Hydrogen storage with graphene functionalized by Titanium

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International Discussion on Hydrogen Energy and Applications

National Enterprise for nanoScience and nanoTechnology

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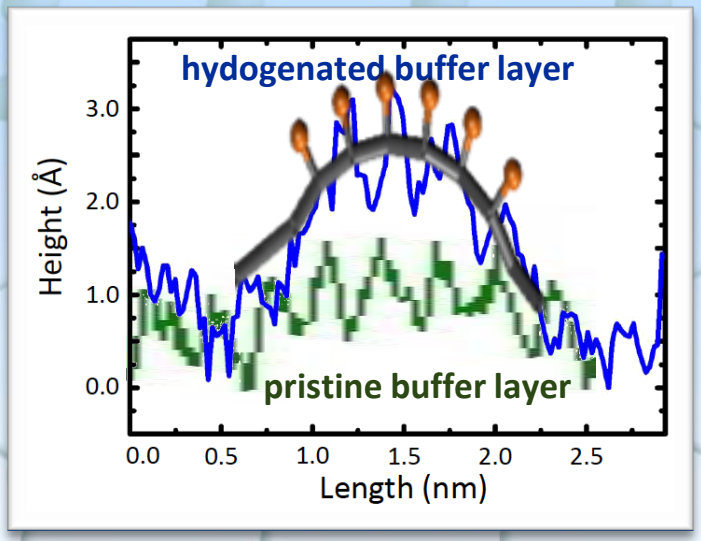
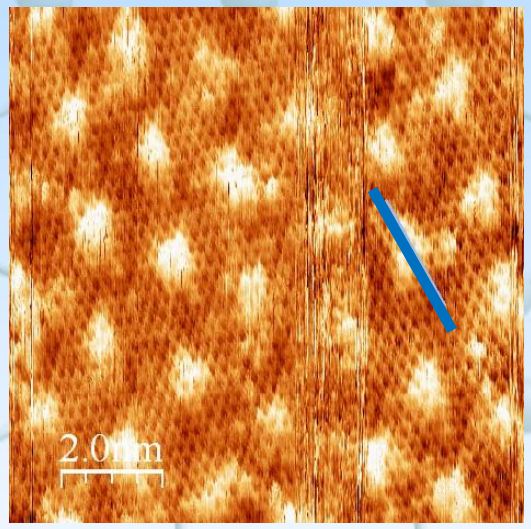
Outline

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

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

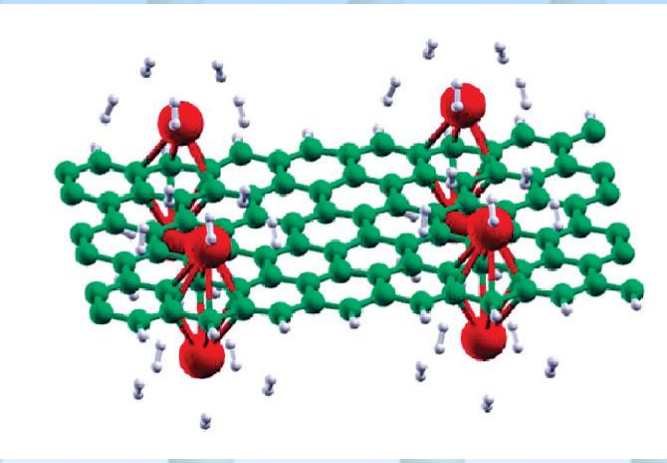




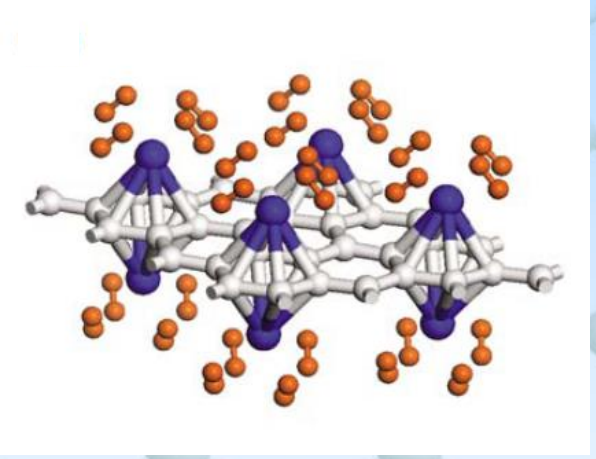
S. Goler *et al.*: J. Phys. Chem. C **117**, 11506 (2013).

