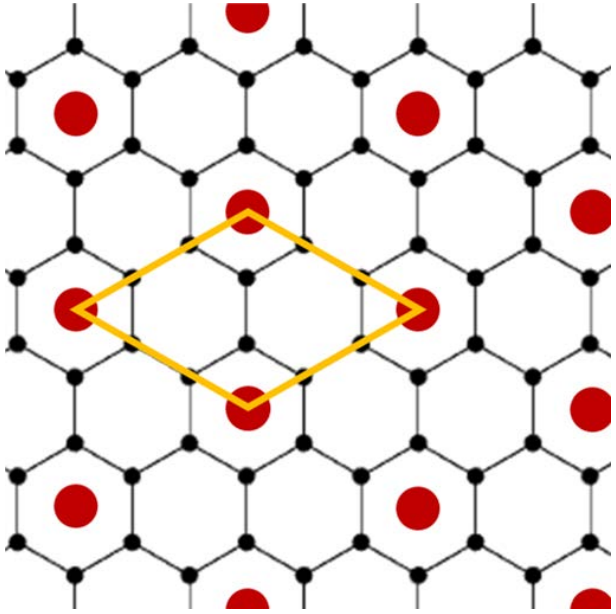
Rb coverage 1/4 ML
(0.25 ML)





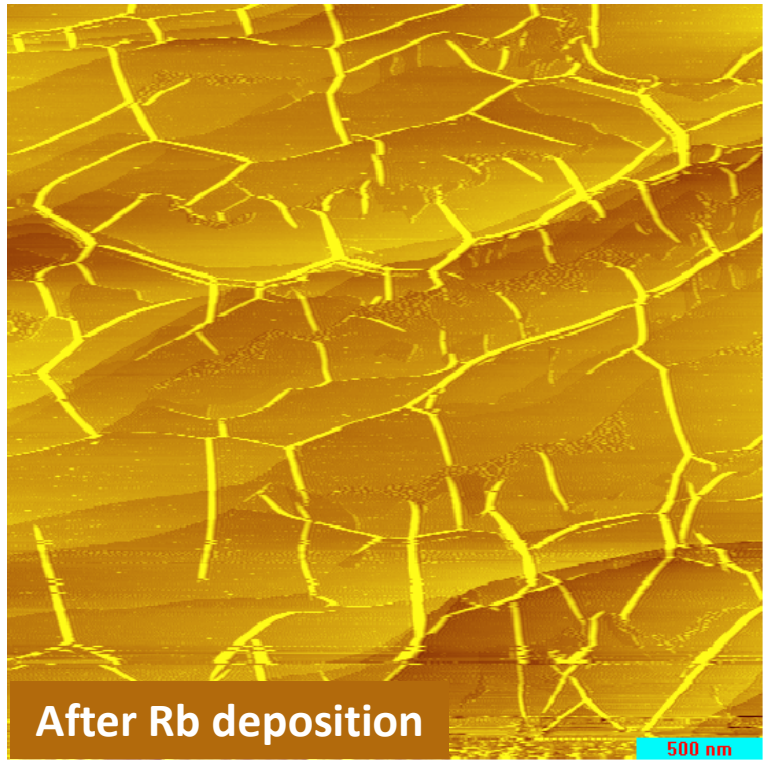
3 min Rb
Rb$(\sqrt{3} \times \sqrt{3})R30°$

Rb coverage 1/3 ML
(0.33 ML)



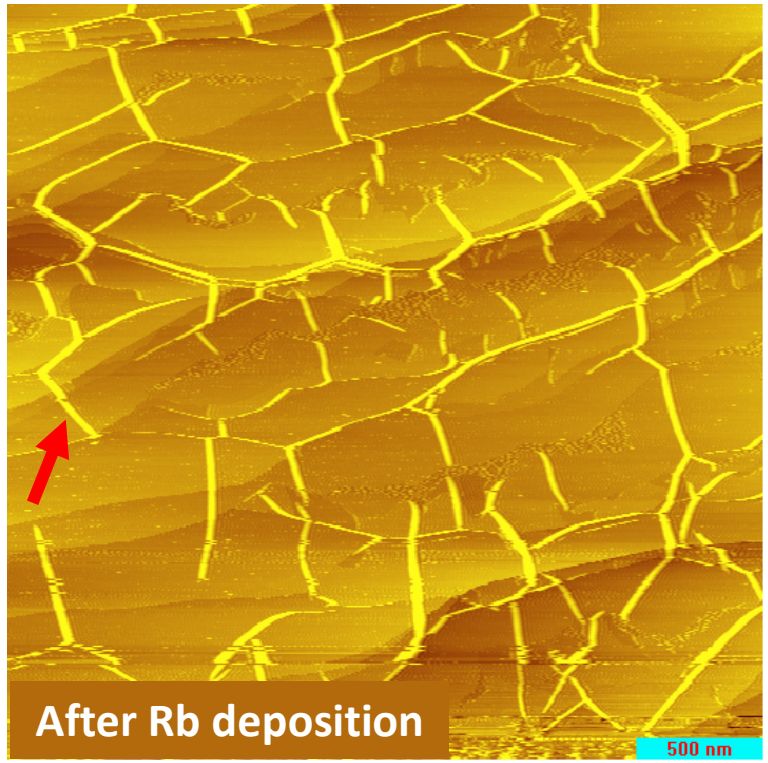
Rubidium on EG/SiC(0001)

Step-terrace morphology still well recognizable



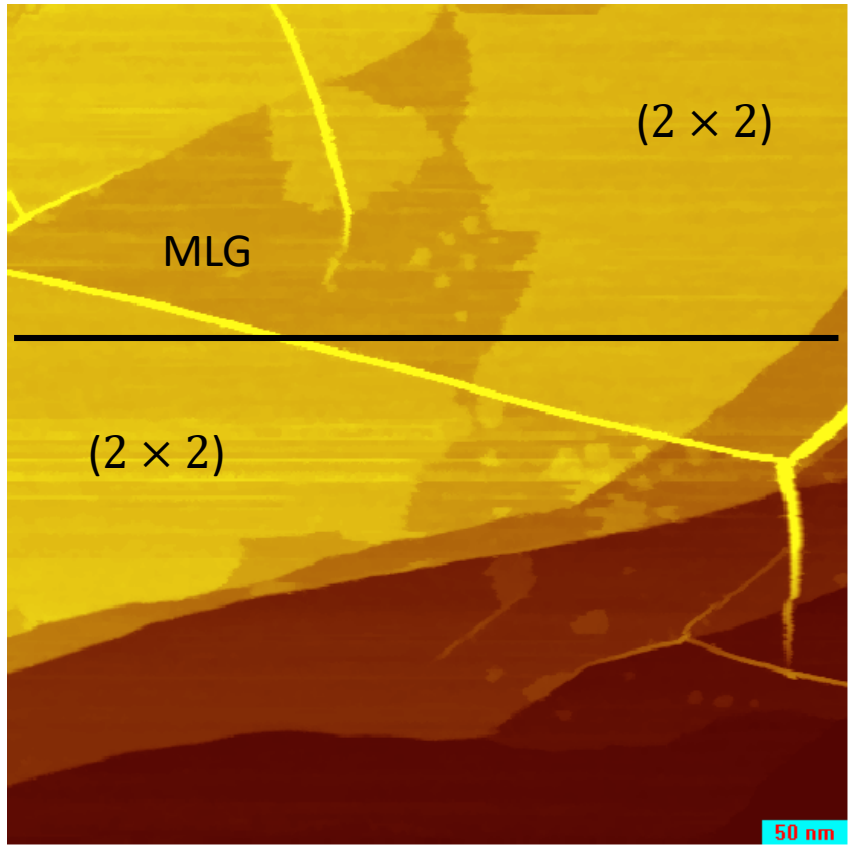
Rubidium on EG/SiC(0001)

