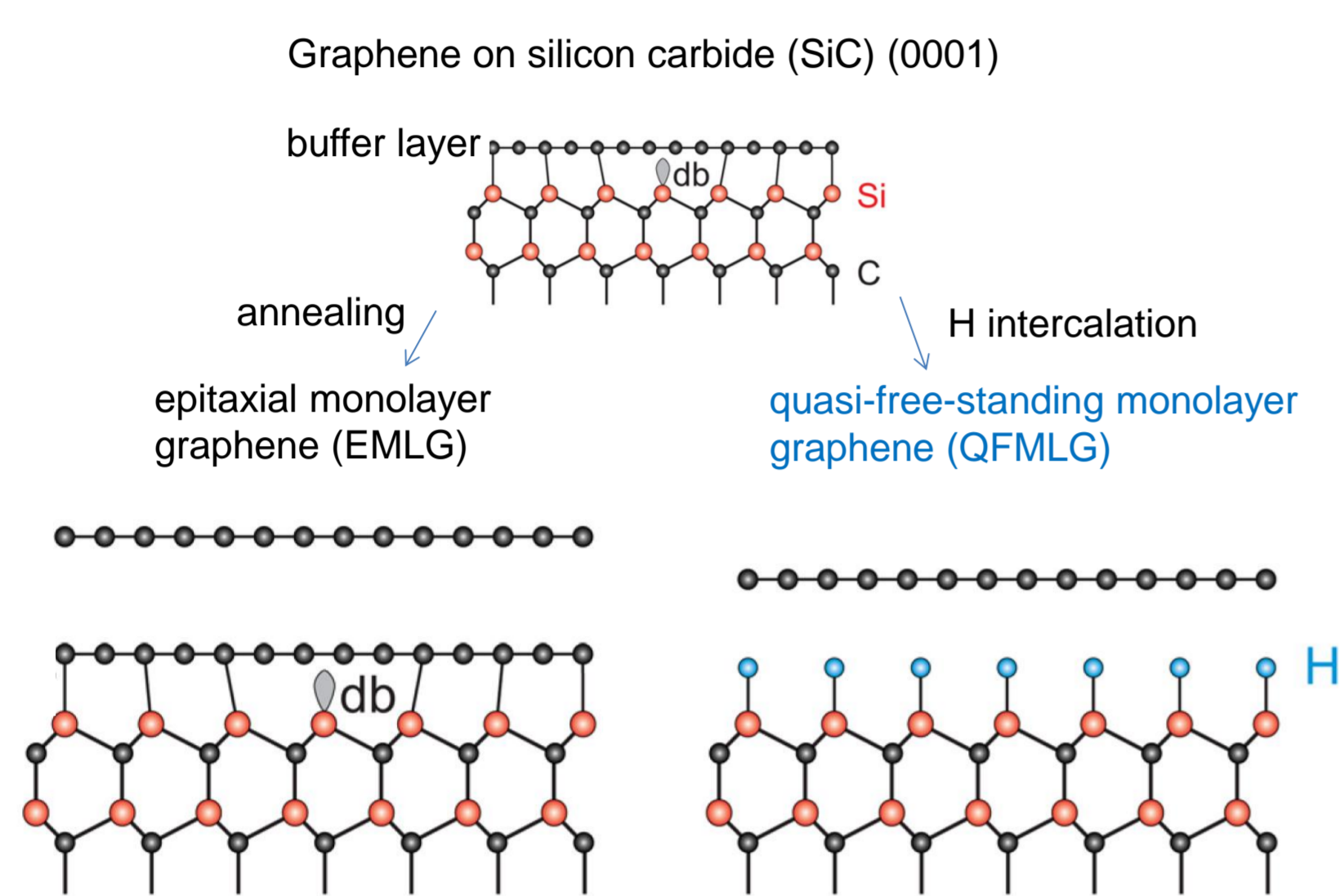


Correlation between Morphology and Transport Properties of Quasi-Free-Standing Monolayer Graphene