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

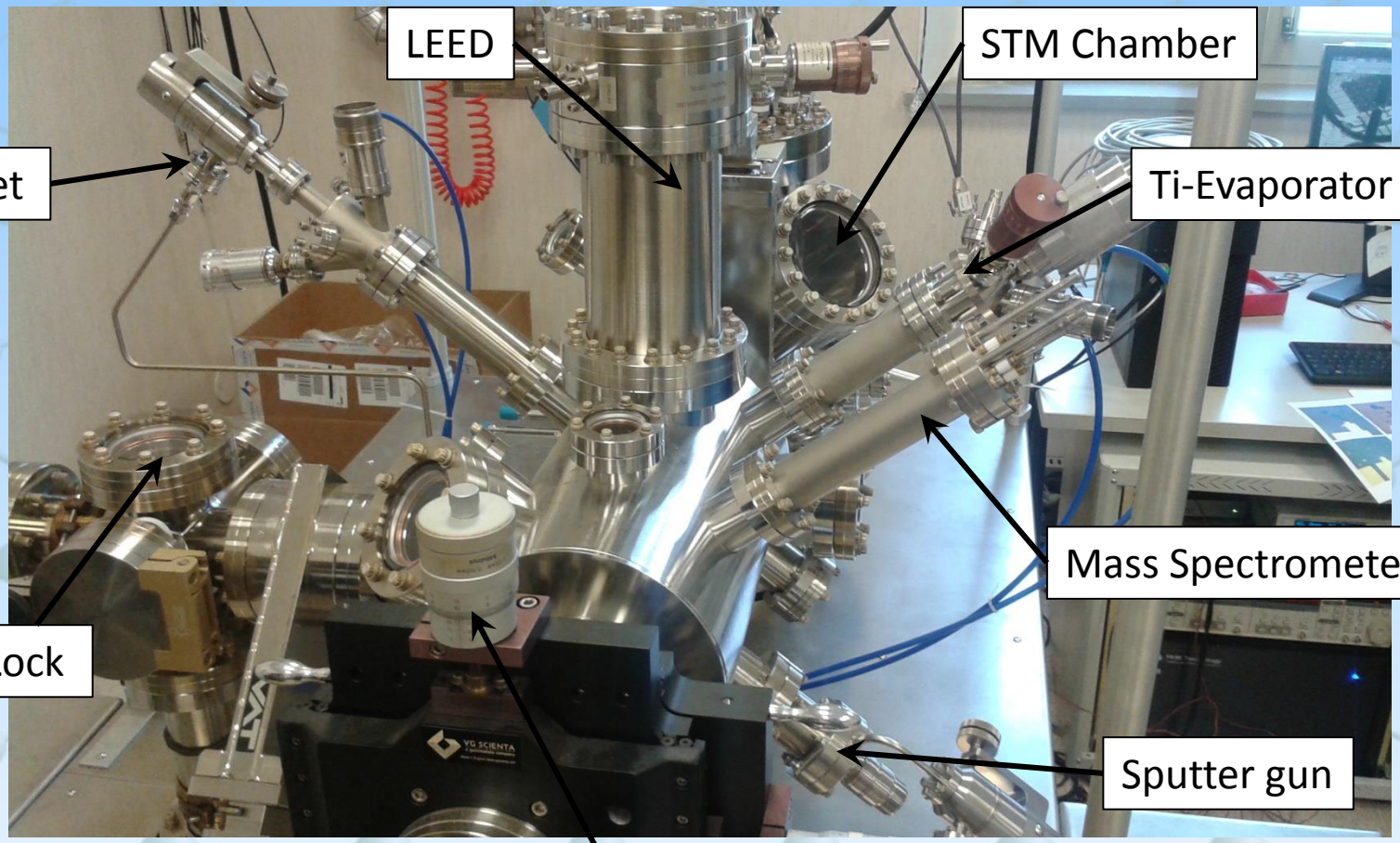


Lee et al., Nano Lett. 10 (2010) 793



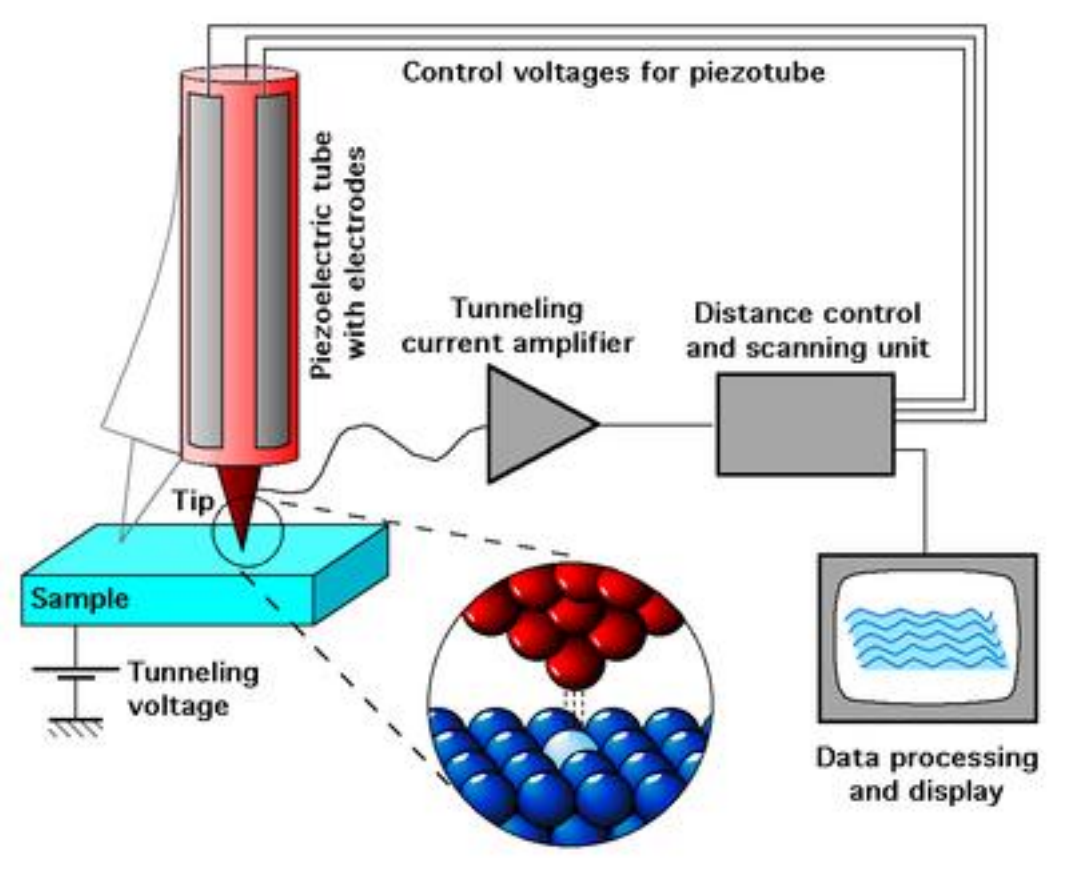
Durgen et al., PRB 77 (2007) 085405

UHV System

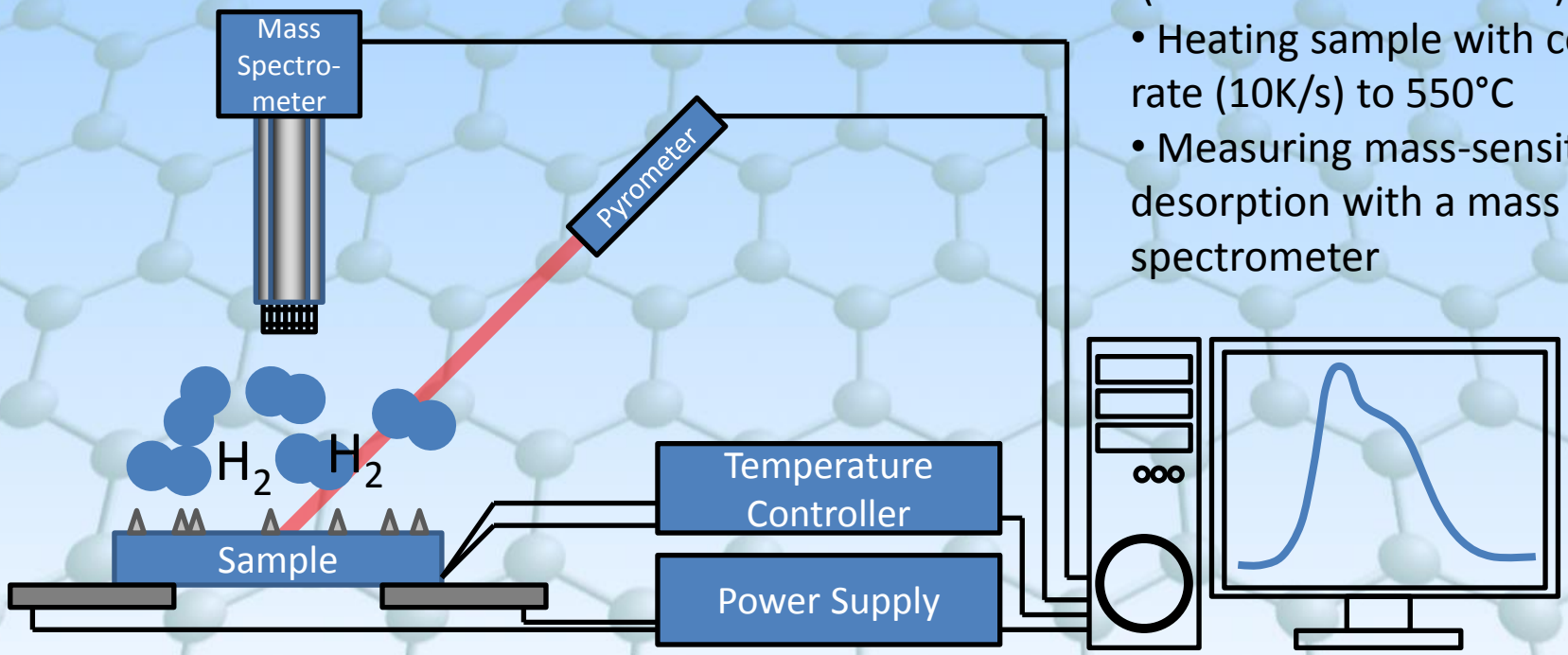


Base pressure: $<10^{-10}$mbar

Experimental Setup (STM)