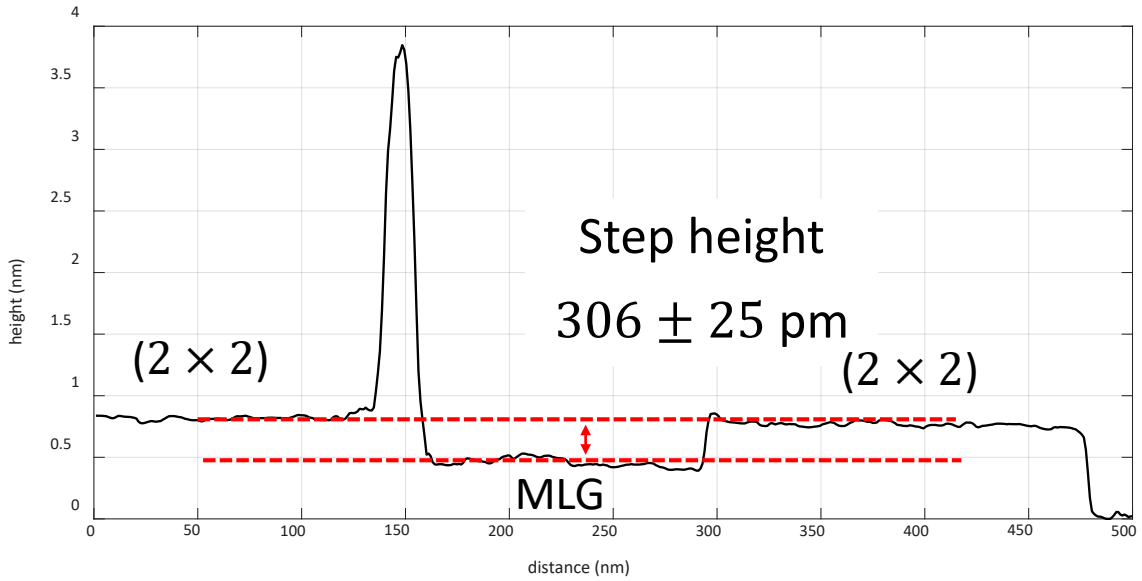
One-dimensional lines a few nm high form (red arrow)



Rubidium on EG/SiC(0001)

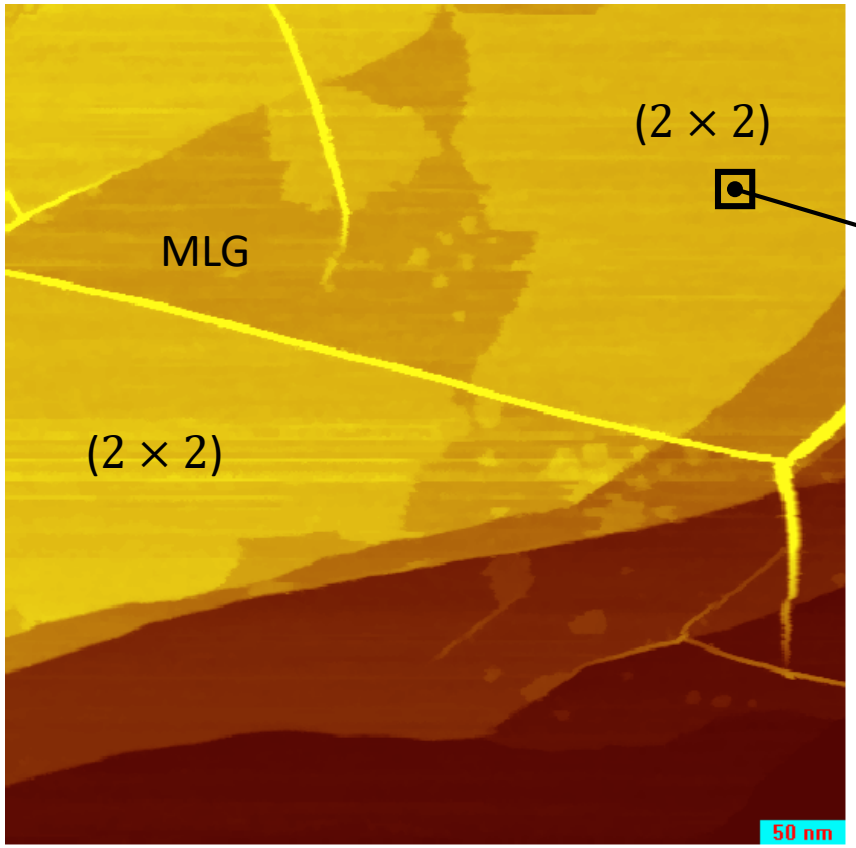
1 min Rb deposition (2×2)

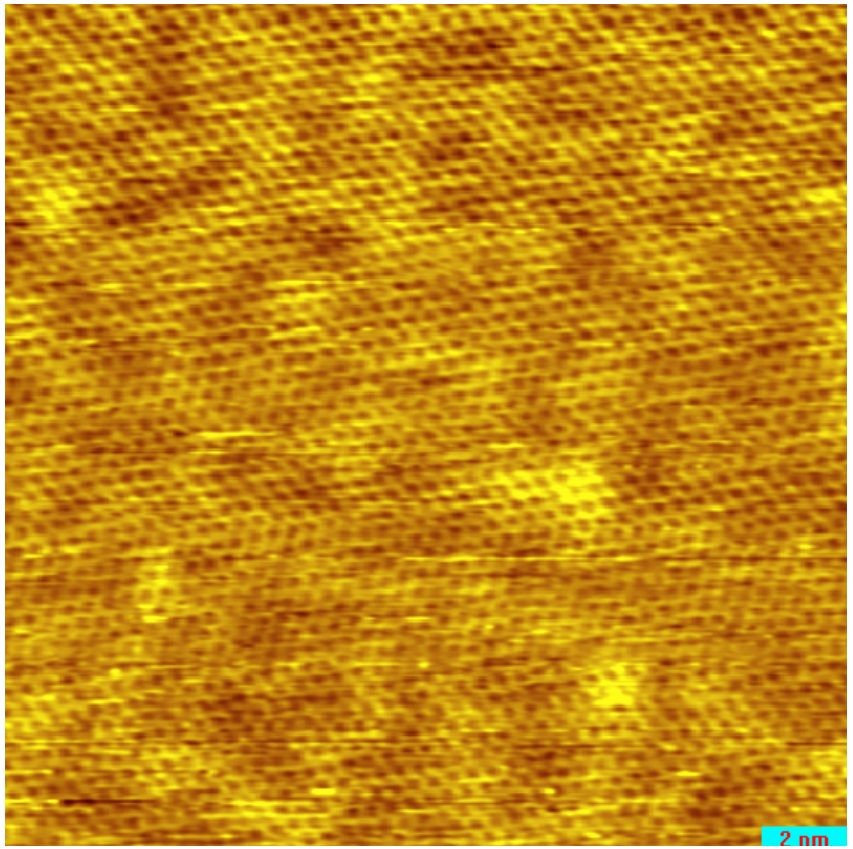




Rubidium on EG/SiC(0001)

