Functionalized graphene as a system for hydrogen storage

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ISTITUTO ITALIANO DI TECNOLOGIA

GRAPHENE WEEK

National Enterprise for nanoScience and nanoTechnology

26.06.2014

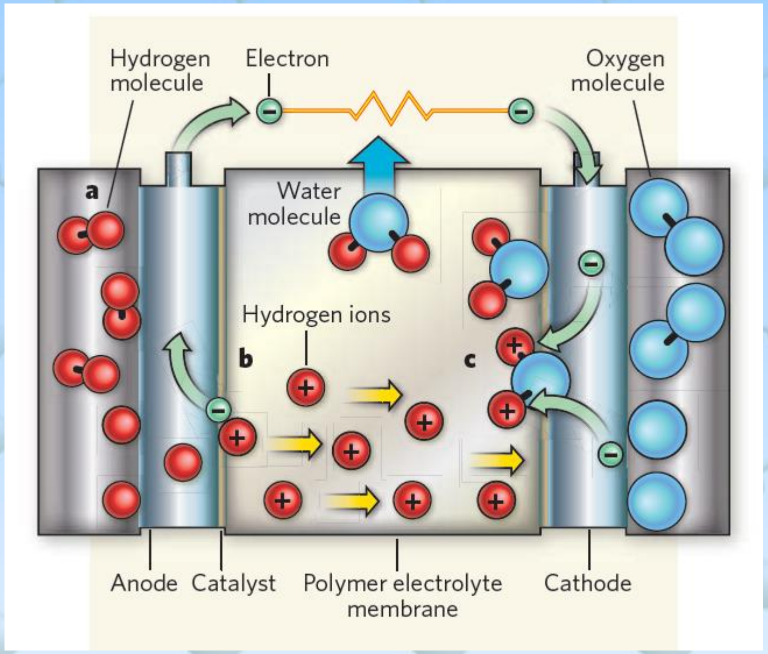
Outline

- Introduction
- Experimental setup
- Titanium on graphene
- Increasing the active surface area by sputtering
- Summary and Outlook

Hydrogen & energy

As a fuel, hydrogen has advantages:

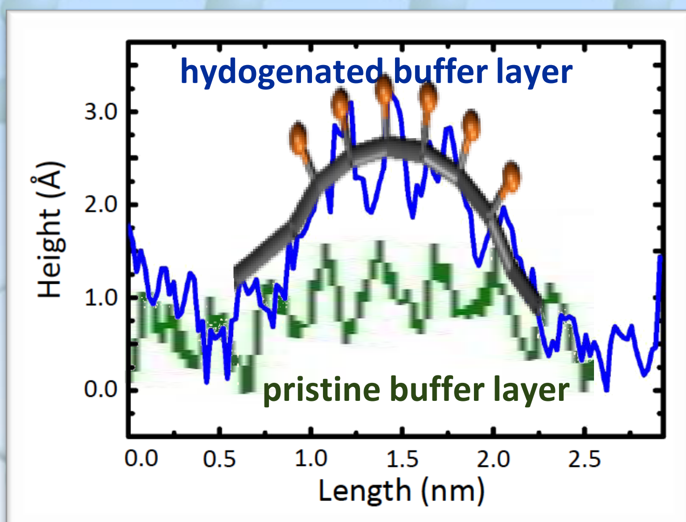
- high energy-to-mass ratio
- $H_2 + 1/2\ O_2 \rightarrow H_2O$ $\Delta H = -2.96eV$
- Non-toxic and “clean” (product = water)
- Unlimited resource
- Reduction in CO_2 emission
- Reduction of oil dependency

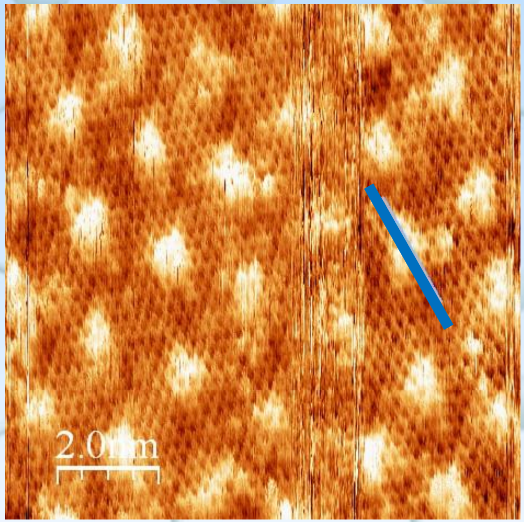


A hydrogen fuel cell

Graphene for hydrogen storage

- Graphene is lightweight, inexpensive, robust, chemically stable
- Large surface area (~ 2600 m^2/g)
- Hydrogen storage possible by chemisorption and physisorption





S. Goler *et al.*: J. Phys. Chem. C **117**, 11506 (2013).

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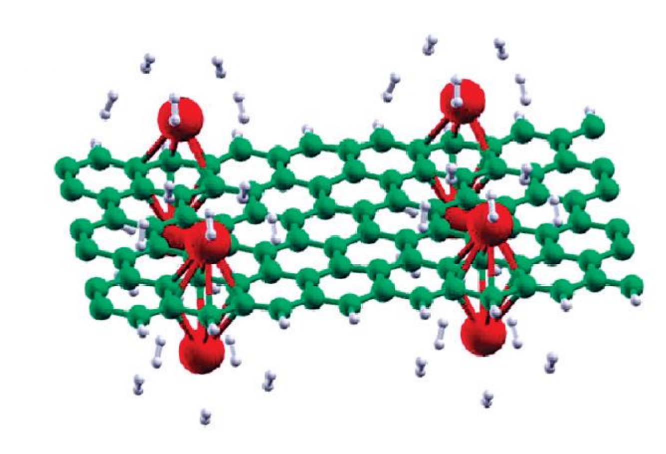
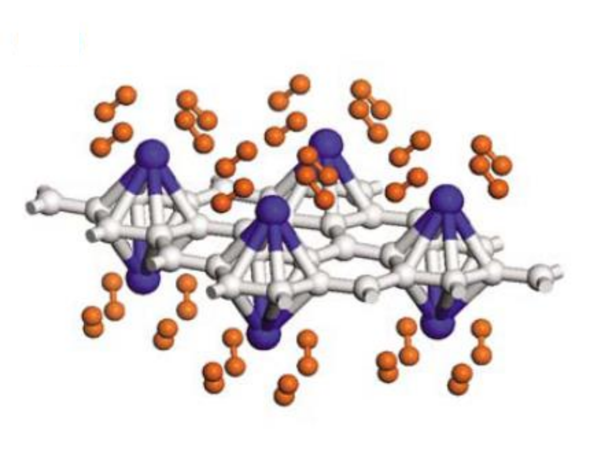
Functionalized graphene