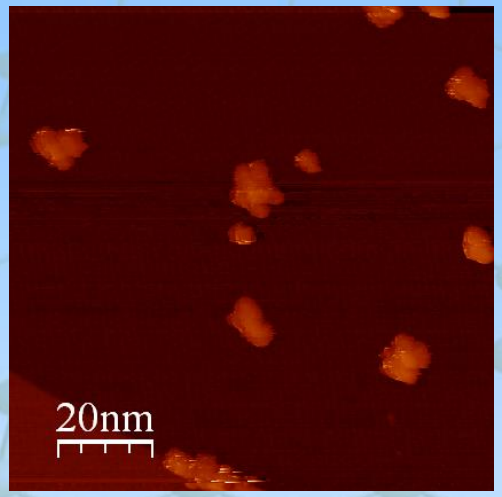


Experimental Setup (TDS)

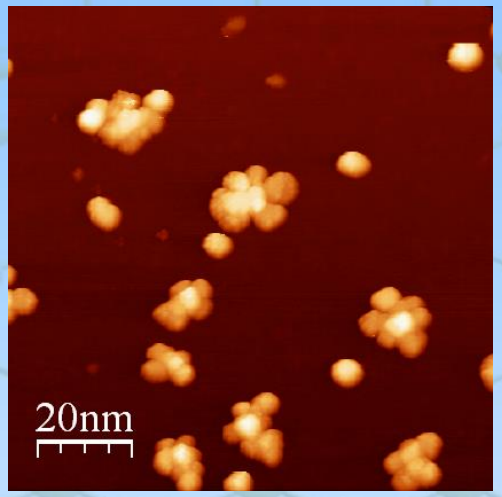


- Deposition of different amounts of Titanium
- Offering Hydrogen (D_2) ($1x10^{-7}$ mbar for 5 min)
- Heating sample with constant rate (10K/s) to 550°C
- Measuring mass-sensitive desorption with a mass spectrometer