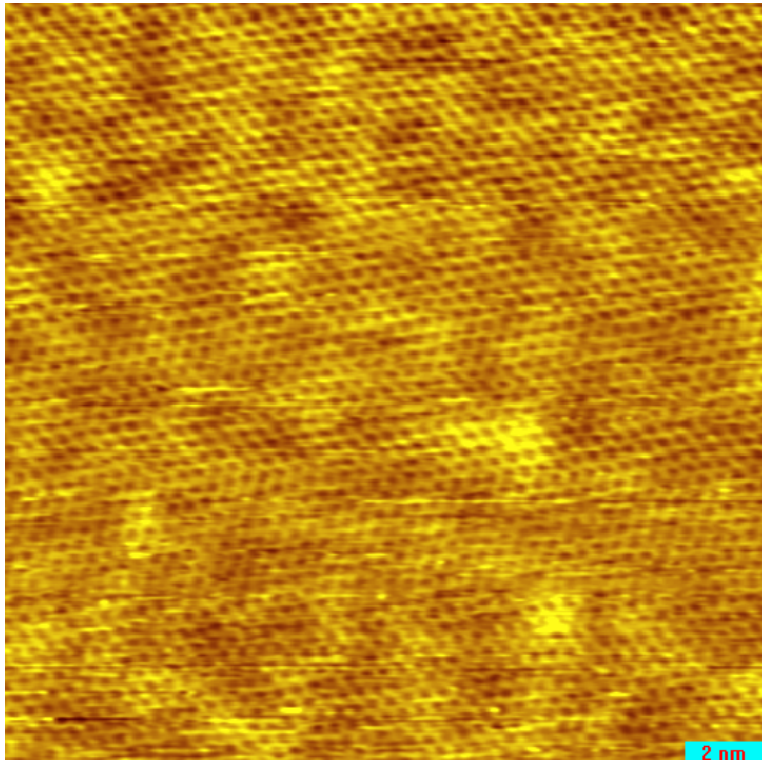
1 min Rb deposition (2×2)

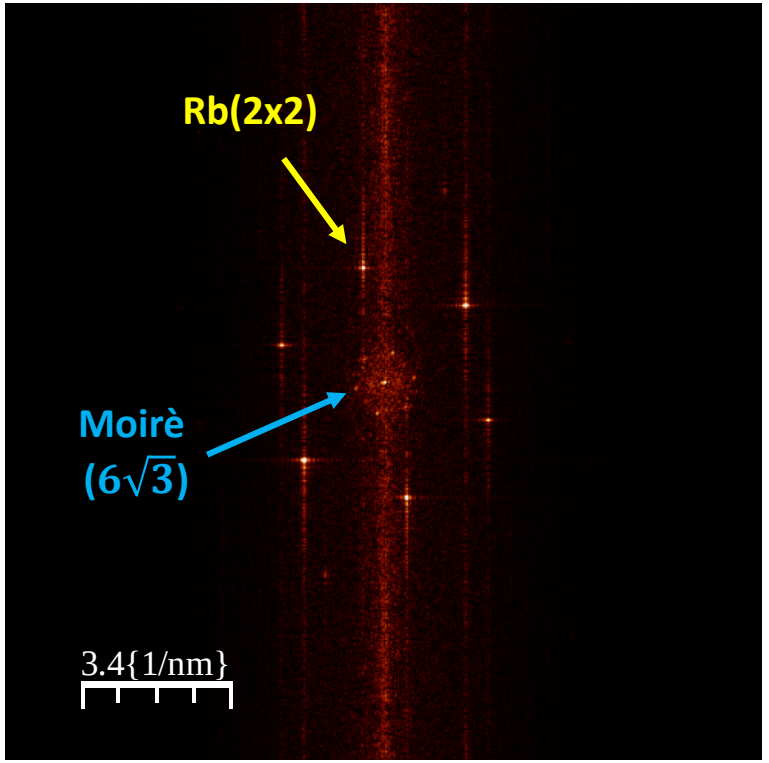




Rubidium on EG/SiC(0001)

1 min Rb deposition (2×2)