- Graphene can be modified with various chemical species, such as calcium or transisiton metals (Titanium)
- Functionalized graphene has been predicted to adsorb up to 9 wt% of hydrogen

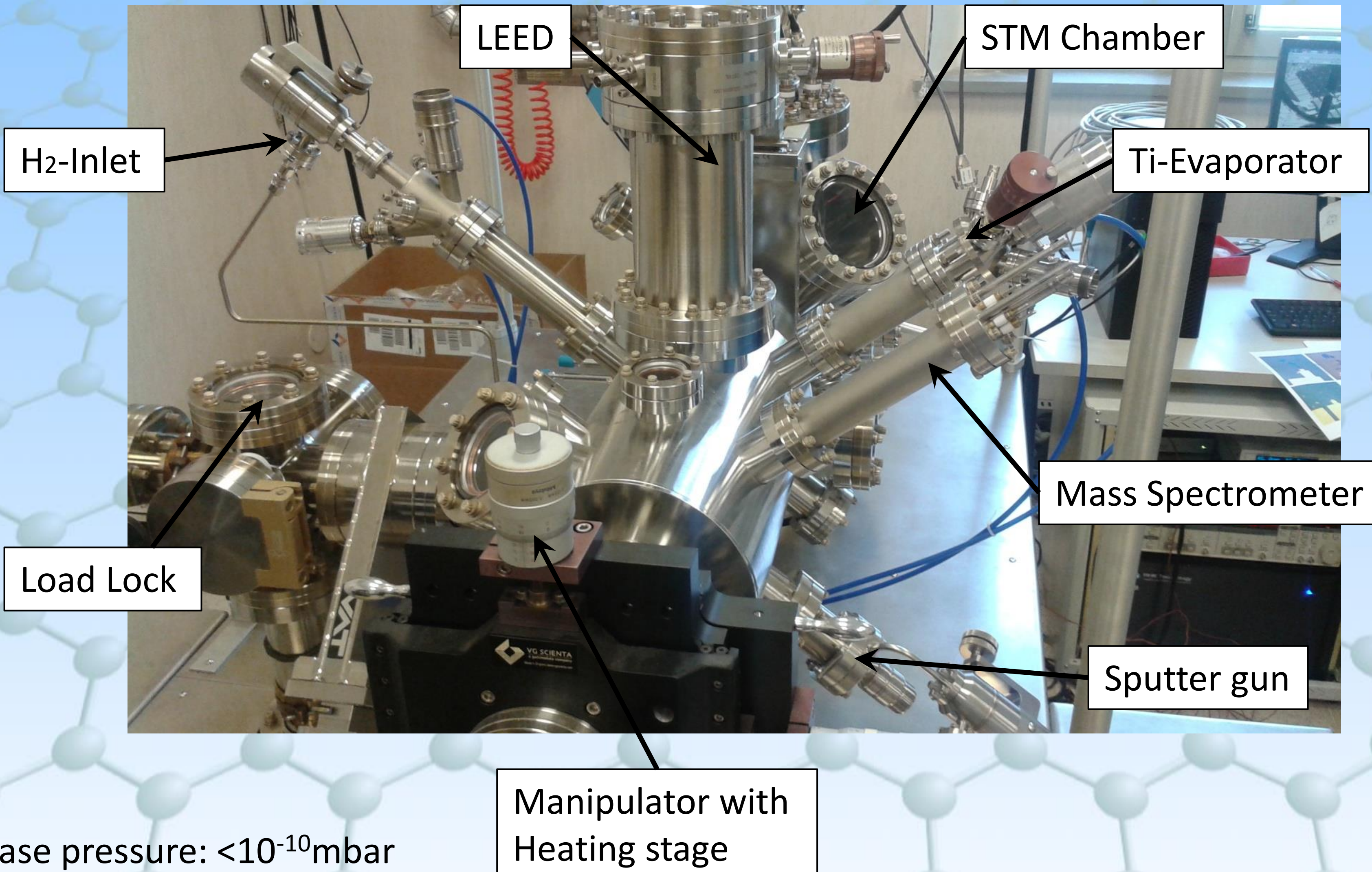


Lee et al., Nano Lett. 10 (2010) 793



Durgen et al., PRB 77 (2007) 085405

UHV-system



Base pressure: <10^{-10}mbar

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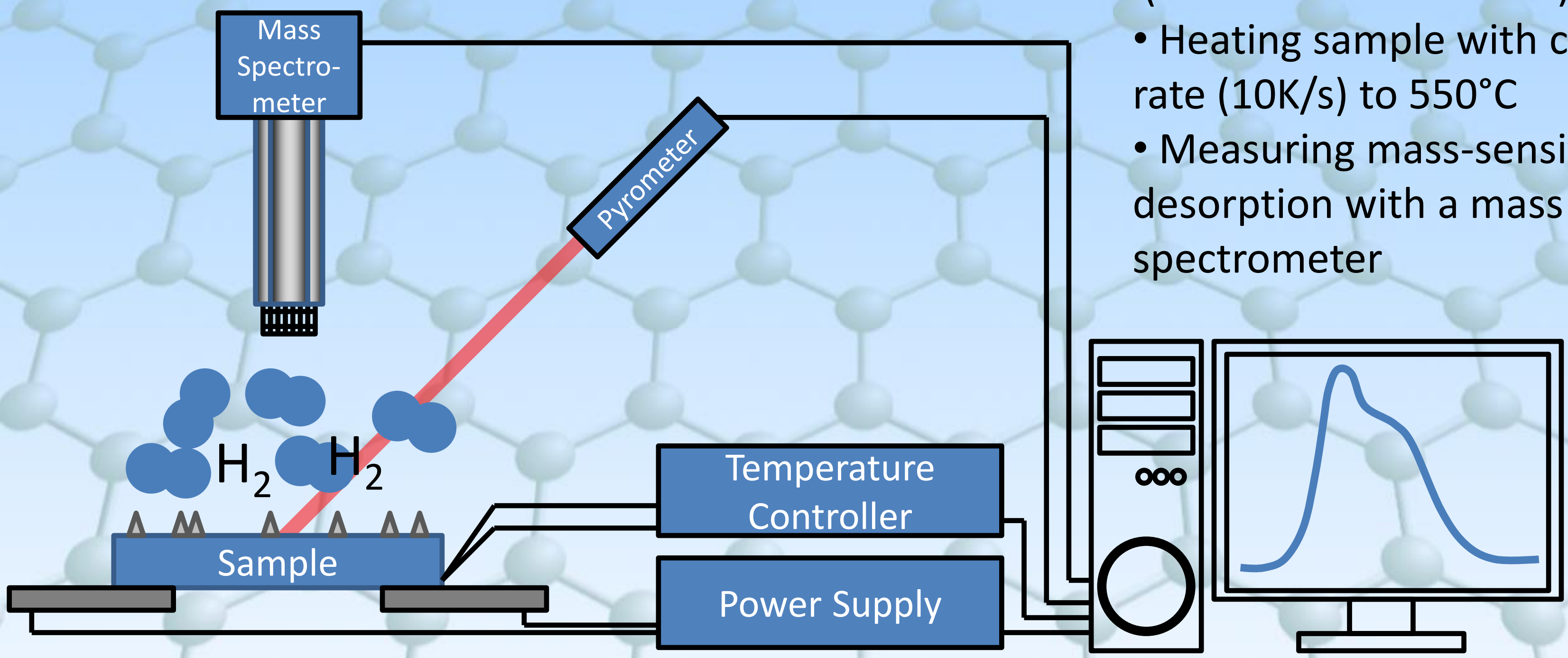
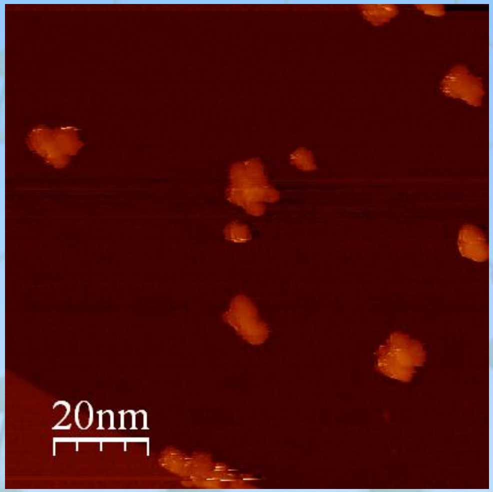
Experimental setup

for thermal desorption spectroscopy (TDS)

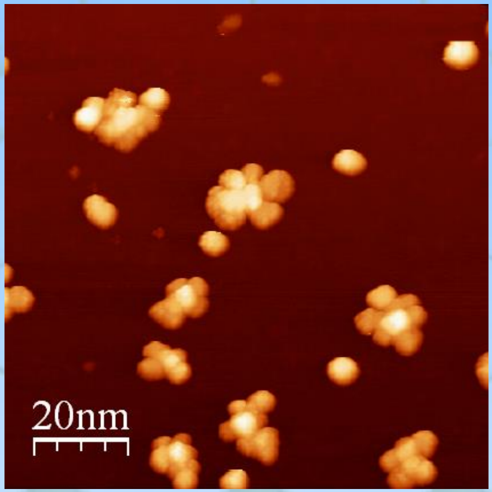
- Deposition of different amounts of Titanium
- Offering Hydrogen (D_2) ($1x10^{-7}$ mbar for 5 min)
- Heating sample with constant rate (10K/s) to 550°C
- Measuring mass-sensitive desorption with a mass spectrometer