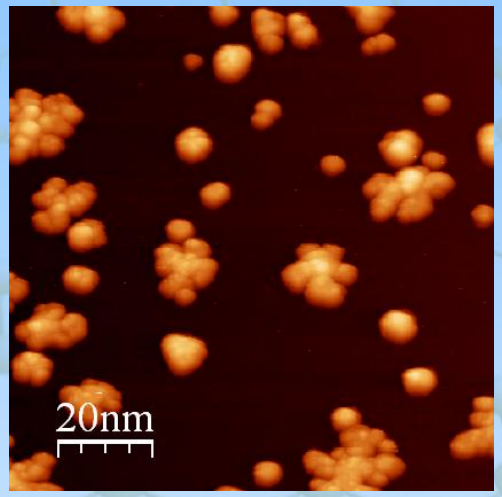
Titanium growth



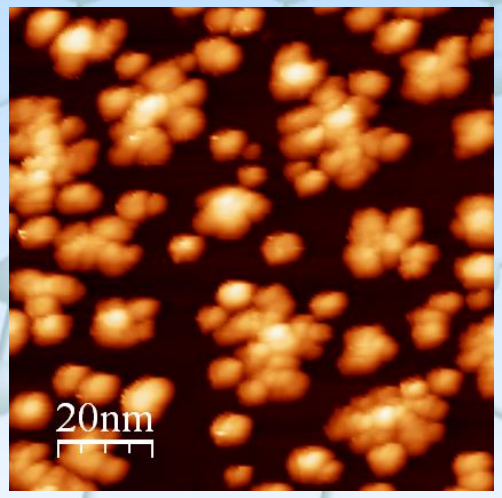
6% Coverage



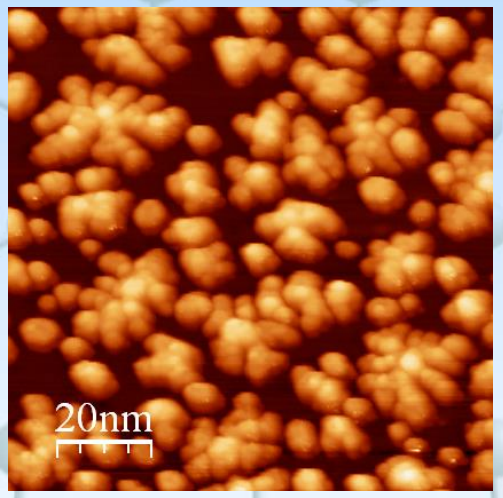
16% Coverage



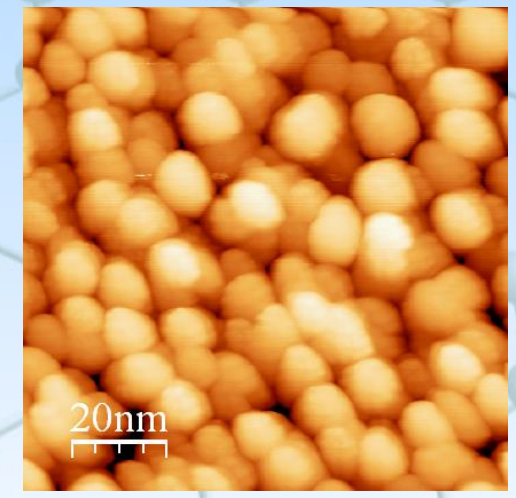
29% Coverage



53% Coverage



79% Coverage



100% Coverage

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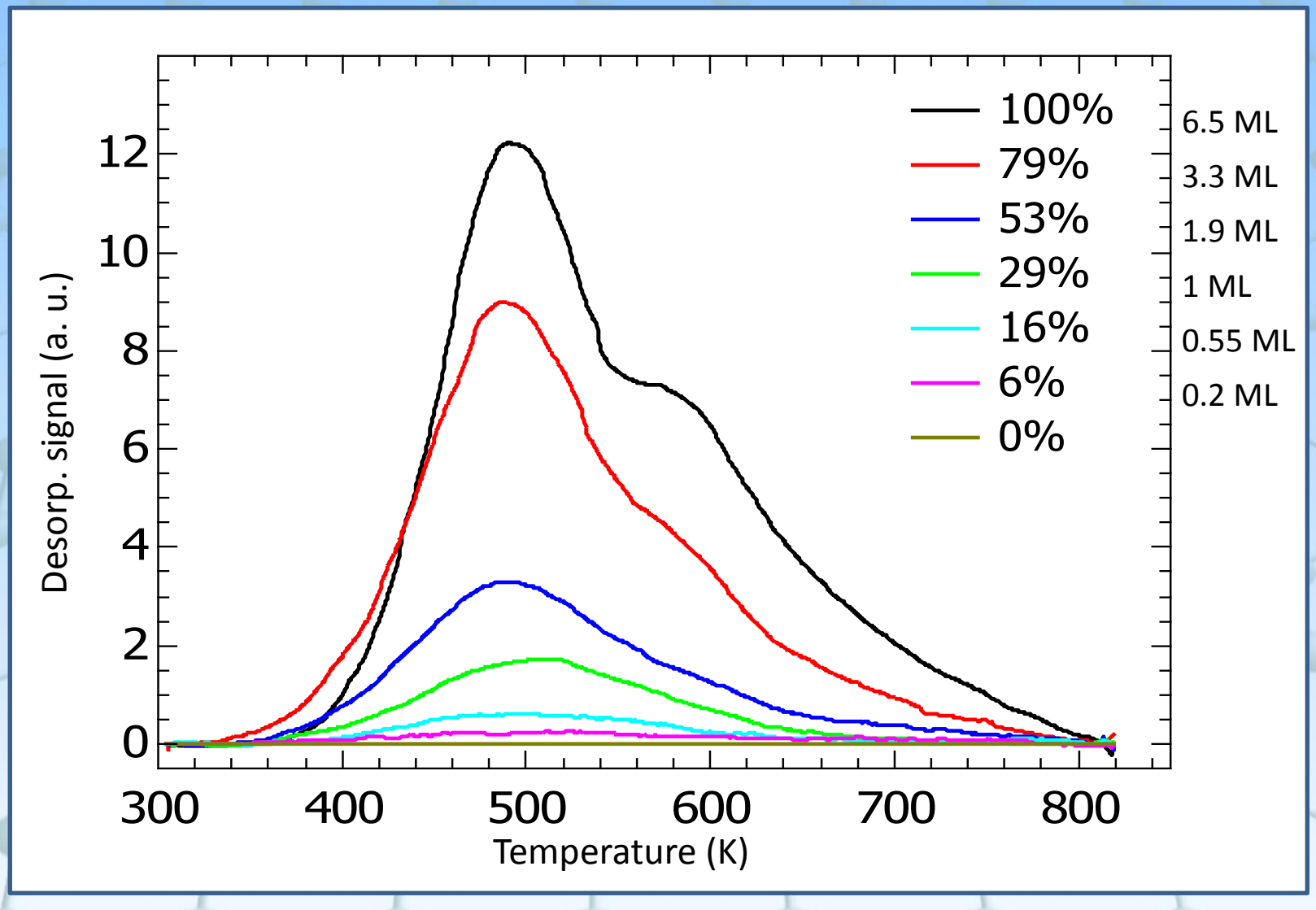
NEST

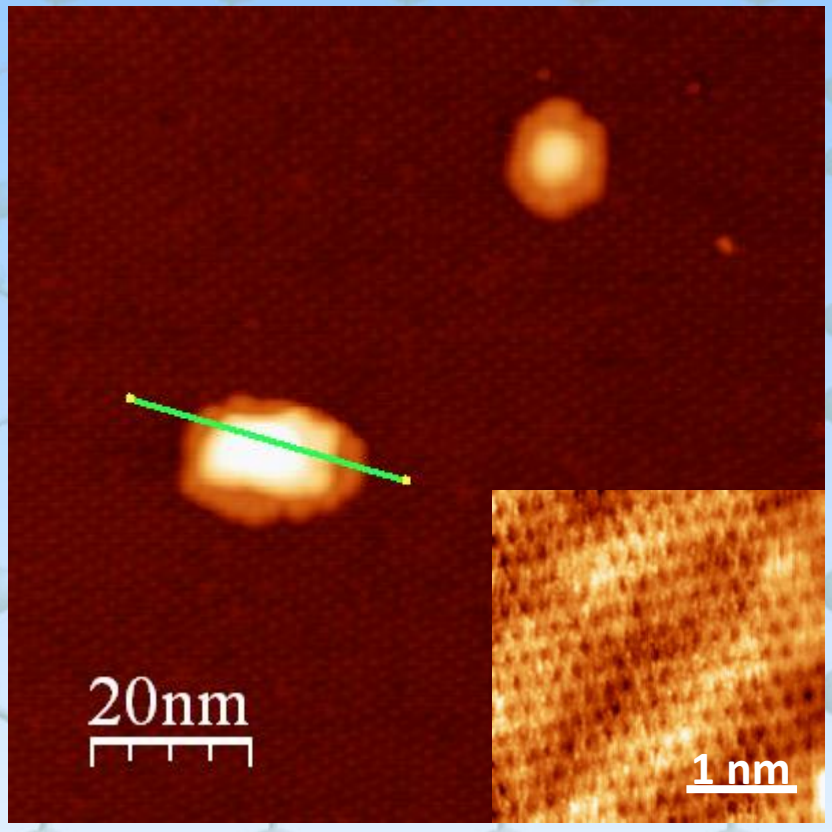
T. Mashoff *et al.*: Appl. Phys. Lett. **103**, 013903 (2013)

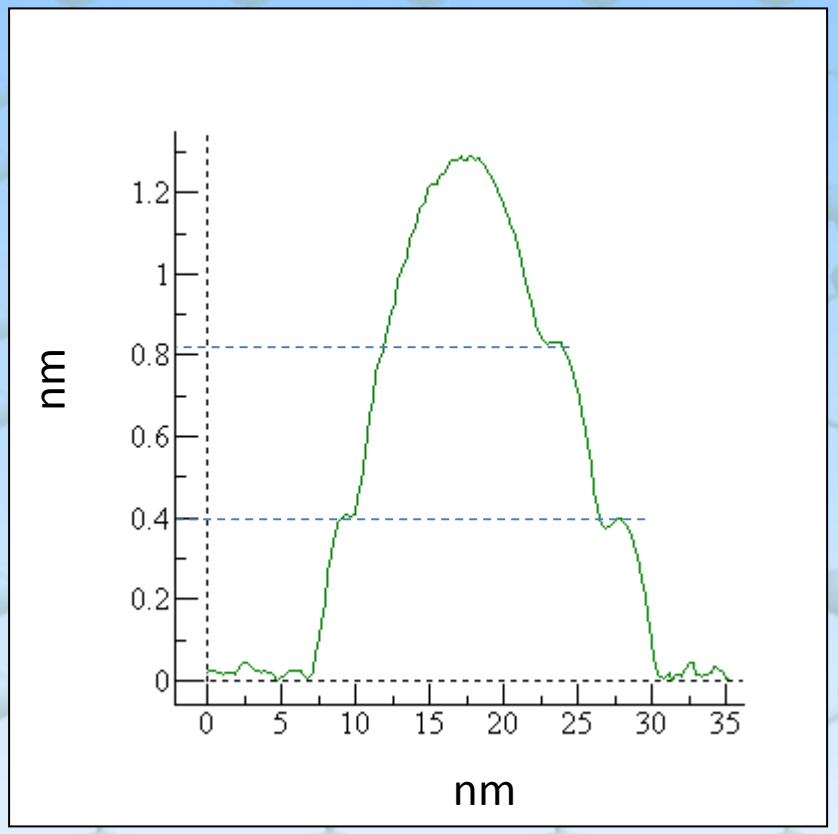
Desorption spectra of D_2 for different Ti-coverages