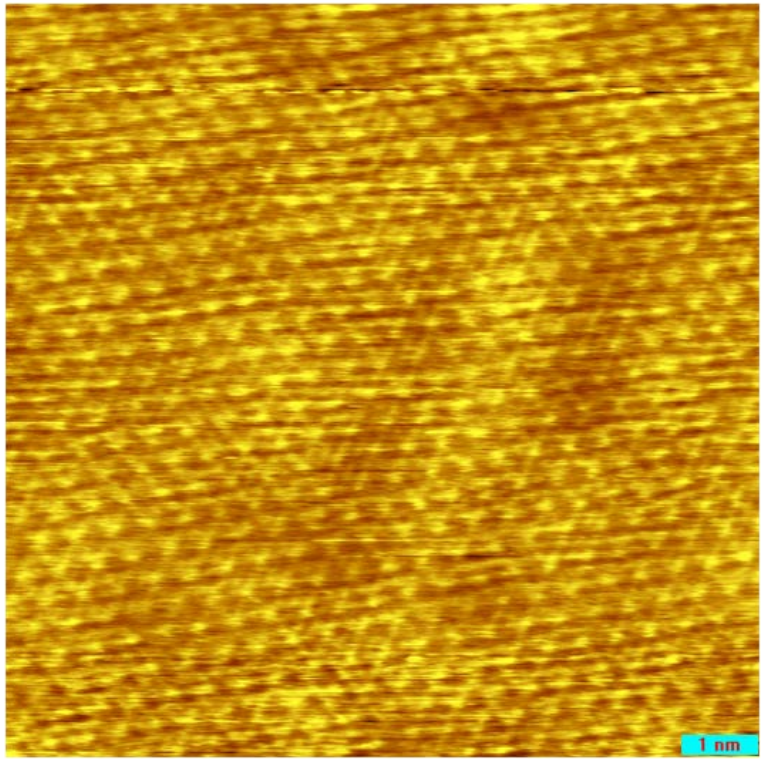


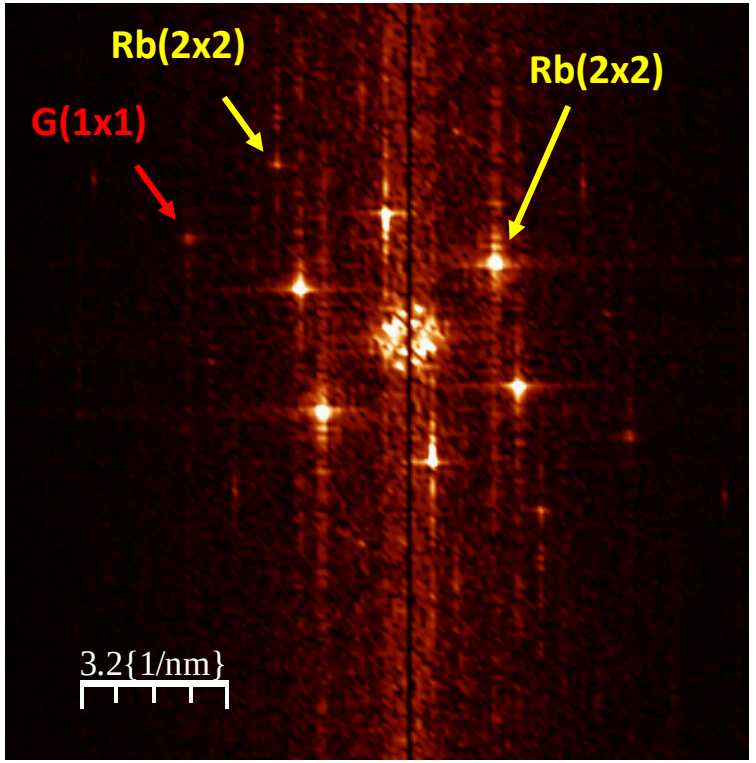


Moirè $(6\sqrt{3})$ is faintly visible and only in larger size STM images while the (2×2) superstructure is clearly distinguishable.

Rubidium on EG/SiC(0001)

1 min Rb deposition (2 × 2)

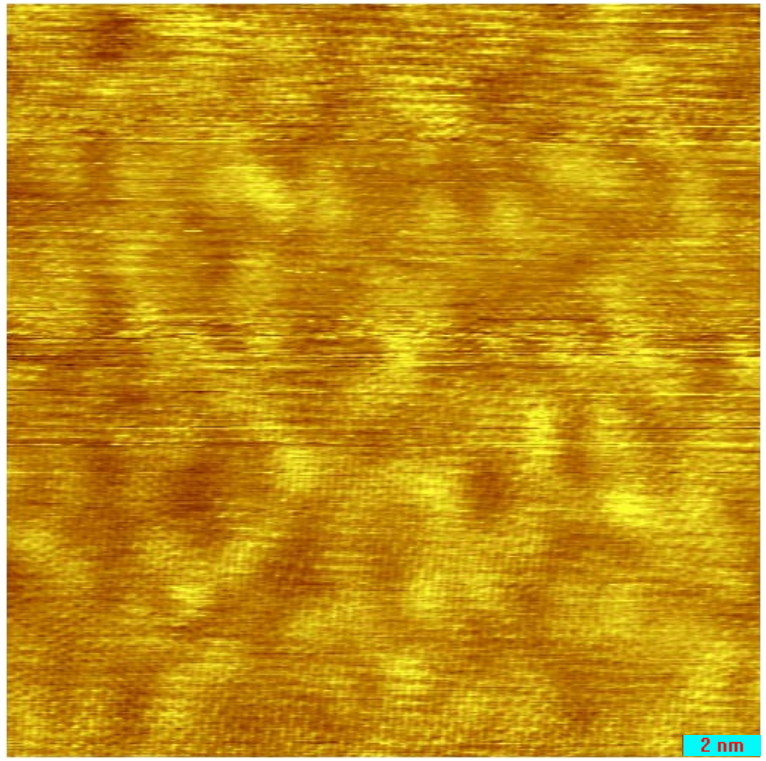


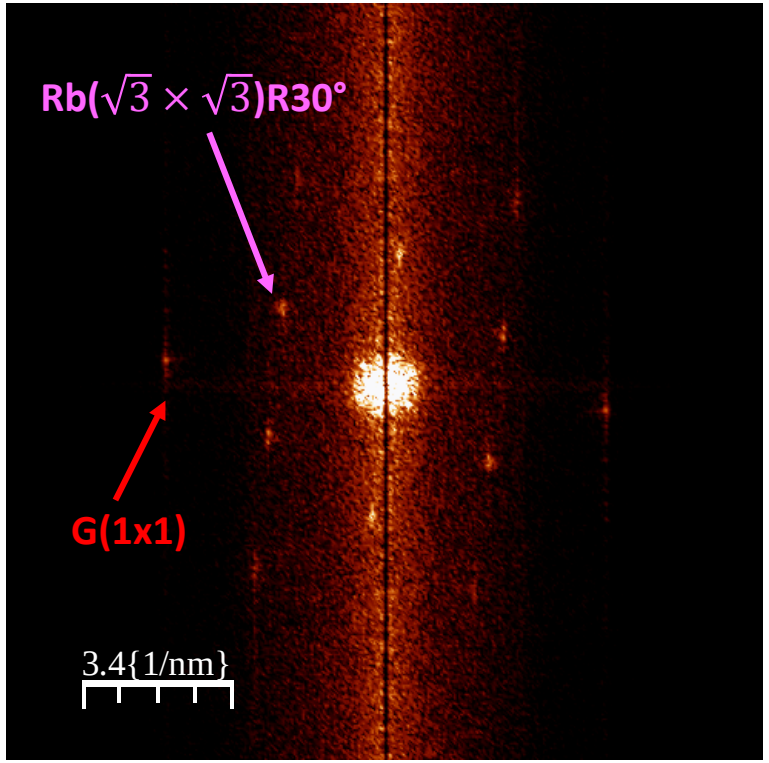


The (2 × 2) superstructure and at the same time the graphene lattice can be resolved.

Rubidium on EG/SiC(0001)