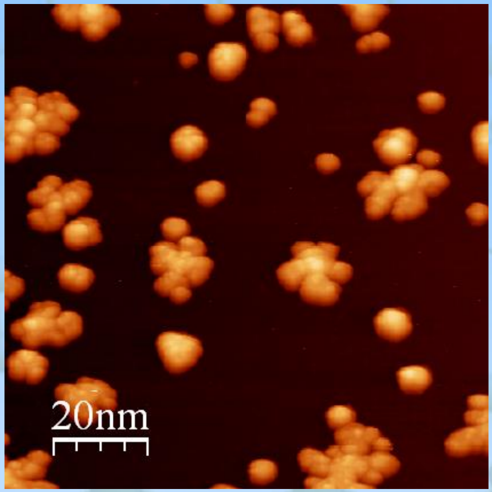
Titanium growth



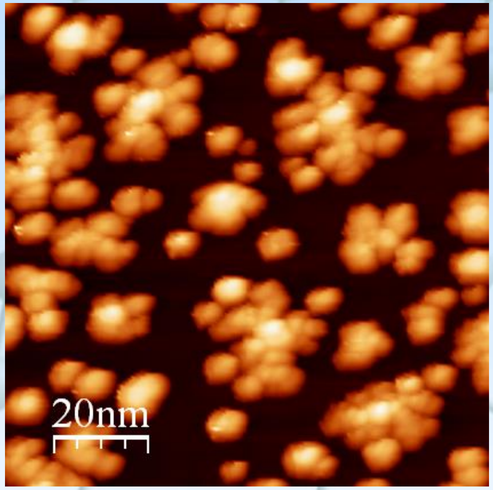
6% Coverage



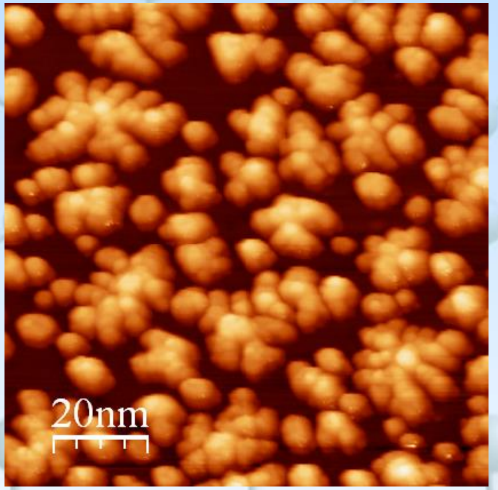
16% Coverage



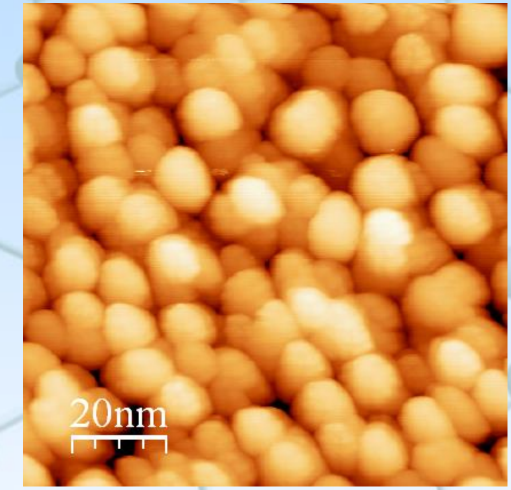
29% Coverage



53% Coverage



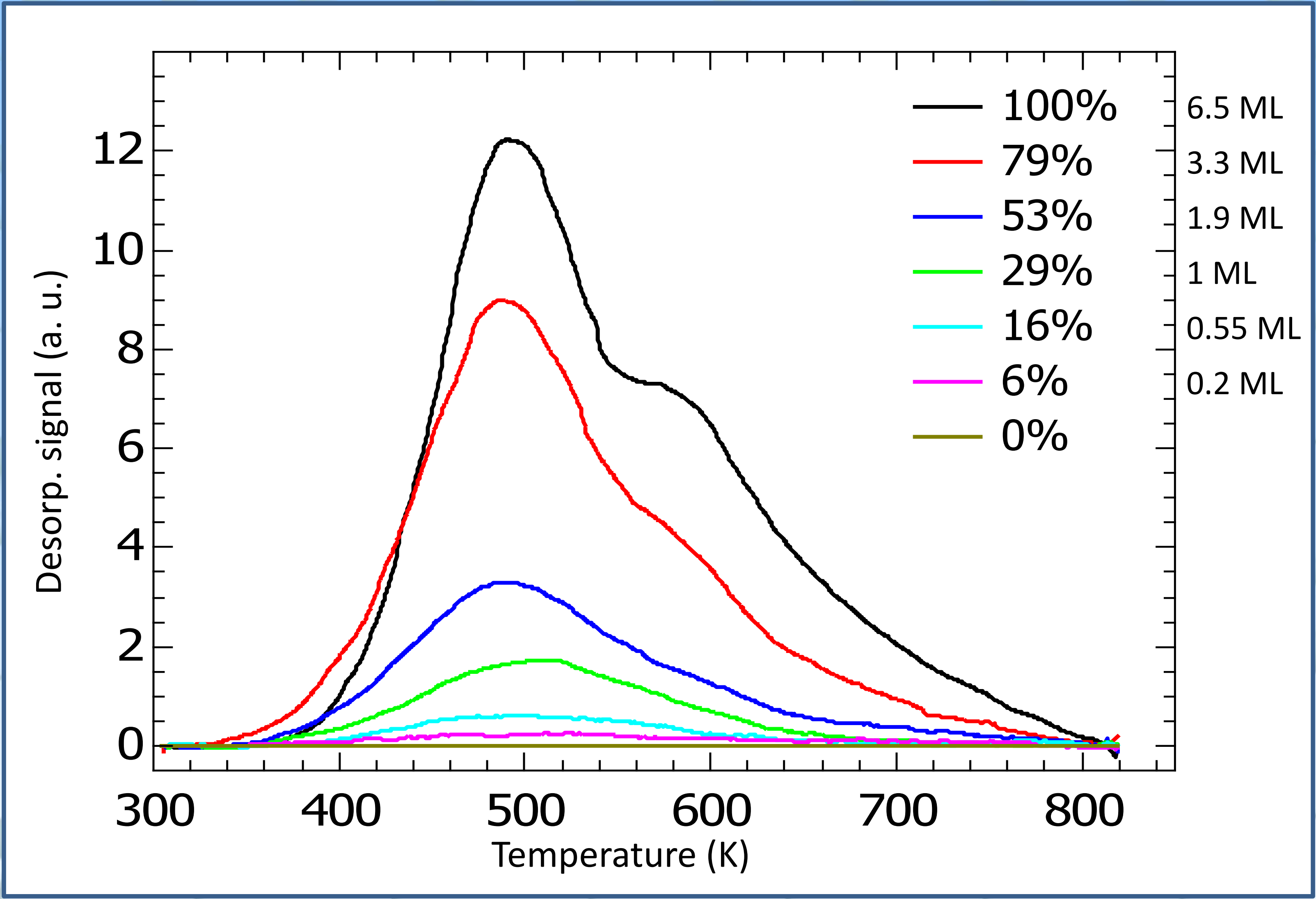
79% Coverage



100% Coverage