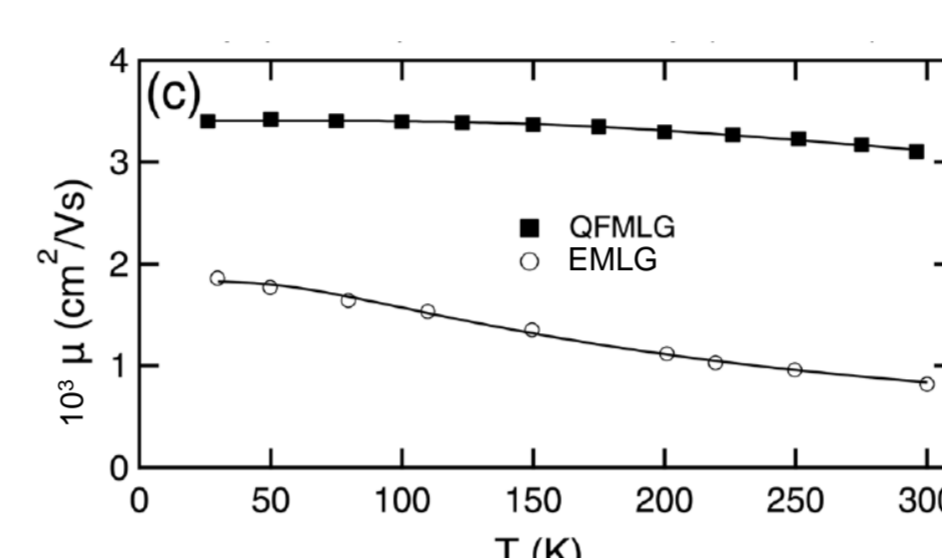
Y. Murata,¹ T. Mashoff,² M. Takamura,³ S. Tanabe,³ H. Hibino,³ F. Beltram,^{1,2} and S. Heun¹

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³ NTT Basic Research Laboratories, NTT Corporation, Atsugi, Kanagawa, Japan

Introduction



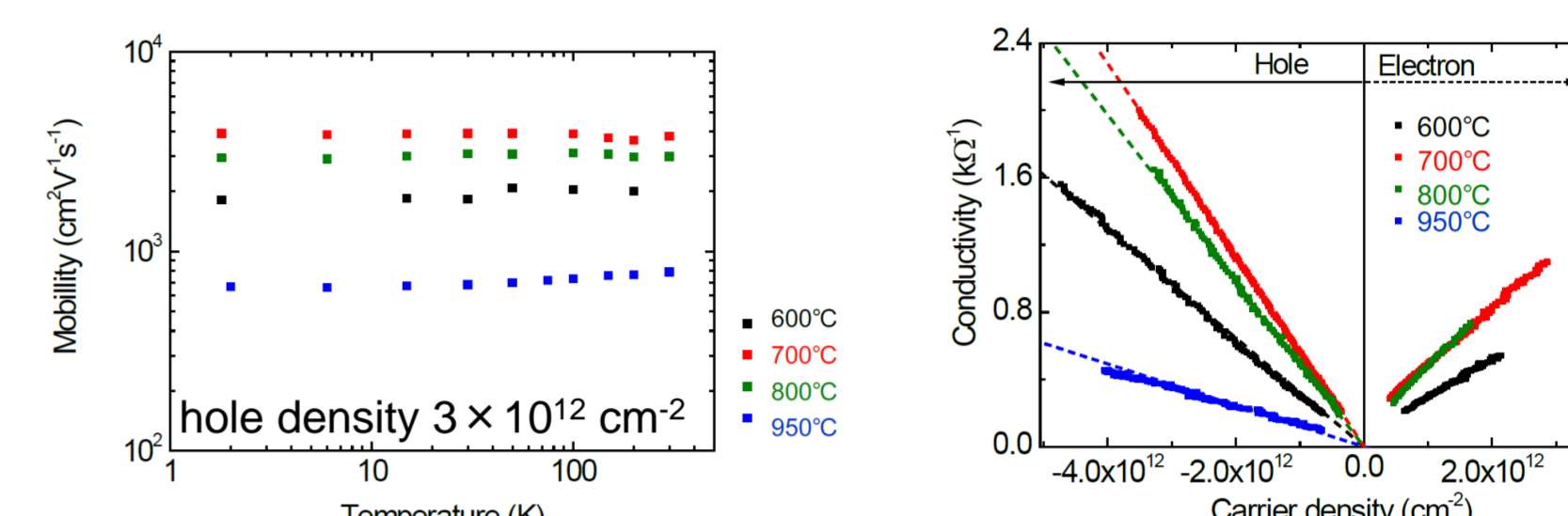
C. Riedl, C. Coletti, T. Iwasaki, A. A. Zakharov, and U. Starke, Phys. Rev. Lett. **103**, 246804 (2009)



The carrier mobility of QFMLG shows less temperature dependence than EMLG, indicating less interaction between QFMLG and the SiC substrate.