3 min Rb deposition $(\sqrt{3} \times \sqrt{3})$R30°



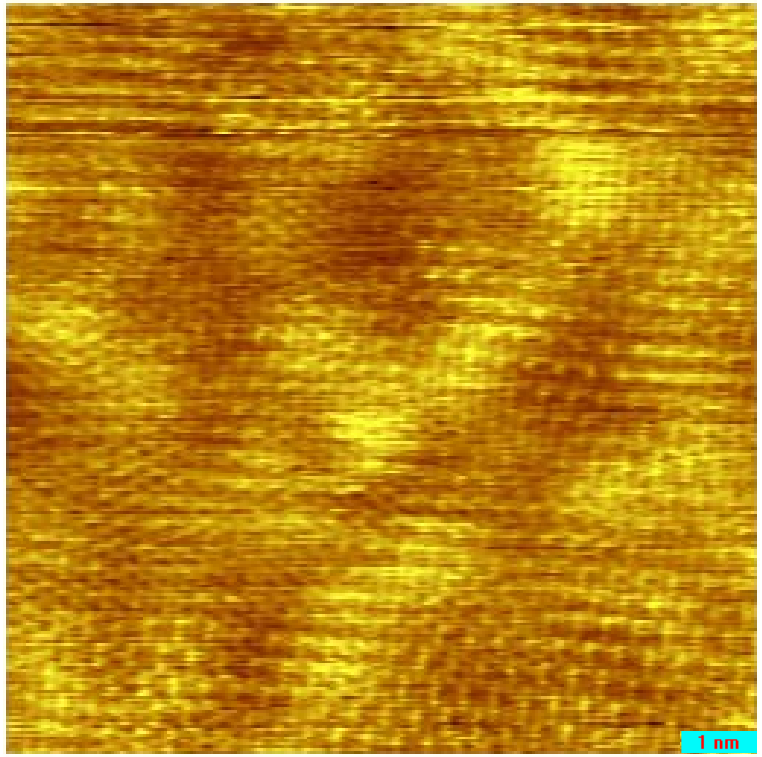


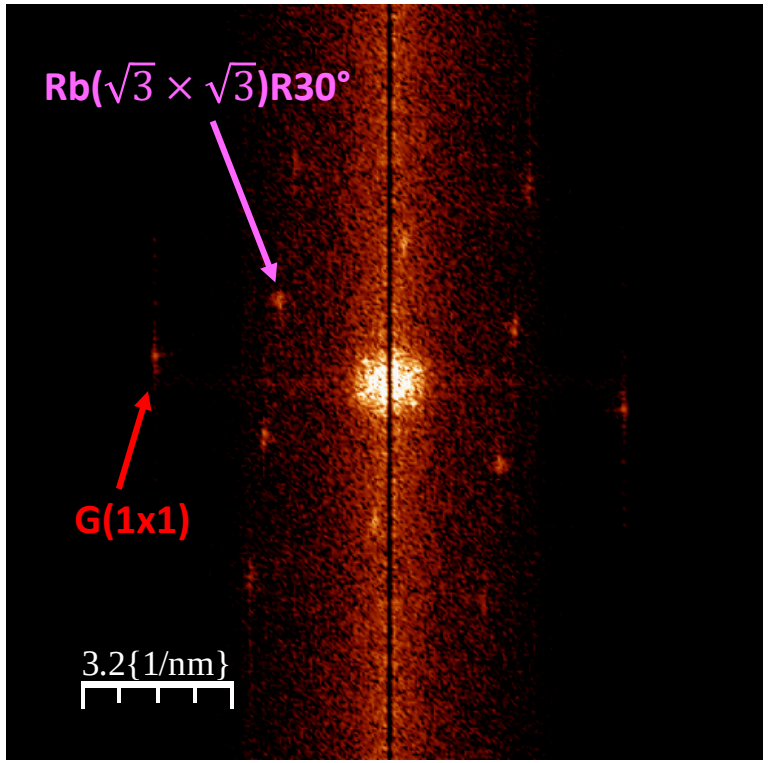
Moirè ($6\sqrt{3}$) is not present, not even faintly visible in larger size STM images.

A $(\sqrt{3} \times \sqrt{3})$R30° superstructure is present.

Rubidium on EG/SiC(0001)

3 min Rb deposition $(\sqrt{3} \times \sqrt{3})$R30°



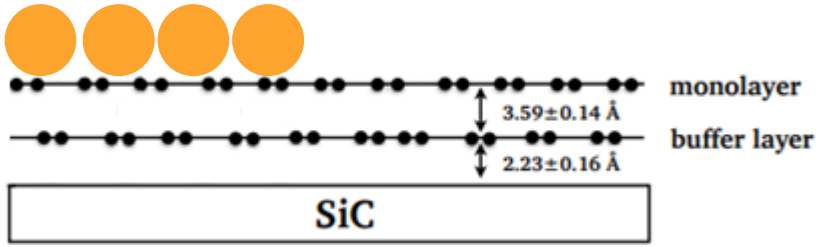


The $(\sqrt{3} \times \sqrt{3})$R30° superstructure and at the same time the graphene lattice can be resolved.

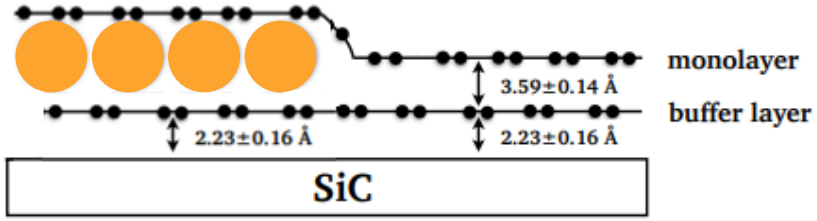
Rubidium on EG/SiC(0001)

Model Rb(2 × 2)

Rb



(2 × 2) EMLG

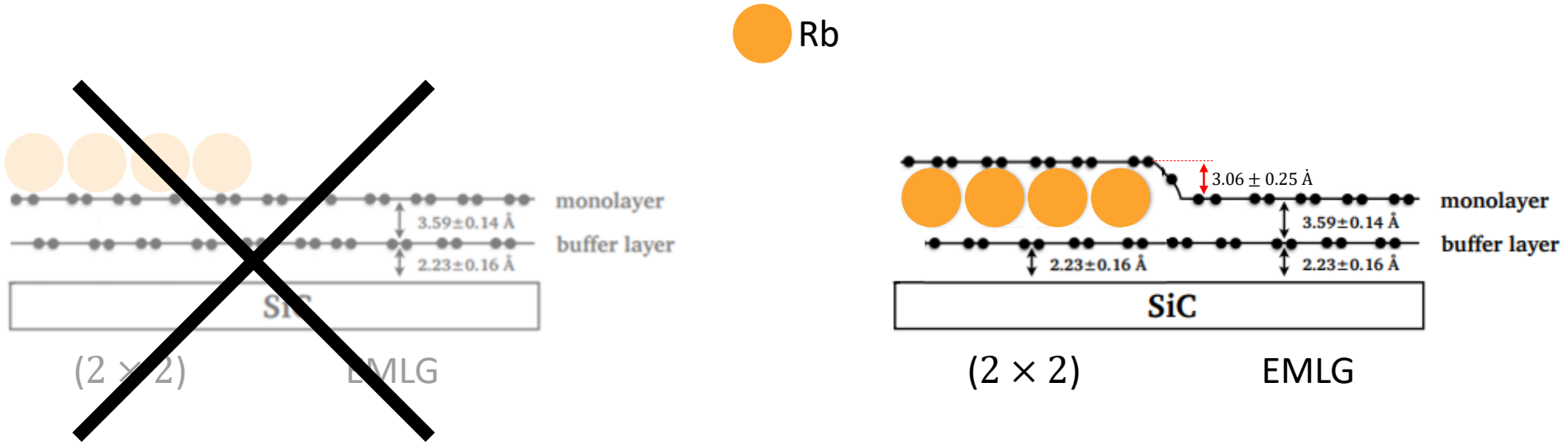


(2 × 2) EMLG

The (2 × 2) has been associated in literature to Rb either on top or intercalated between the two graphene layers. Phase with Rb coverage 1/4 ML.