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

Desorption spectra of D_2 for different Ti-coverages



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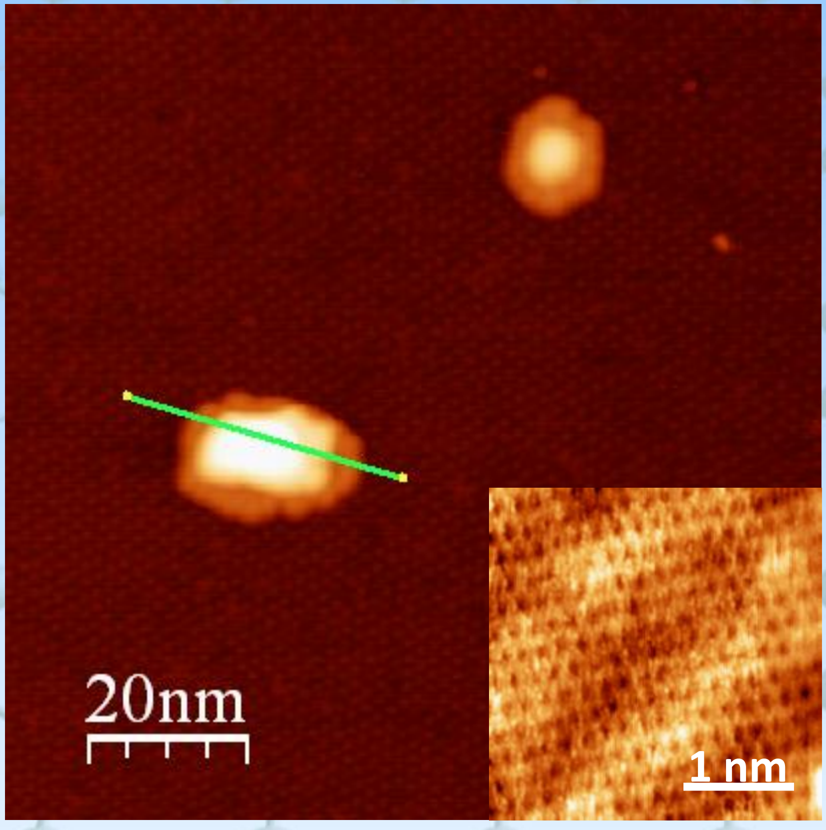
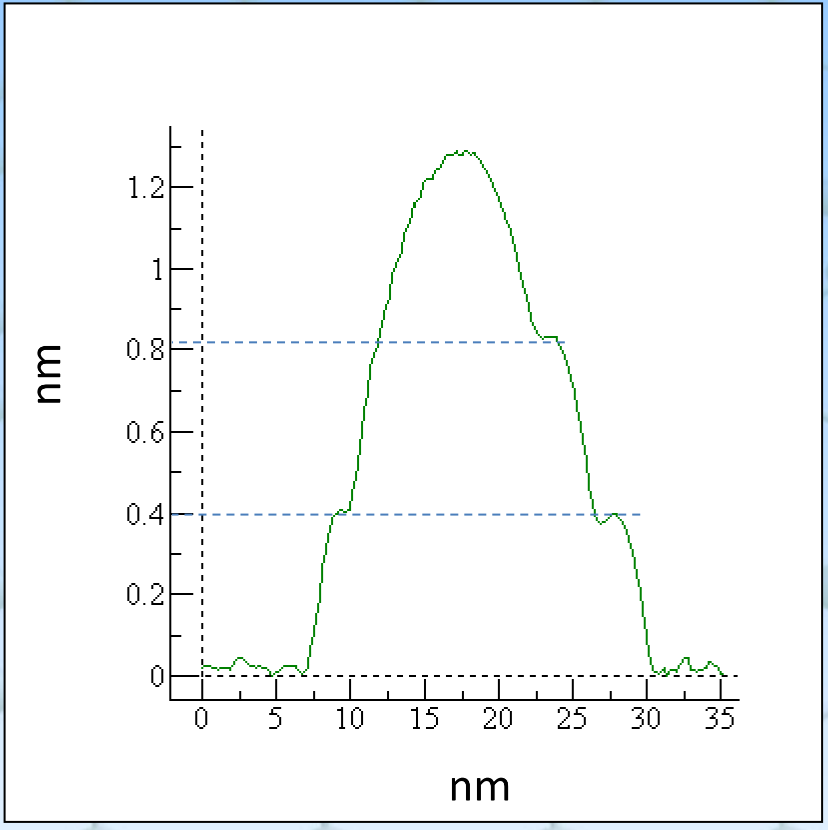
T. Mashoff *et al.*: Appl. Phys. Lett. **103**, 013903 (2013)