However, the mobility of QFMLG ($\sim 3000 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$) is still lower than exfoliated graphene on SiO_2 or free standing graphene.

F. Speck, J. Jobst, F. Fromm, M. Ostler, D. Waldmann, M. Hundhausen, H. B. Weber, and Th. Seyller, Appl. Phys. Lett. **99**, 122106 (2011)



S. Tanabe, M. Takamura, Y. Harada, H. Kageshima, and H. Hibino, Jpn. J. Appl. Phys. **53**, 04EN01 (2014).

The QFMLG mobility depends on T_H , the substrate temperature during H intercalation
 highest mobility by $T_H = 700^\circ\text{C}$

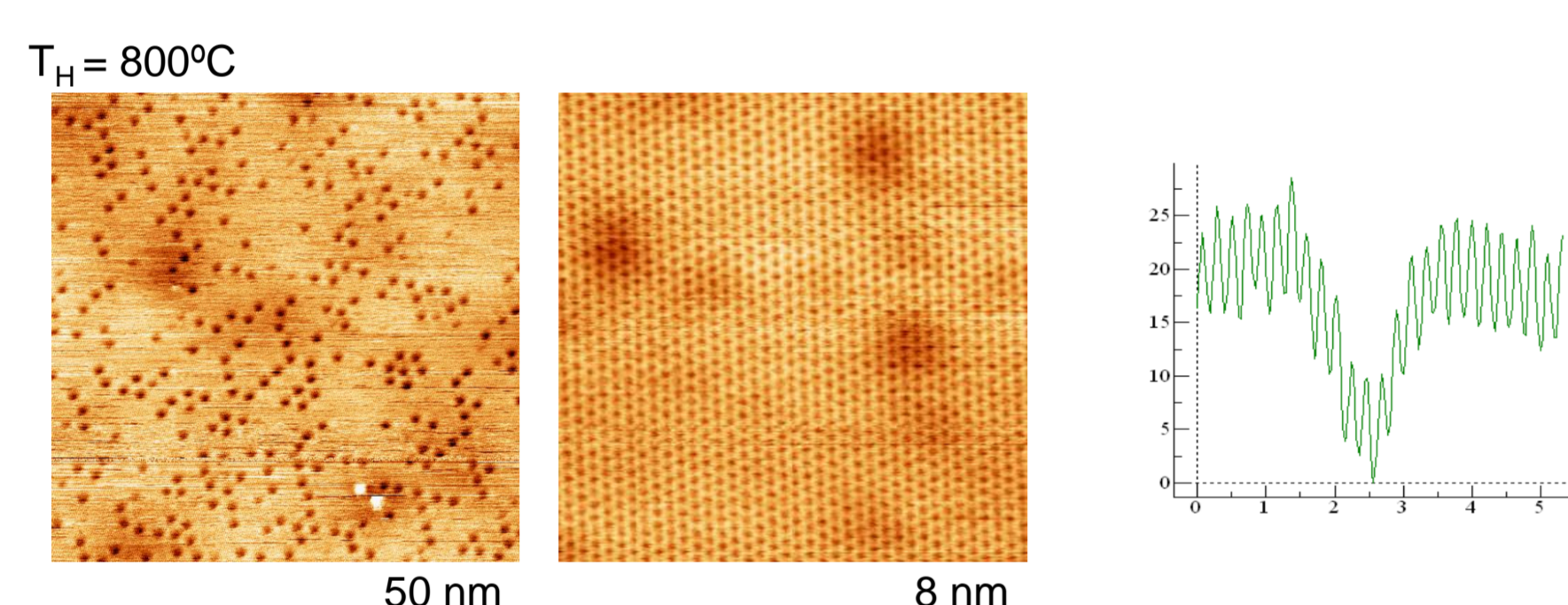
conductivity – carrier density

- linear for $T_H = 600\text{--}800^\circ\text{C}$ - charged impurity
- sublinear for $T_H = 950^\circ\text{C}$ - additional scattering by defect