Rubidium on EG/SiC(0001)

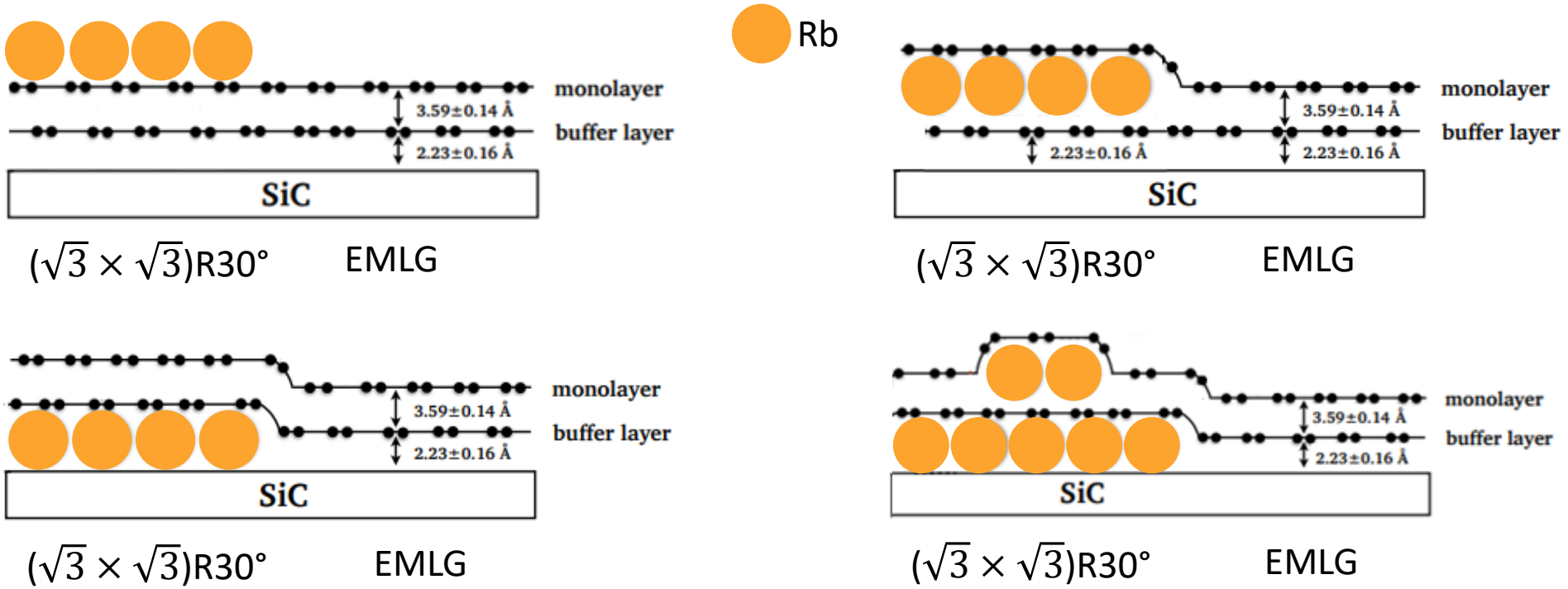
Model Rb(2 × 2)



The graphene lattice can be resolved by STM. Both LEED and STM show the presence of the Moirè $(6\sqrt{3})$ superstructure thus suggesting that Rb is not intercalated below the buffer layer but rather between buffer layer and monolayer graphene.

Rubidium on EG/SiC(0001)

Model Rb($\sqrt{3} \times \sqrt{3}$)R30°



($\sqrt{3} \times \sqrt{3}$)R30° EMLG

($\sqrt{3} \times \sqrt{3}$)R30° EMLG

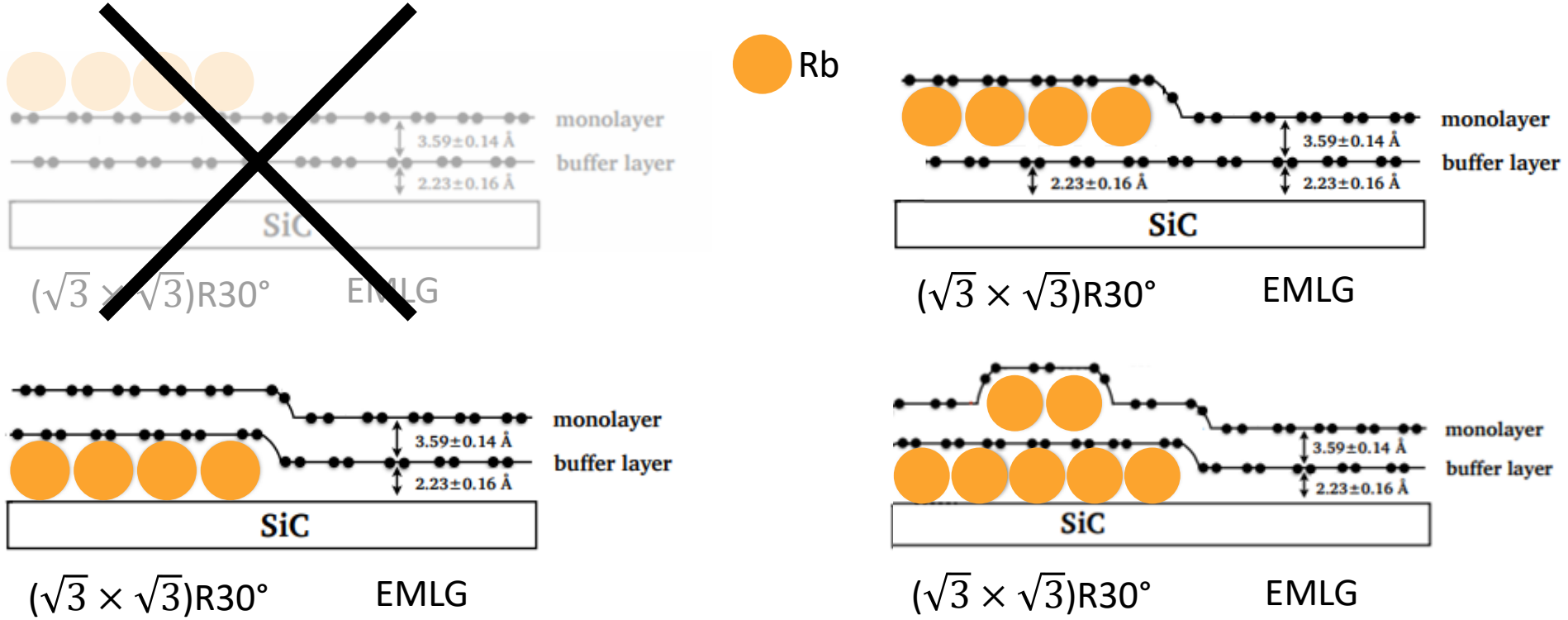
($\sqrt{3} \times \sqrt{3}$)R30° EMLG

($\sqrt{3} \times \sqrt{3}$)R30° EMLG

The ($\sqrt{3} \times \sqrt{3}$)R30° has been associated in literature to AM either on top or intercalated between the two graphene layers. Phase with AM coverage 1/3 ML.