Forming of islands



100 nm, 1 V, 82 pA



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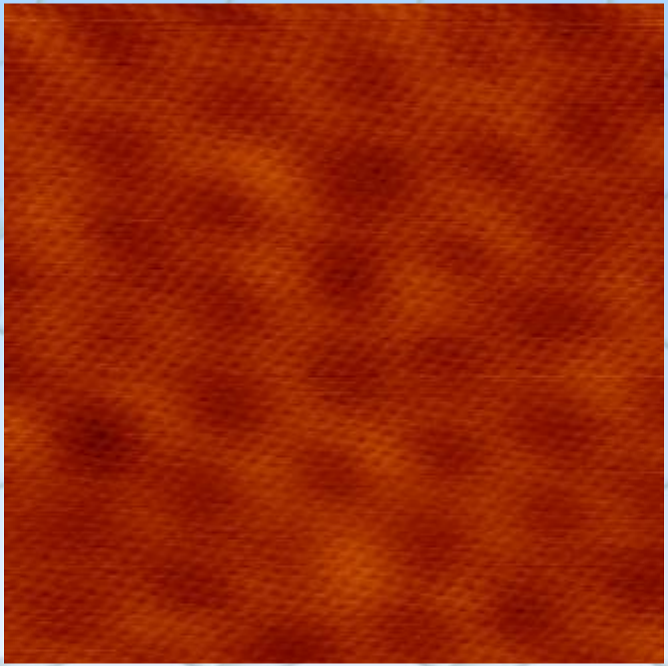
N_2 - sputtering of the graphene surface

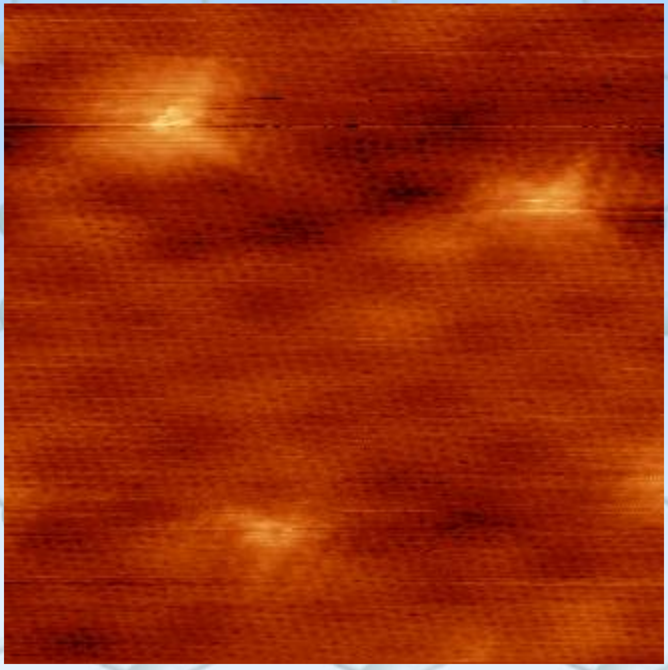
Defects in the graphene film should reduce the mobility of Ti-atoms and lead to more and smaller islands.