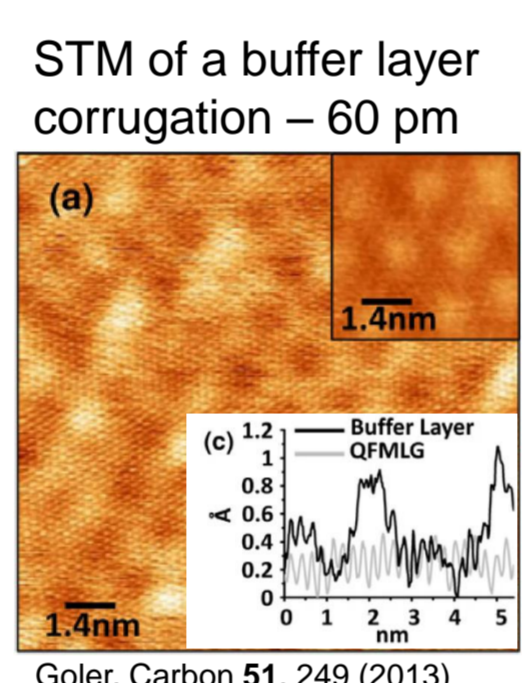
Purpose :
 to observe the morphology of QFMLG formed at different T_H and investigate the relationship with transport property

Results

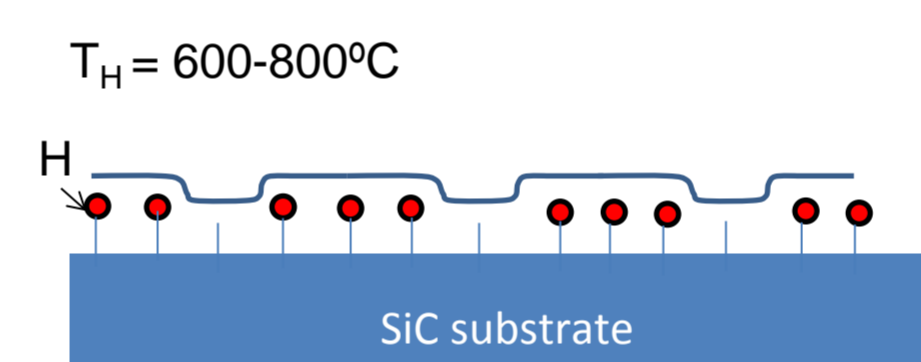
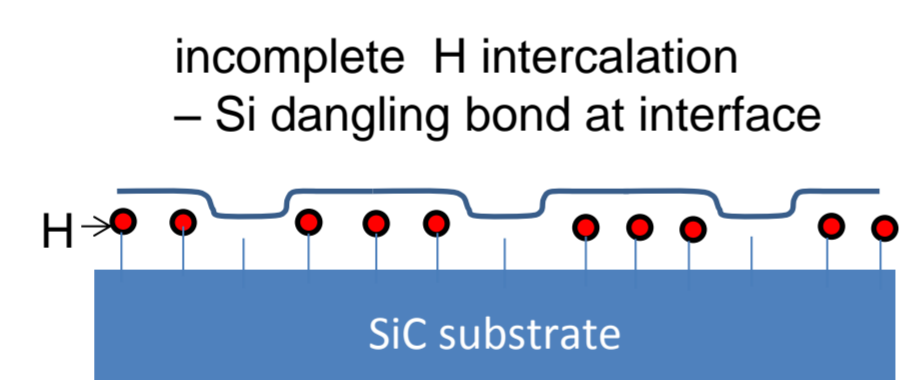
Intercalation at 600-800°C