Rubidium on EG/SiC(0001)

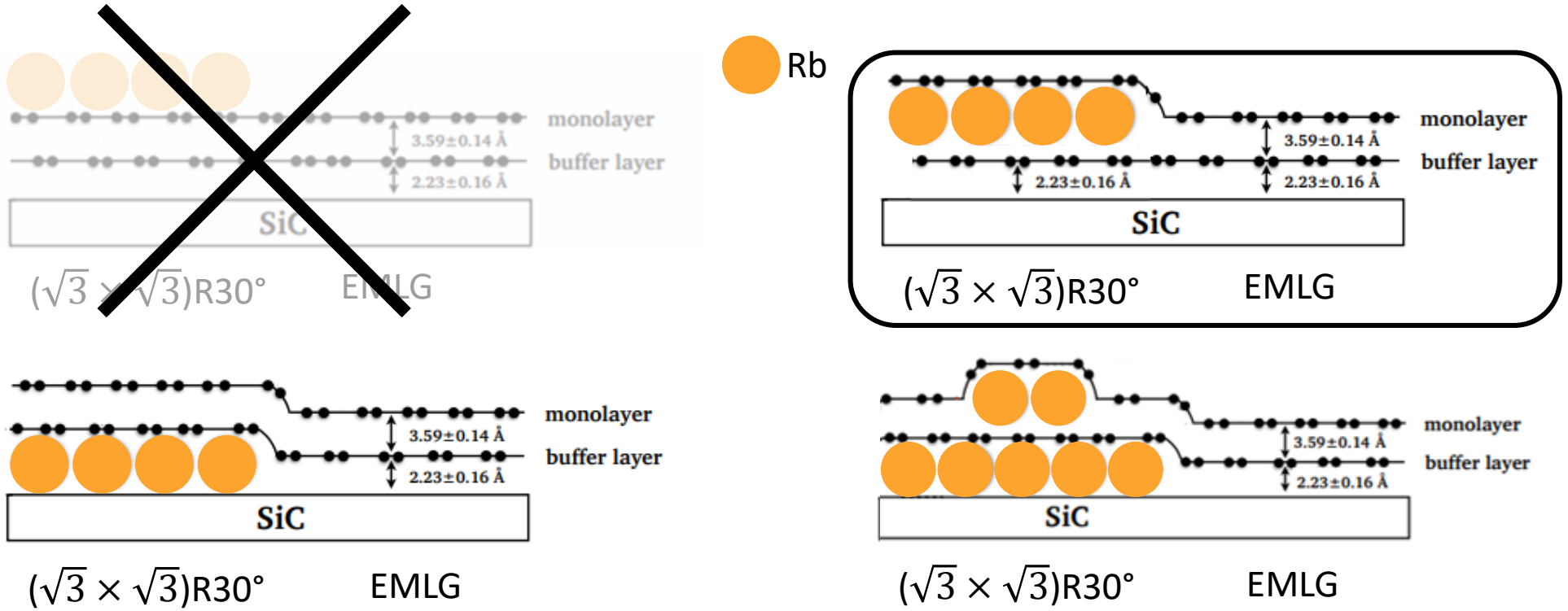
Model Rb($\sqrt{3} \times \sqrt{3}$)R30°



The graphene lattice can be resolved together with the Rb($\sqrt{3} \times \sqrt{3}$)R30° by STM. Thus Rb cannot be on top.

Rubidium on EG/SiC(0001)

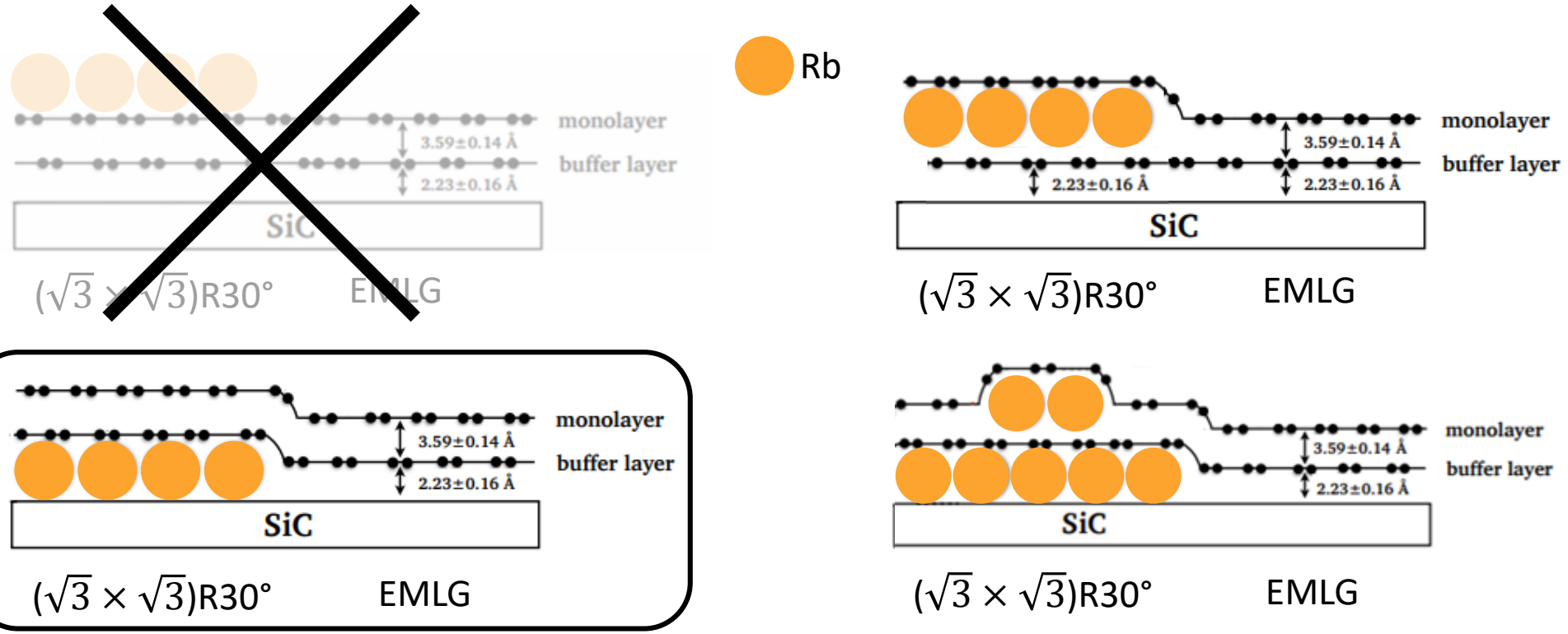
Model Rb($\sqrt{3} \times \sqrt{3}$)R30°



To obtain a Rb($\sqrt{3} \times \sqrt{3}$)R30° it is necessary more than double the amount we need to obtain a Rb(2 × 2) and no Moirè ($6\sqrt{3}$) superstructure can be observed neither at LEED nor at STM.