Clean graphene surface



10x10 nm^2, 1V, 0.8nA

Sputtered 150s @100eV



10x10 nm^2, 1V, 0.8nA

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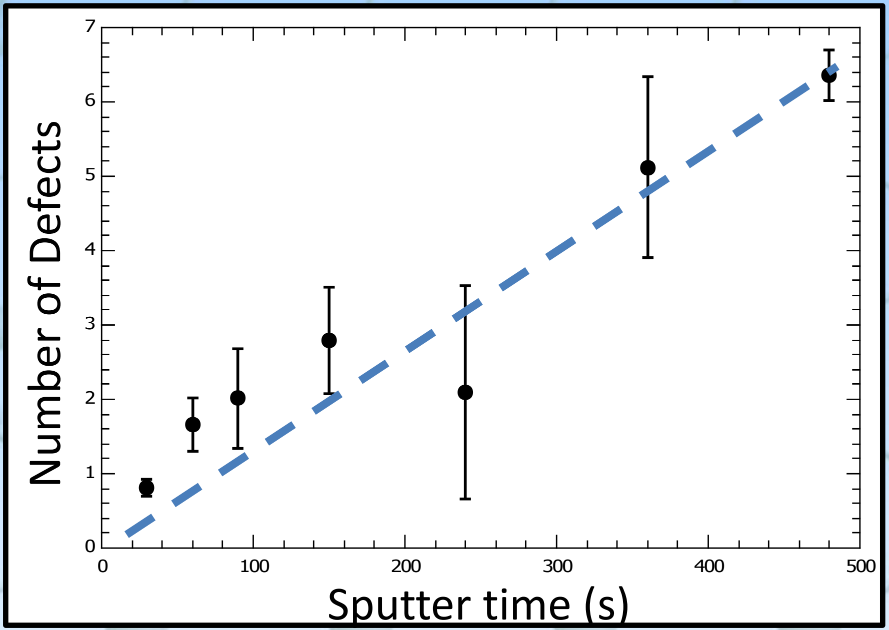
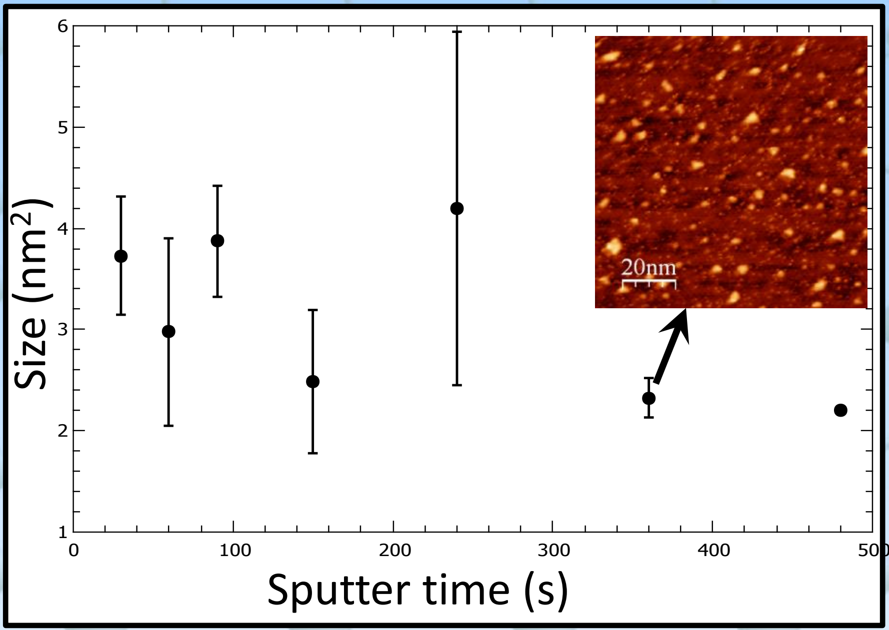
Distribution of defects in graphene