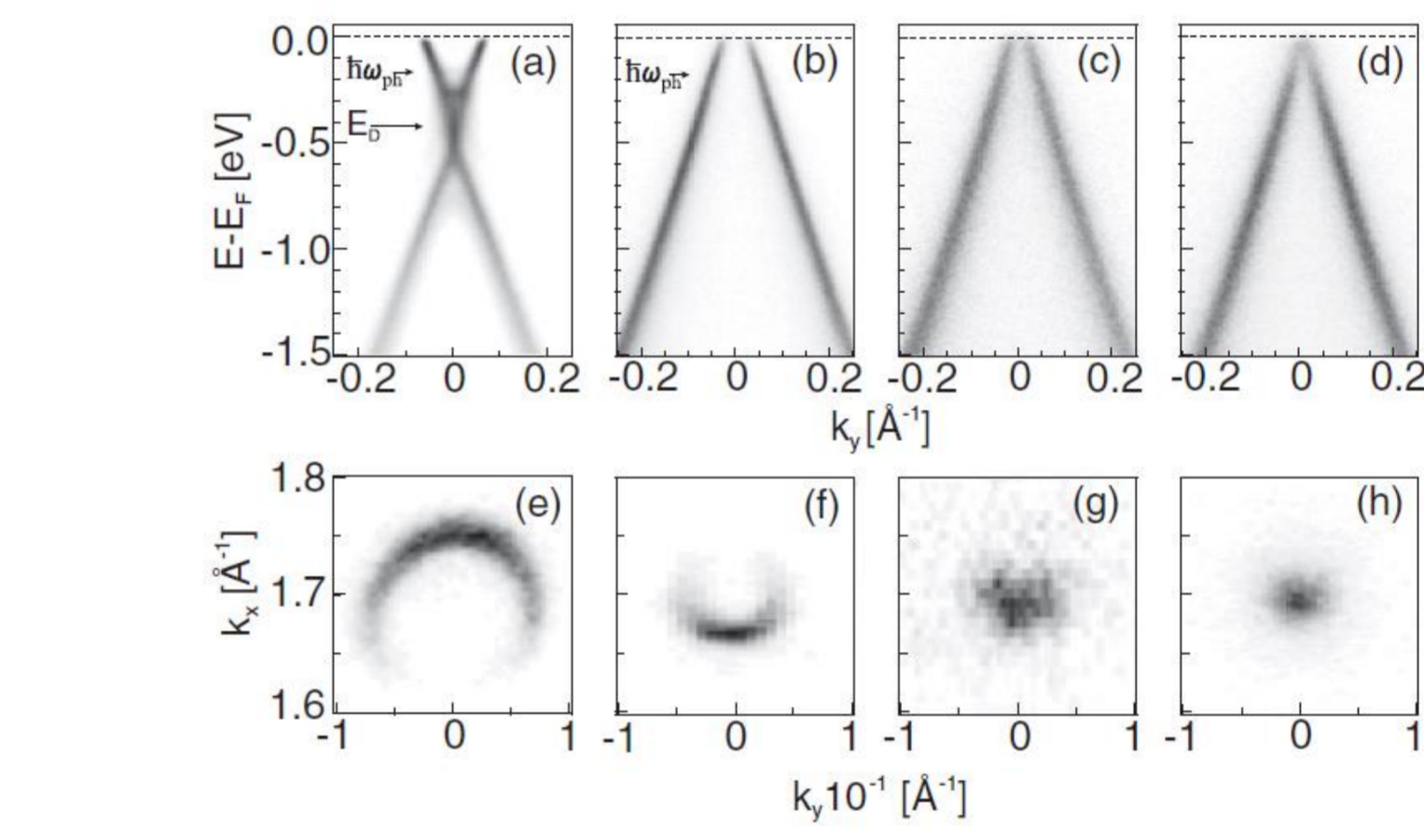
- Width: 1.5 nm
- Depth: 15-25 pm
- Density $1 \times 10^{13} \text{ cm}^{-1}$
- Honeycomb inside, no defect
- Align along SiC(1120)
- Periodicity: 1.8 nm = SiC-6 × 6



Goler, Carbon **51**, 249 (2013)