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

Forming of Islands



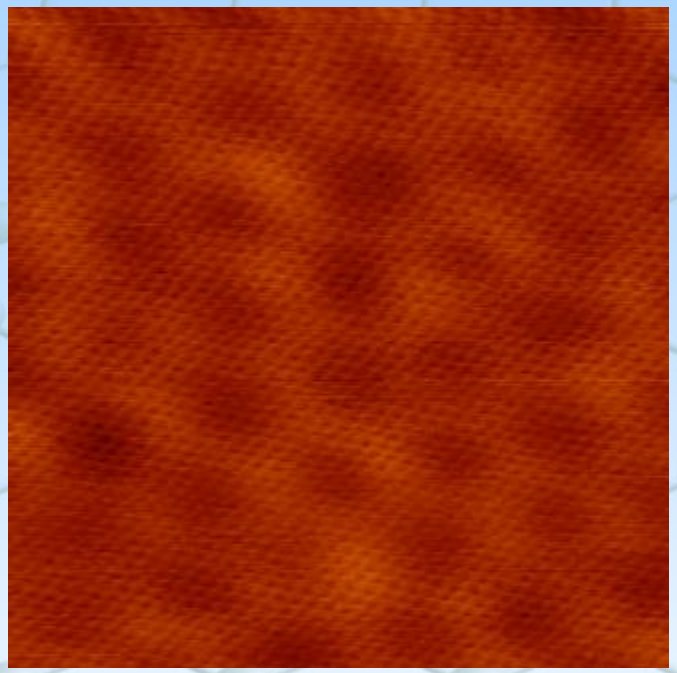


100 nm, 1 V, 82 pA

N_2 - sputtering of the graphene surface

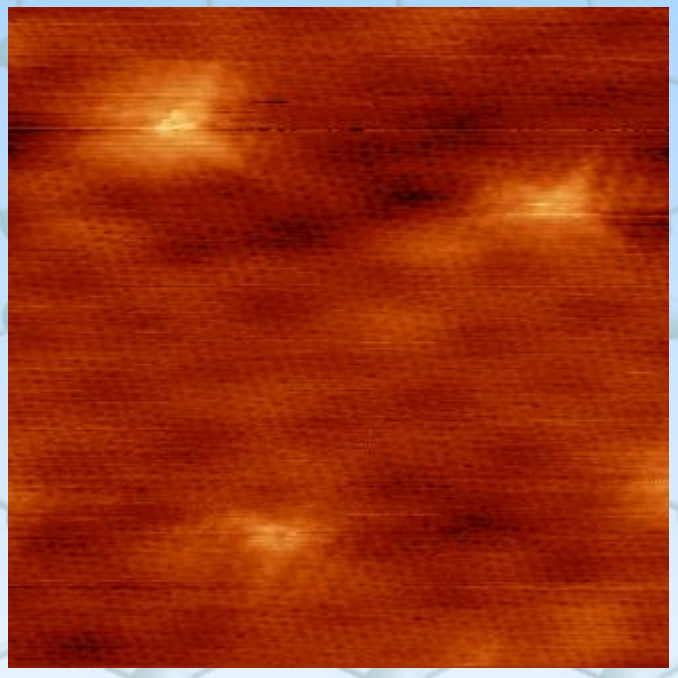
Defects in the graphene film should reduce the mobility of Ti-atoms and lead to more and smaller islands.