Number of Defects per 100nm^2



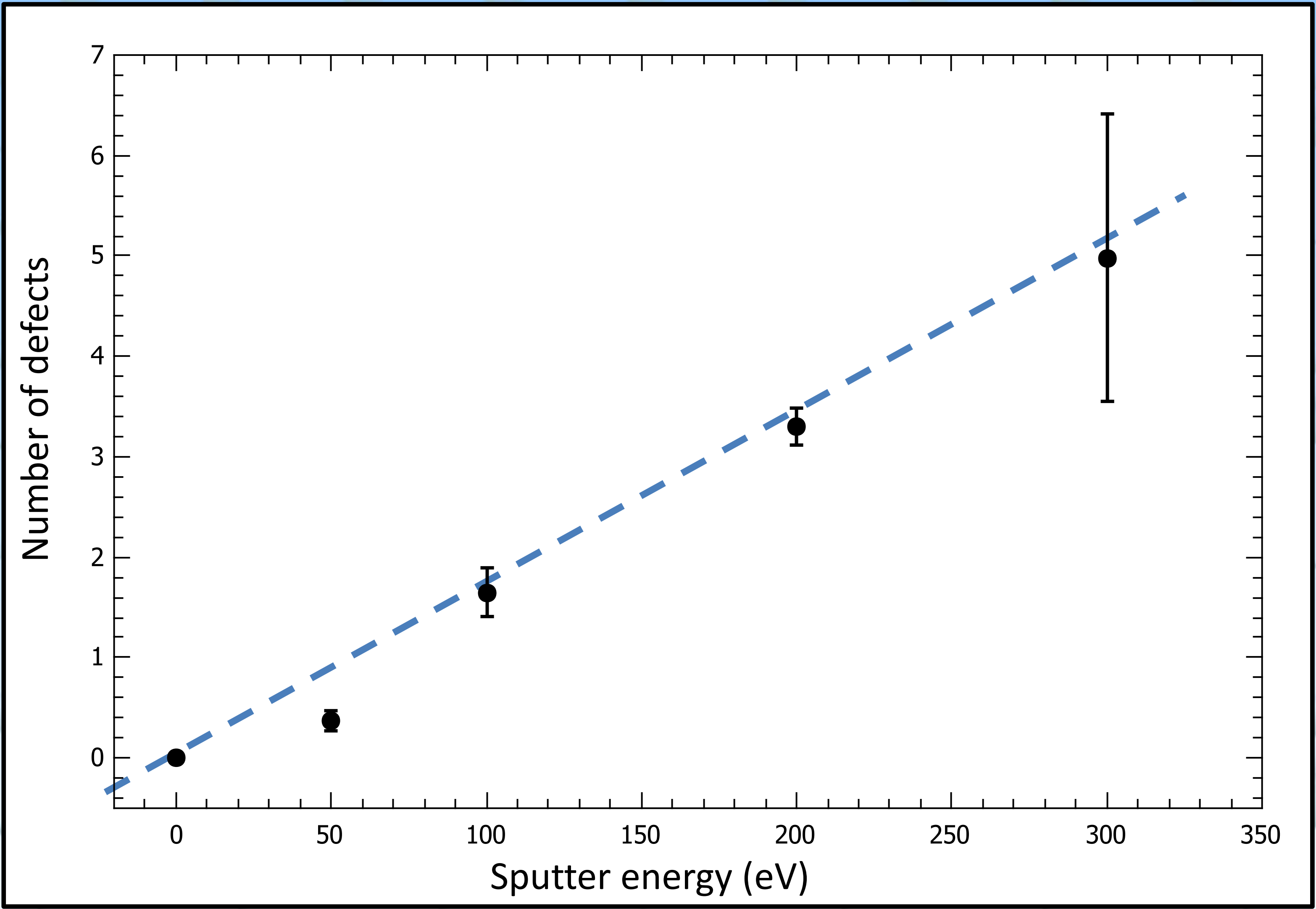
Average size of defects



Energy: 200eV,

Ion Current: (5.7 +/- 1) nA

Average number of induced defects per 100nm^2



Sputter time: 150s

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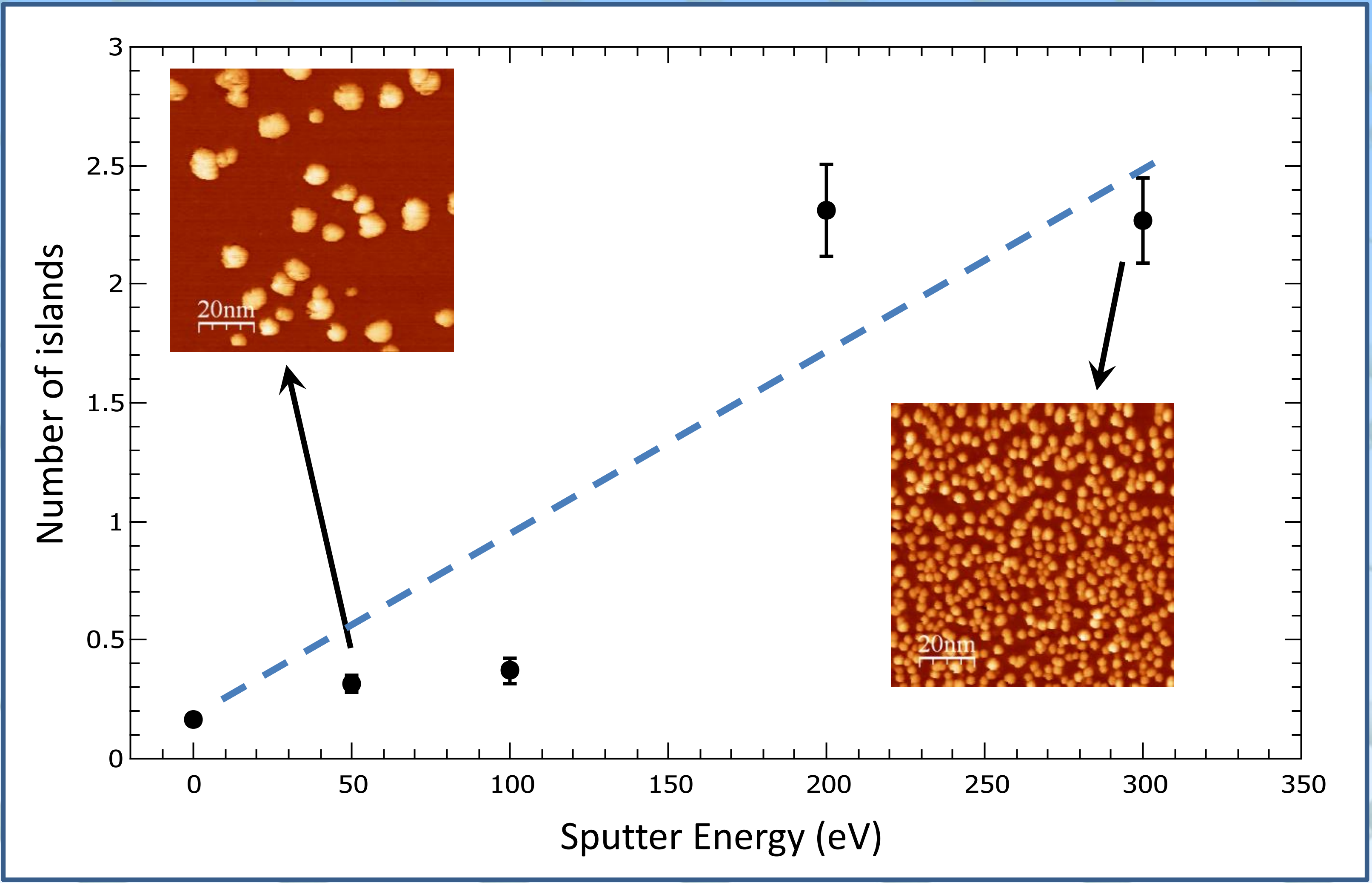
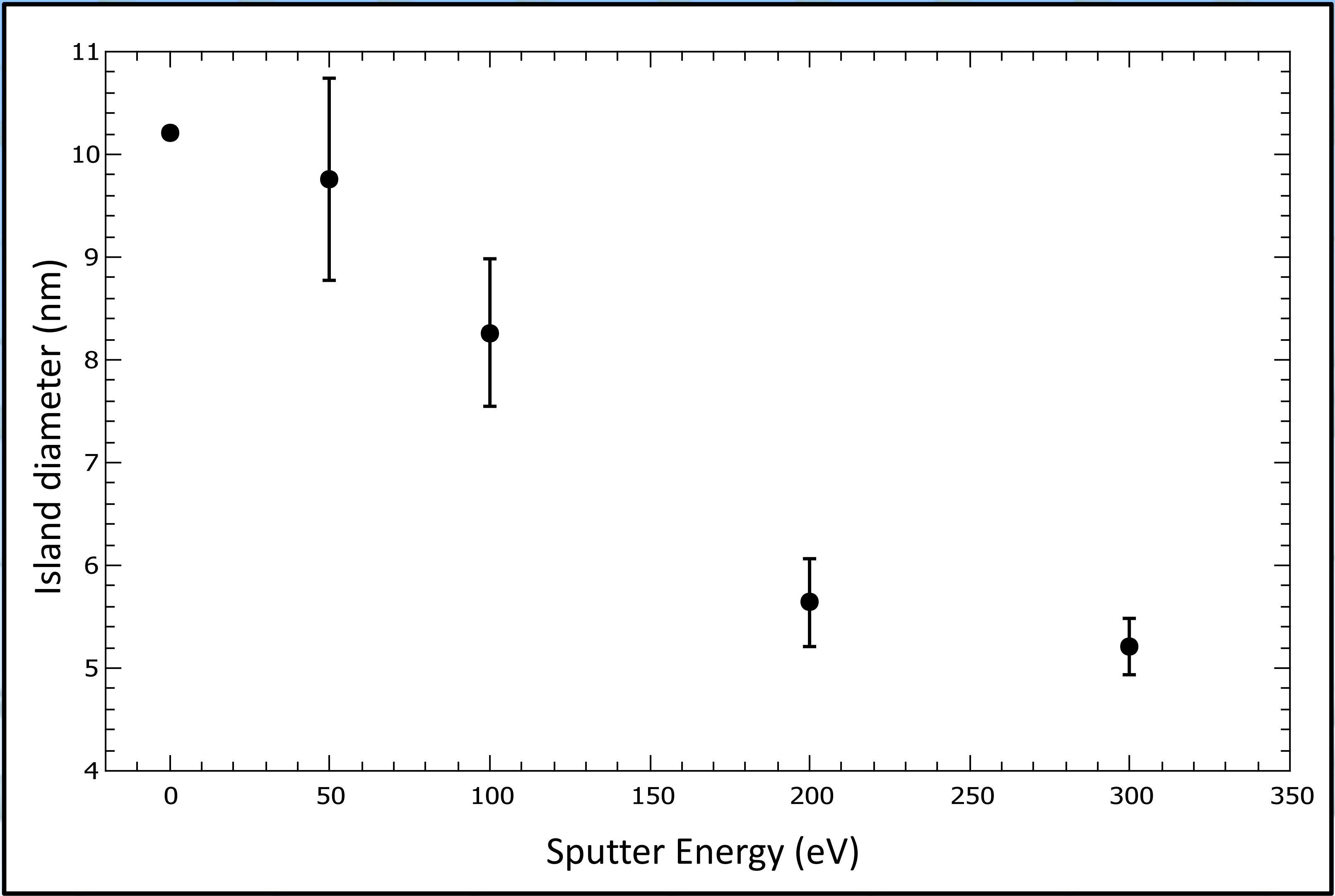
Average number of Islands per 100 nm^2