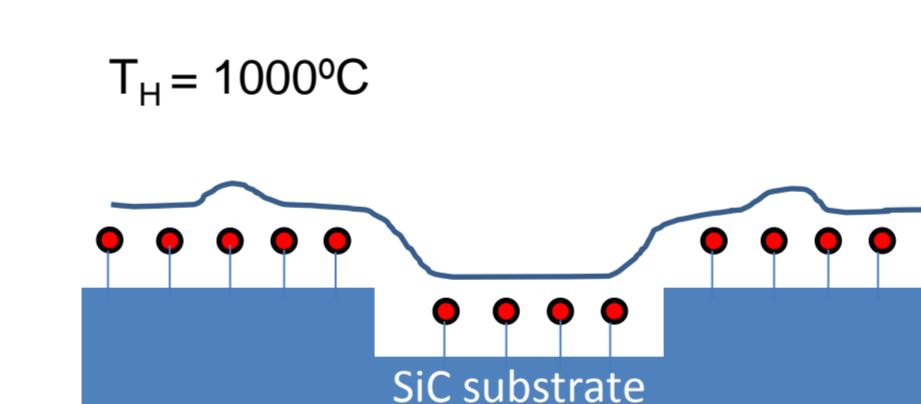


- small dark spots
- incomplete H intercalation - Si dangling bonds

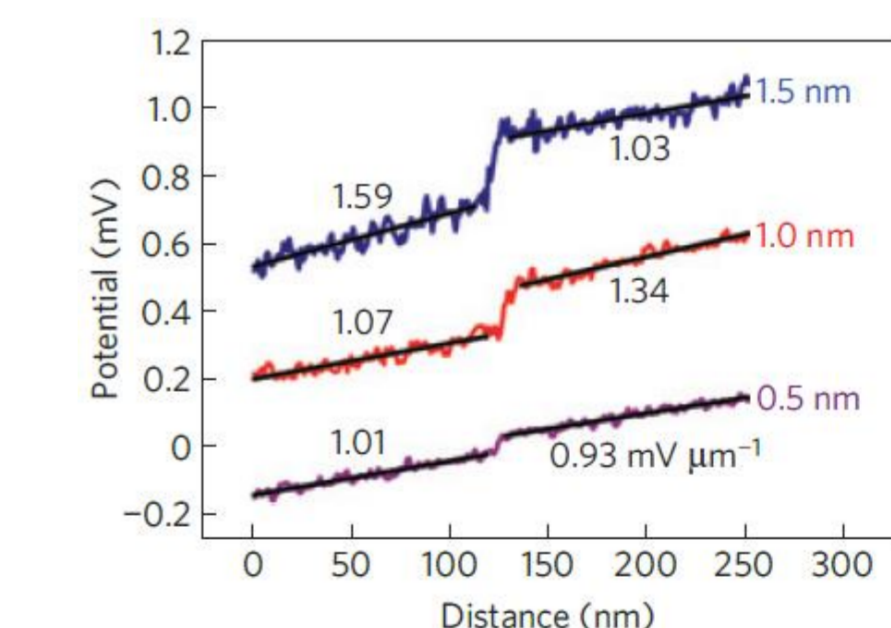


ARPES (Forti, et.al., Phys. Rev. B **84**, 125449 (2011).)

annealing QFMLG in vacuum: H atoms desorb, Si dangling bonds donate charge to graphene and act as charged scattering centers.



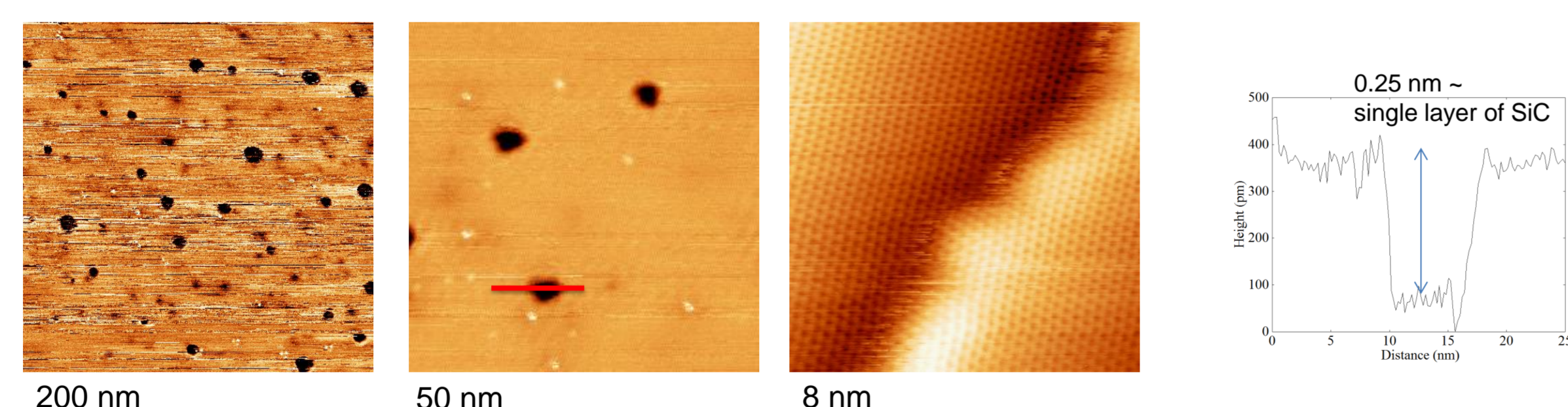
- dark spot – hole in SiC substrate
- wrinkle of graphene