Clean graphene surface



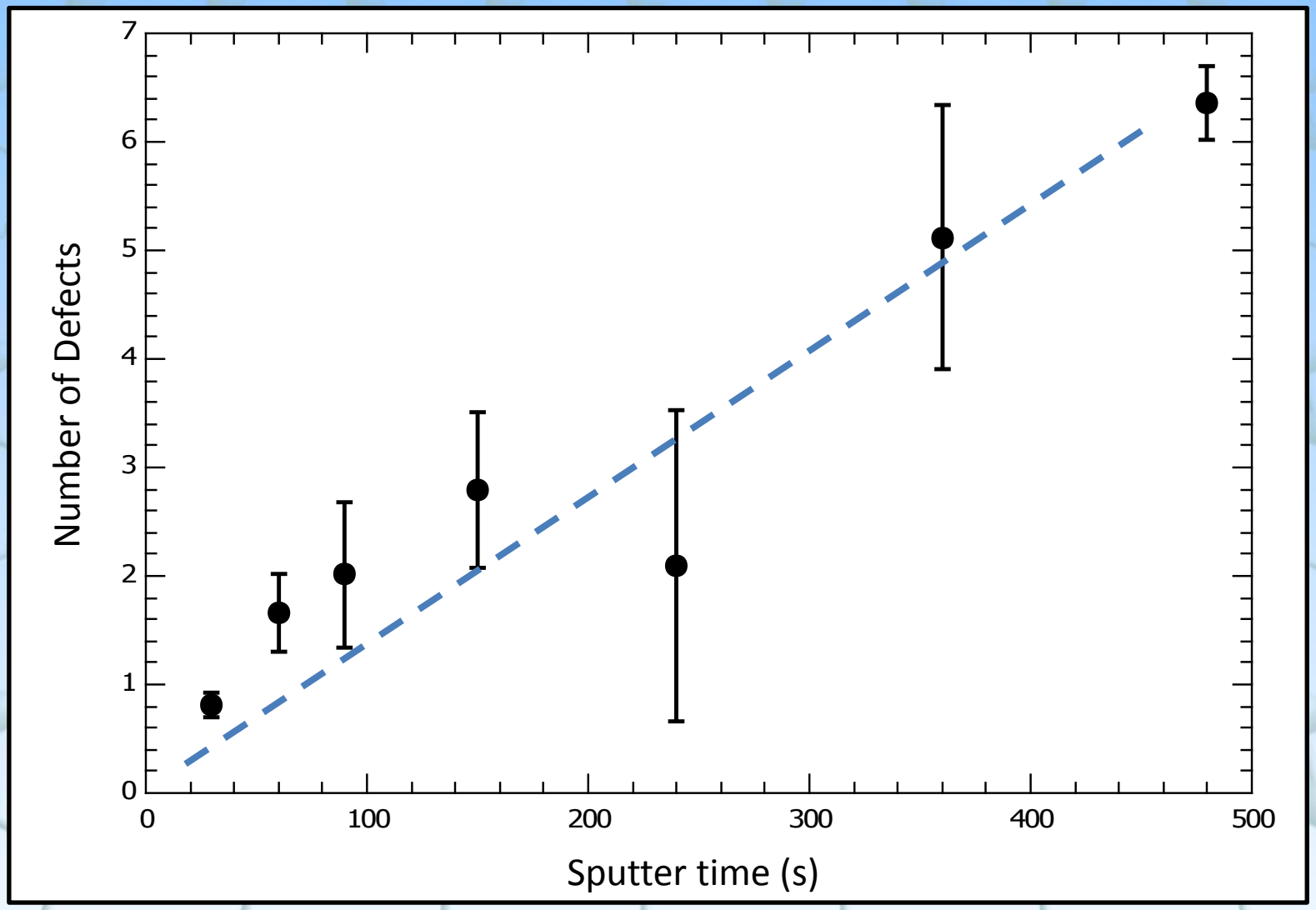
10x10 nm^2, 1V, 0.8nA

Sputtered 150s @100eV



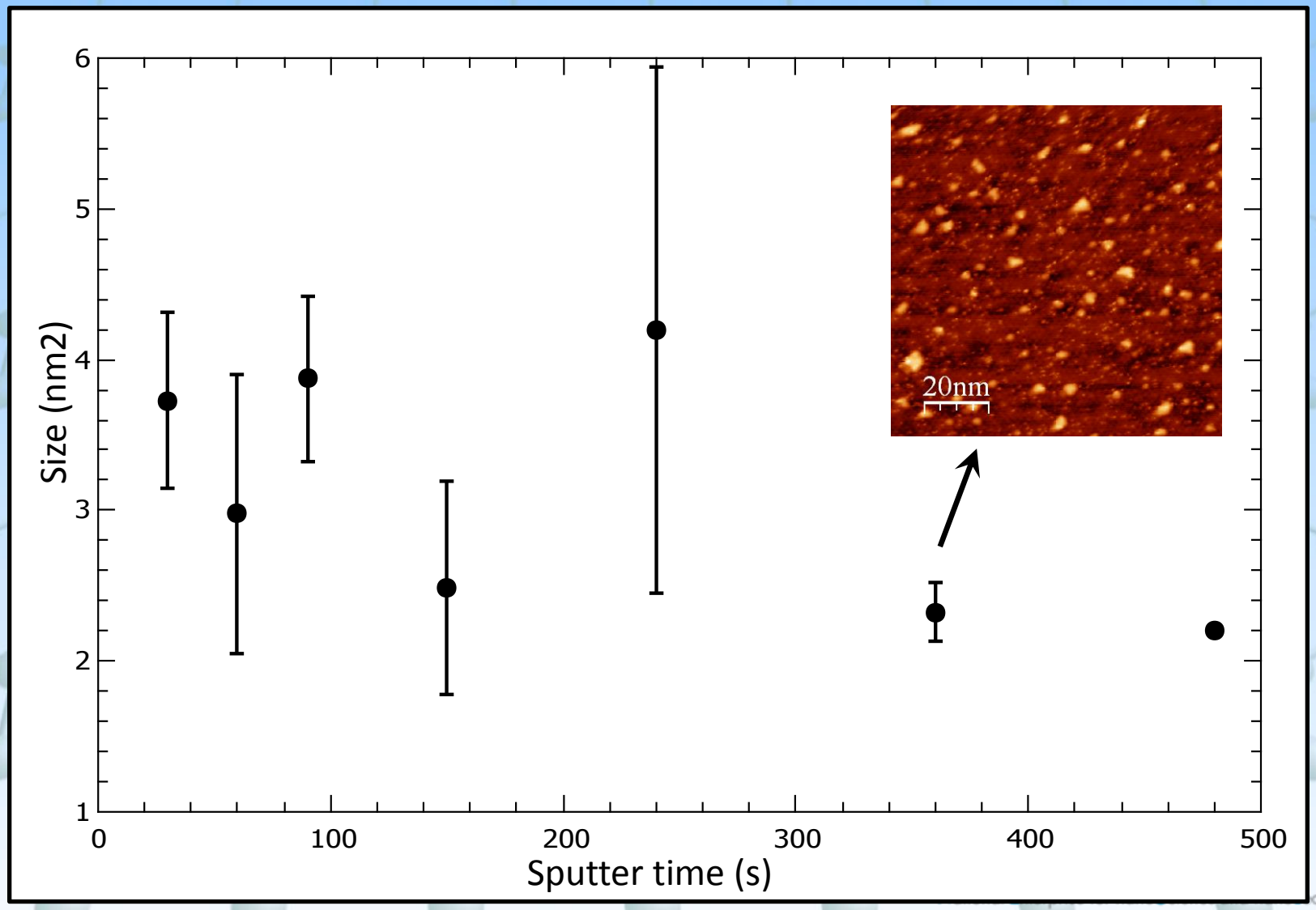
10x10 nm^2, 1V, 0.8nA

Average number of induced defects per 100nm^2

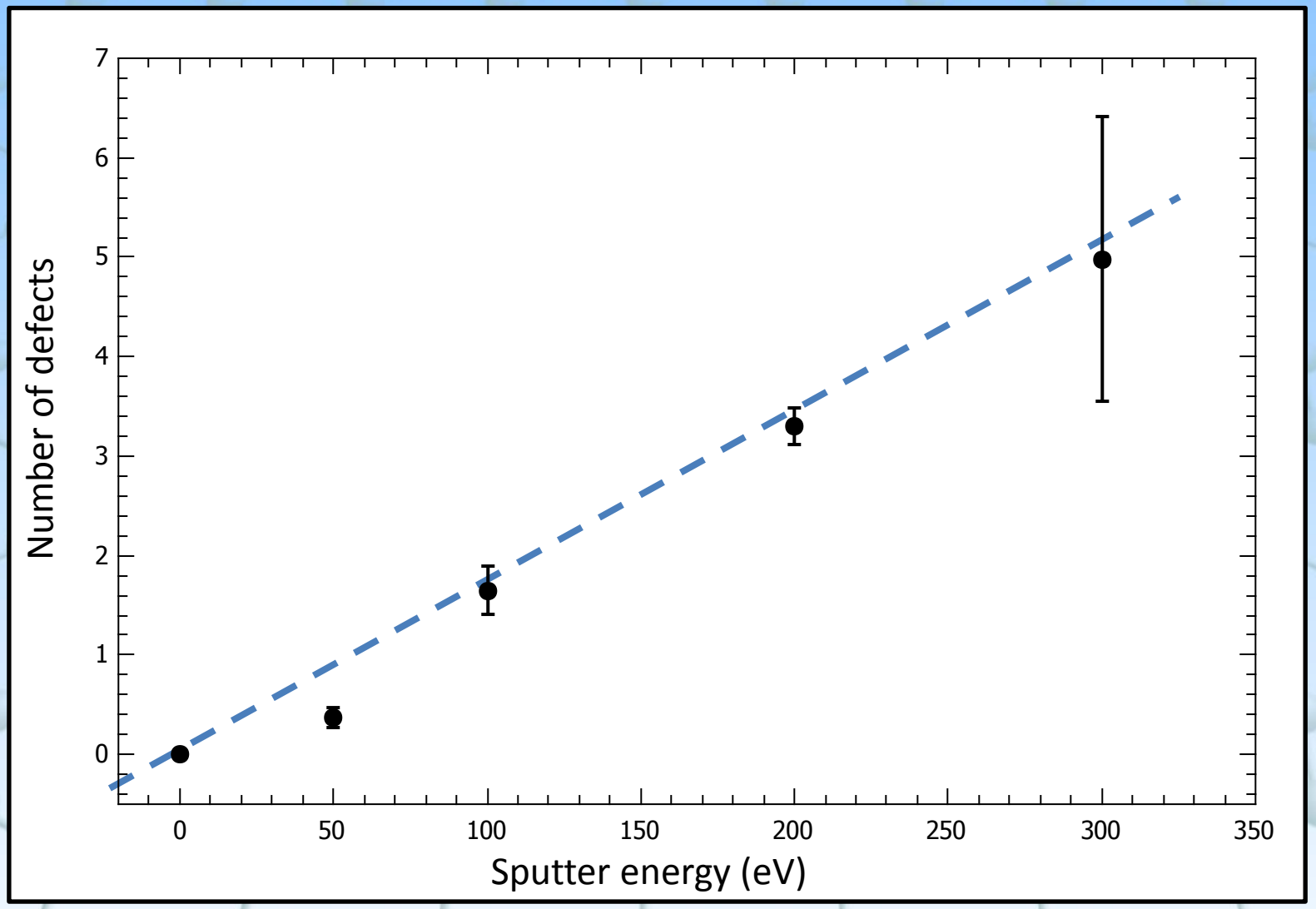


Energy: 200eV,
Ion Current: (5.7 +/- 1) nA

Average size of Defects

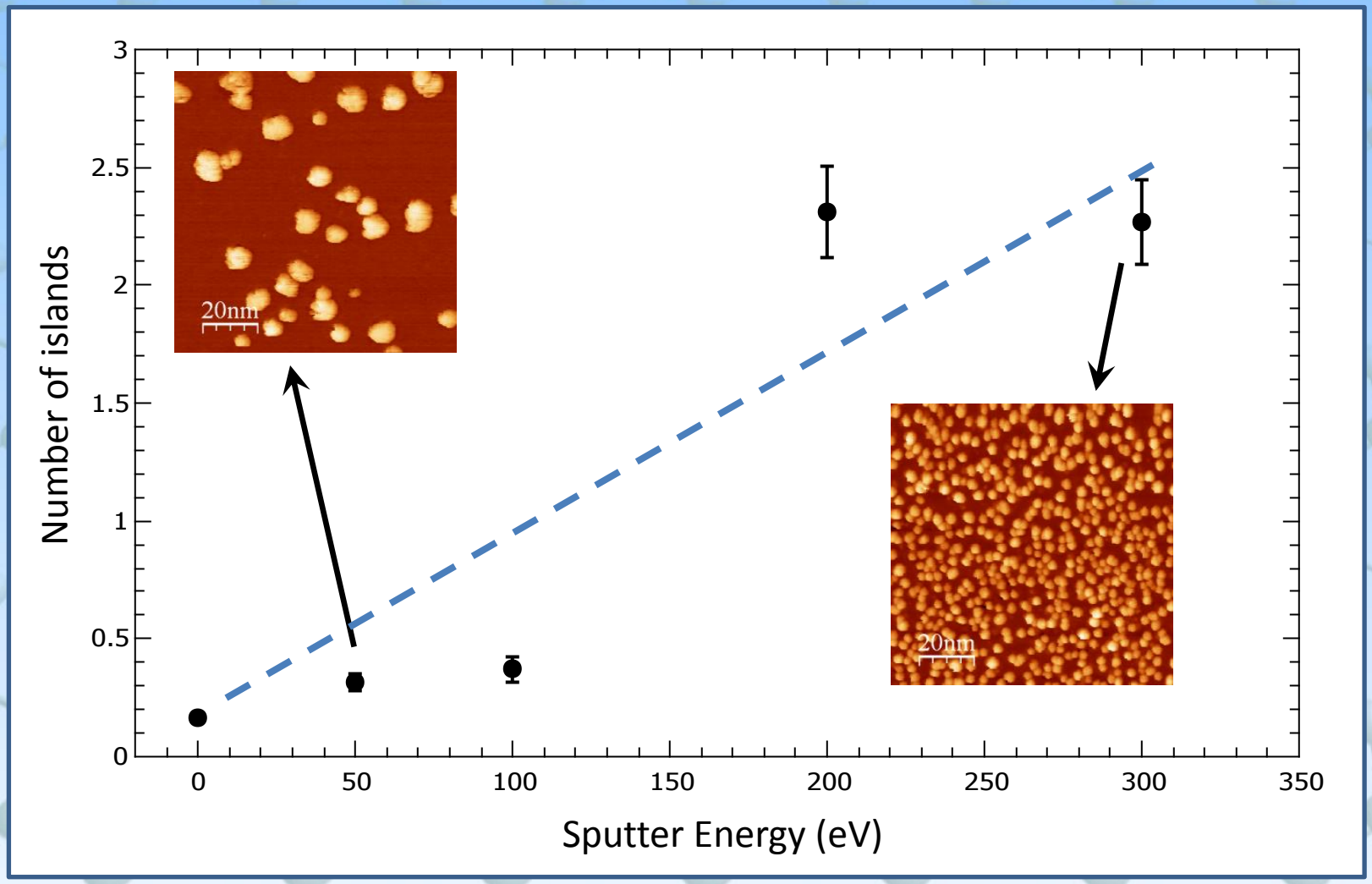