Rubidium on EG/SiC(0001)

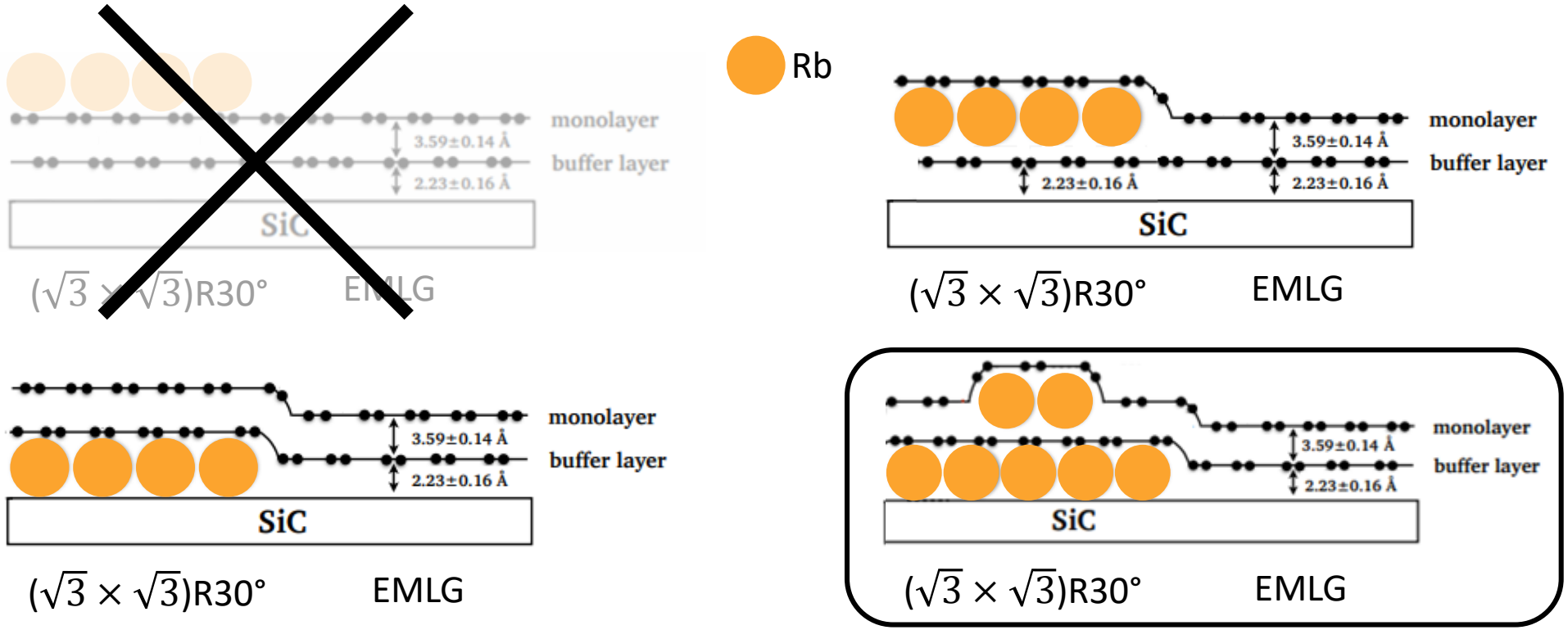
Model Rb($\sqrt{3} \times \sqrt{3}$)R30°



It has been reported for some metal that intercalation below the buffer layer can create a ($\sqrt{3} \times \sqrt{3}$)R30°. However, to obtain a Rb($\sqrt{3} \times \sqrt{3}$)R30° it is necessary more than double the amount we need to obtain a Rb(2 × 2).

Rubidium on EG/SiC(0001)

Model Rb($\sqrt{3} \times \sqrt{3}$)R30°



This option is the most plausible. Both by LEED and STM no Moirè ($6\sqrt{3}$) superstructure can be observed. In STM the graphene lattice is resolved together with the ($\sqrt{3} \times \sqrt{3}$)R30°. Moreover to obtain a Rb($\sqrt{3} \times \sqrt{3}$)R30° it is necessary more than double the amount we need to obtain a Rb(2 × 2).

Conclusions

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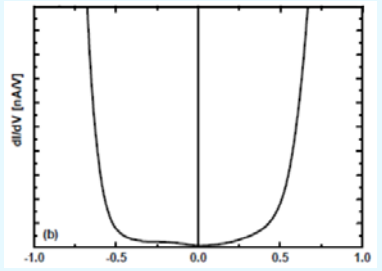
Conclusions

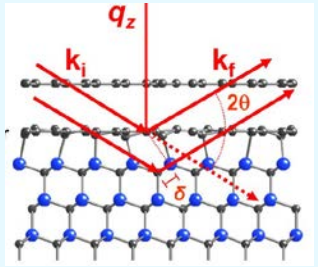
- LEED and STM allows for the first evidence of Rb intercalated monolayer graphene.
- Two Rb ordering have been observed, i.e. (2×2) and $(\sqrt{3} \times \sqrt{3})$R30°.
- At RT, Rb immediately intercalates monolayer graphene.
- Intercalation occurs through SiC step sites or near phase boundaries .

Further studies

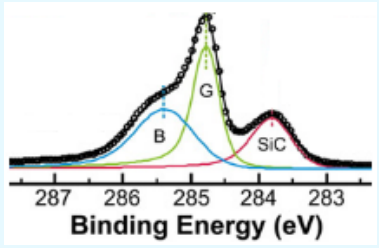
Structural and Electronic properties



STS



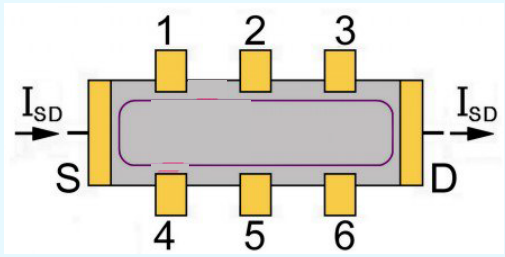
XSW



PES

Superconductivity

Fabrication of electrical contacts

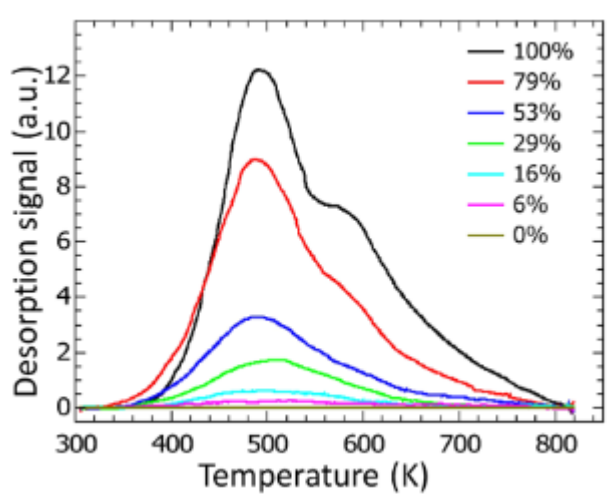


Iagallo et al.,
Semicond. Sci. Technol. 30 (2015) 055007

Transport measurements at low temperature (300 mK)

Hydrogen Storage

Thermal Desorption Spectroscopy



Mashoff et al.,
Appl. Phys. Lett. 103 (2013) 013903

Acknowledgements

Stefano Veronesi

Stefan Heun

Camilla Coletti

Neeraj Mishra

Thank you for your attention!