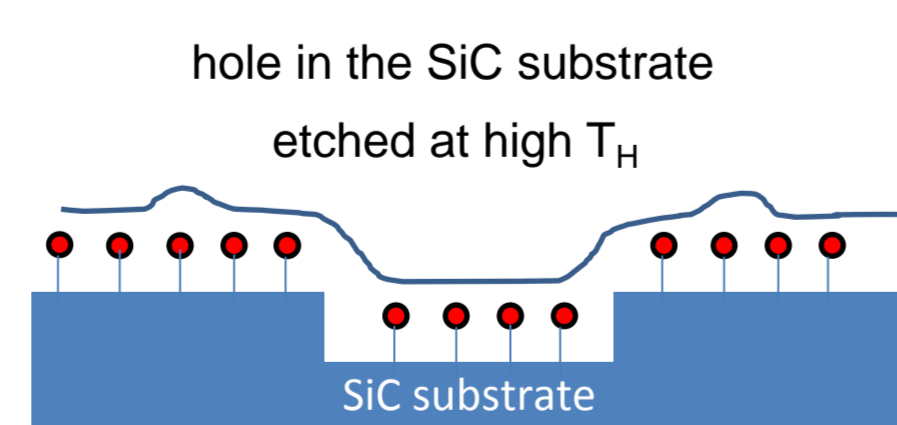
Scanning tunneling potentiometry (Ji, et.al., Nature Materials **11**, 114 (2012)):
 resistance of EMLG increases over SiC substrate steps
 • π - σ hybridization by curvature of graphene
 • strain of graphene
 • reduced doping due to a larger distance at the interface

See also T. Low, V. Perebeinos, J. Tersoff, and Ph. Avouris, Phys. Rev. Lett. **108**, 096601 (2012)

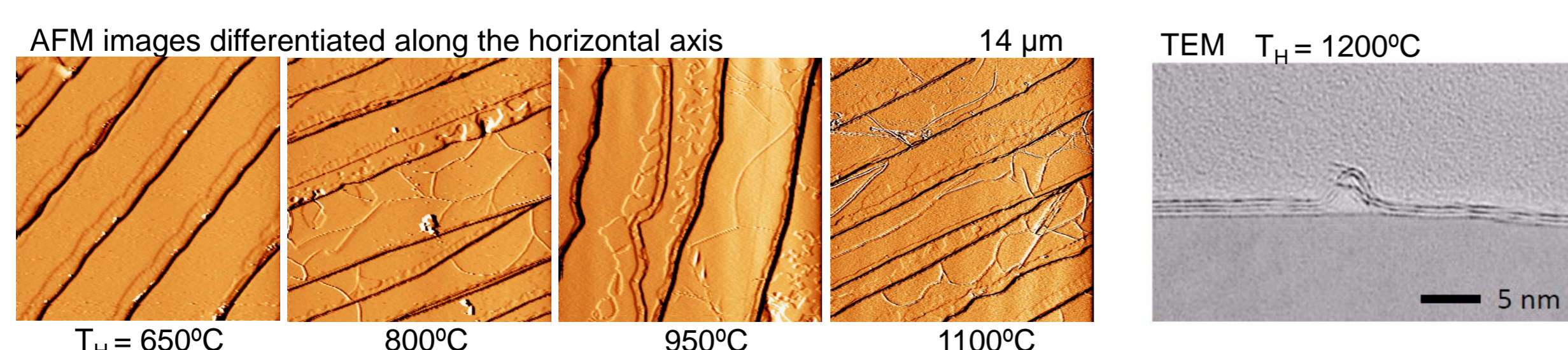
Intercalation at 1000°C



- Large dark spots (width: 4-10 nm, depth: 0.25 nm)
- Density $6 \times 10^{10} \text{ cm}^{-1}$
- Distributed randomly
- Honeycomb inside



Wrinkles of graphene



Wrinkles appear at $T_H > 800^\circ\text{C}$, more pronounced at $T_H > 1100^\circ\text{C}$
 They are due to the difference in thermal expansion coefficients between graphene and SiC

Funding