Average number of induced defects per 100nm^2



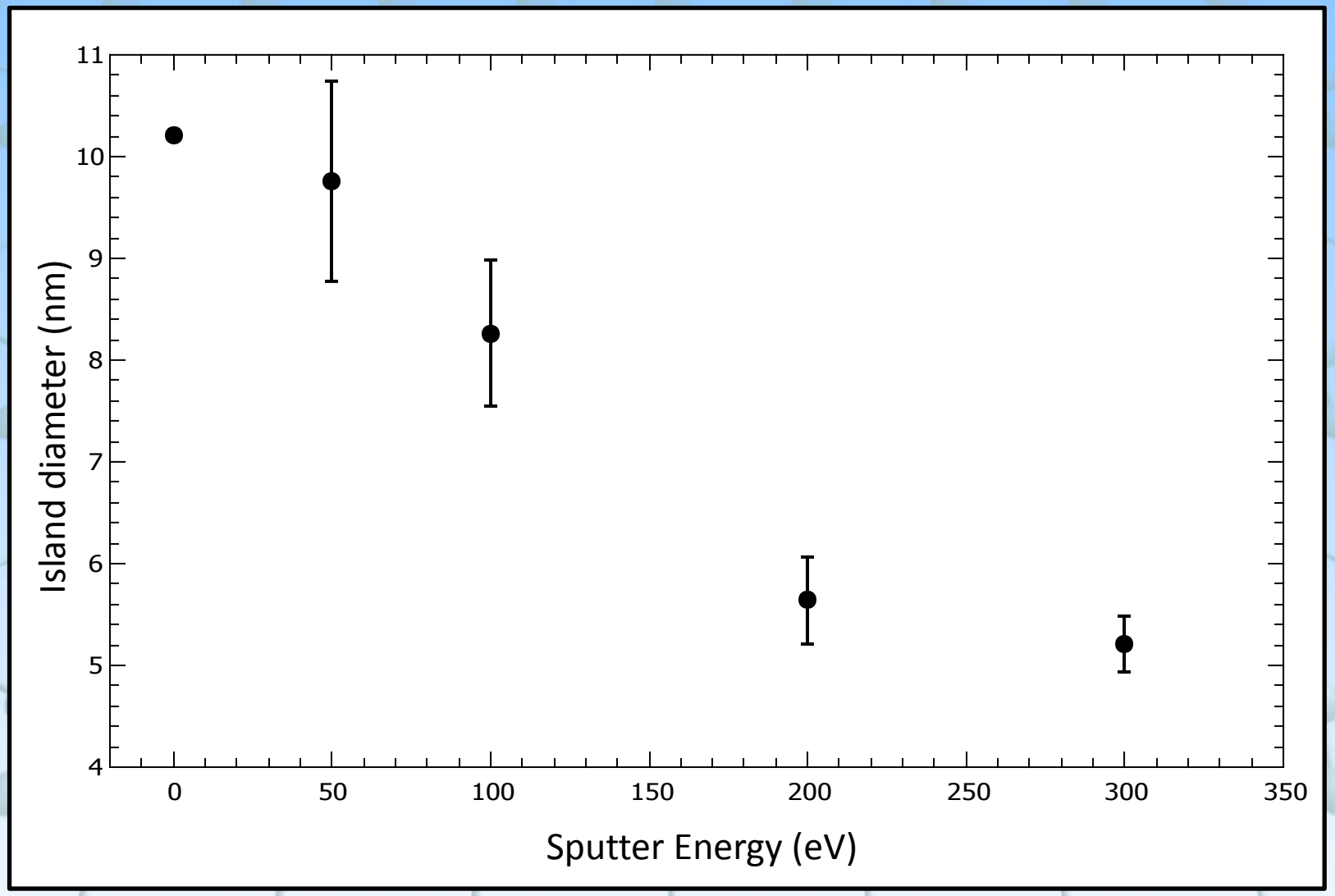
Sputter time: 150s

Average Number of Islands per 100 nm^2

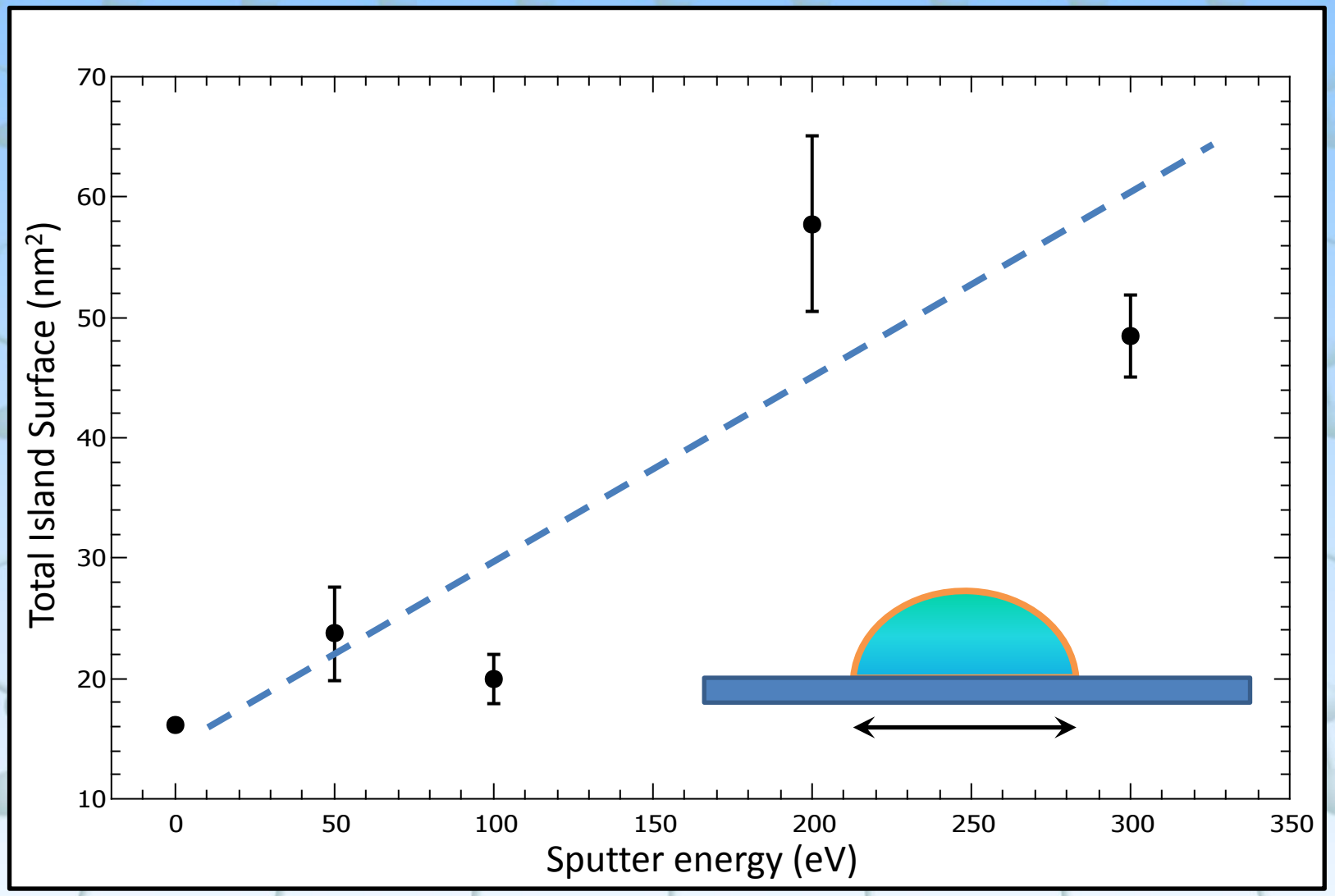


Sputtered 150 s and Deposition of 0.5 ML Titanium

Average diameter of individual Ti-Islands

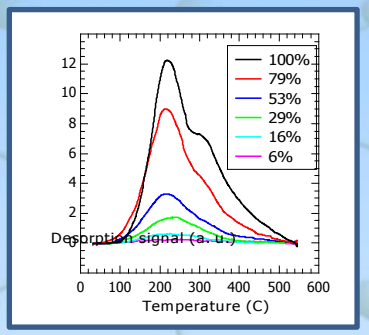


“Active” 3D-surface per 100nm^2

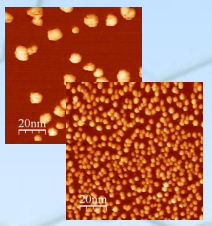


Conclusion and Outlook

First 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

Thank you

for your attention!

Funding:

Consiglio Nazionale delle Ricerche

Japan Society for the Promotion of Science
日本学術振興会

Ministero degli Affari Esteri

GRAPHENE FLAGSHIP

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