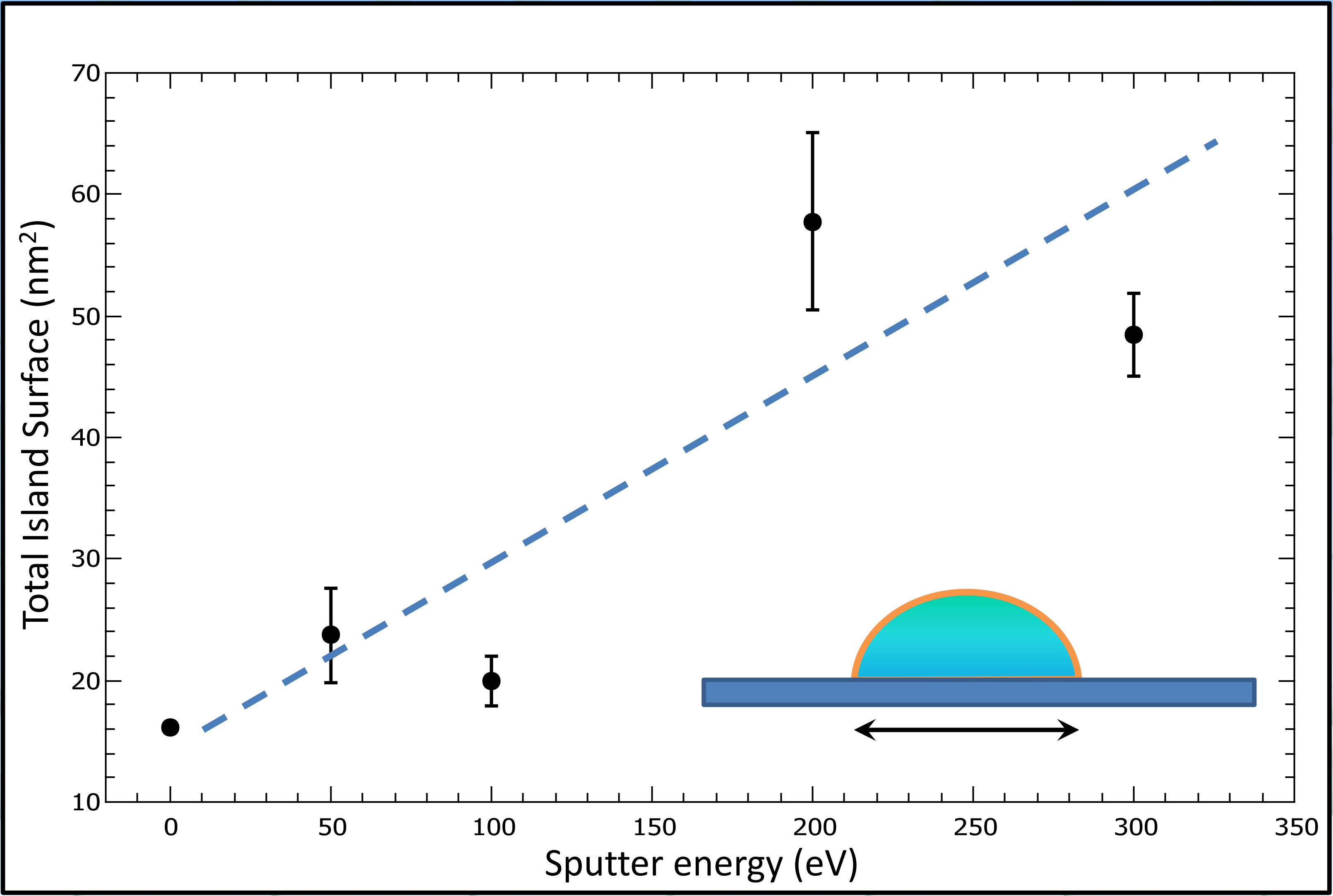


Sputtered 150 s and Deposition of 0.5 ML Titanium

Average diameter of individual Ti-Islands

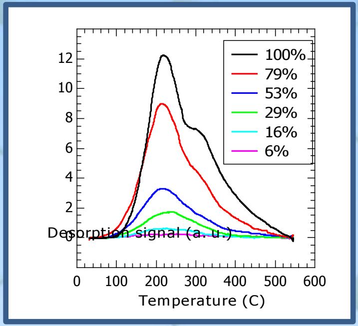


"Active" 3D-surface per 100nm^2

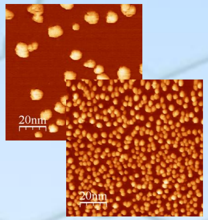


Conclusion and outlook

Experimental demonstration of Ti-functionalized graphene for hydrogen storage



Demonstration of hydrogen adsorption on functionalized graphene



Modifying the size and distribution of Islands by sputtering and increasing the active surface

Outlook: TDS verification of increase in hydrogen uptake

Acknowledgements

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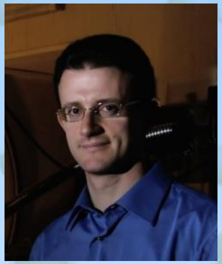
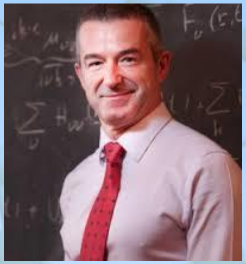

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Thank you
for your attention!

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Ministero degli Affari Esteri

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