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Fundamental Research Insights

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# Hydrogen isotopes functionalization of nano-porous graphene: attainment of stable and low-defect free-standing *graphane*

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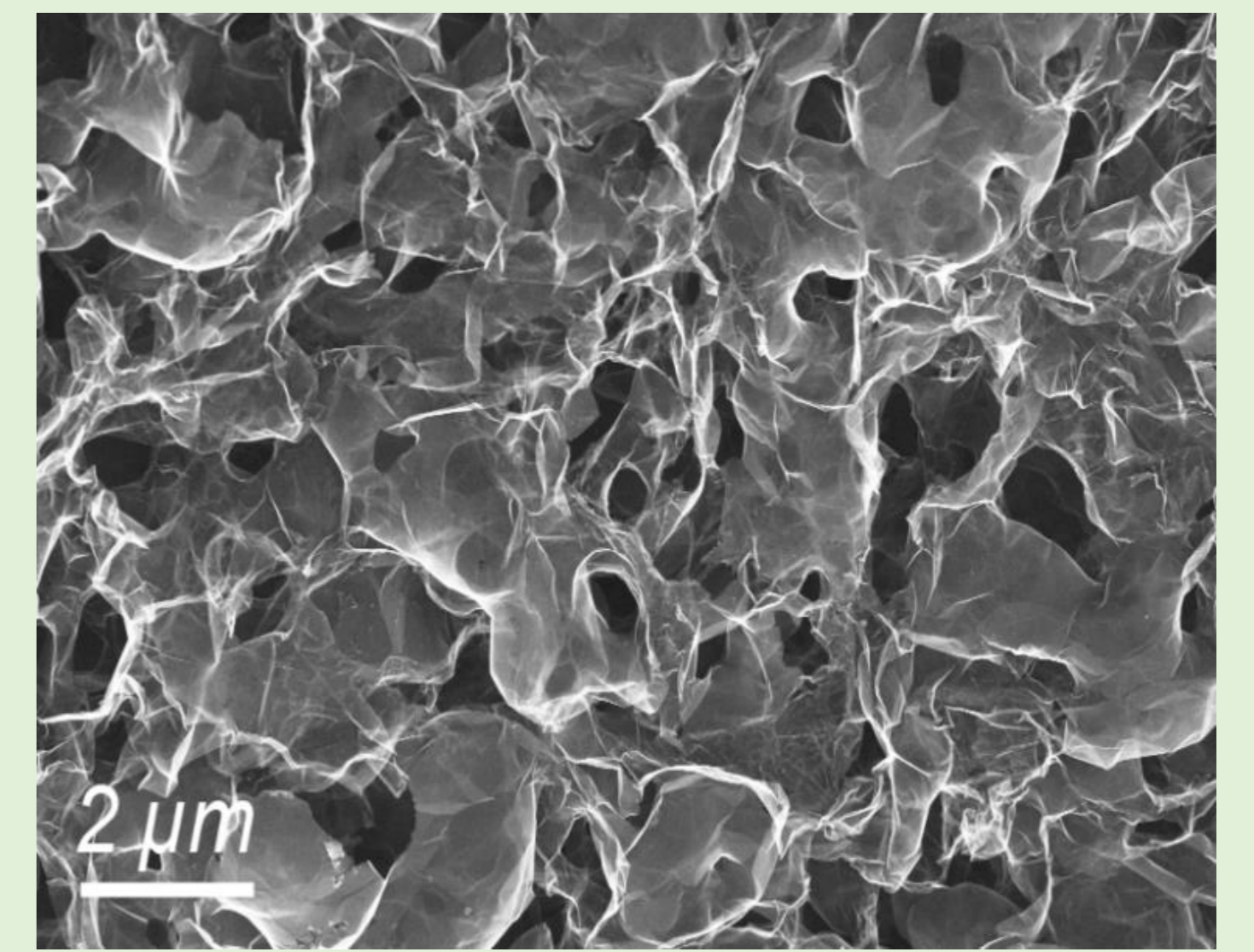
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## 1. Motivation

Semiconducting *graphane*, while maintaining the mechanical characteristics of graphene, is interesting due its potential uses in devices. Achievement of *graphane* through hydrogen isotopes adsorption on graphene is a big challenge. High quality and low-defect nano-porous graphene (NPG) is an outstanding hosting template for enhancing the loading of hydrogen. H and D depositions were performed by both low energy ion irradiation and hot temperature cracked molecules in ultra-high-vacuum (UHV). The NPG functionalized samples were studied by Raman, XPS and UPS, achieving very high quality, stable, and highly H and D uploaded free-standing *graphane*.

Here: fully free-standing nano-porous graphene



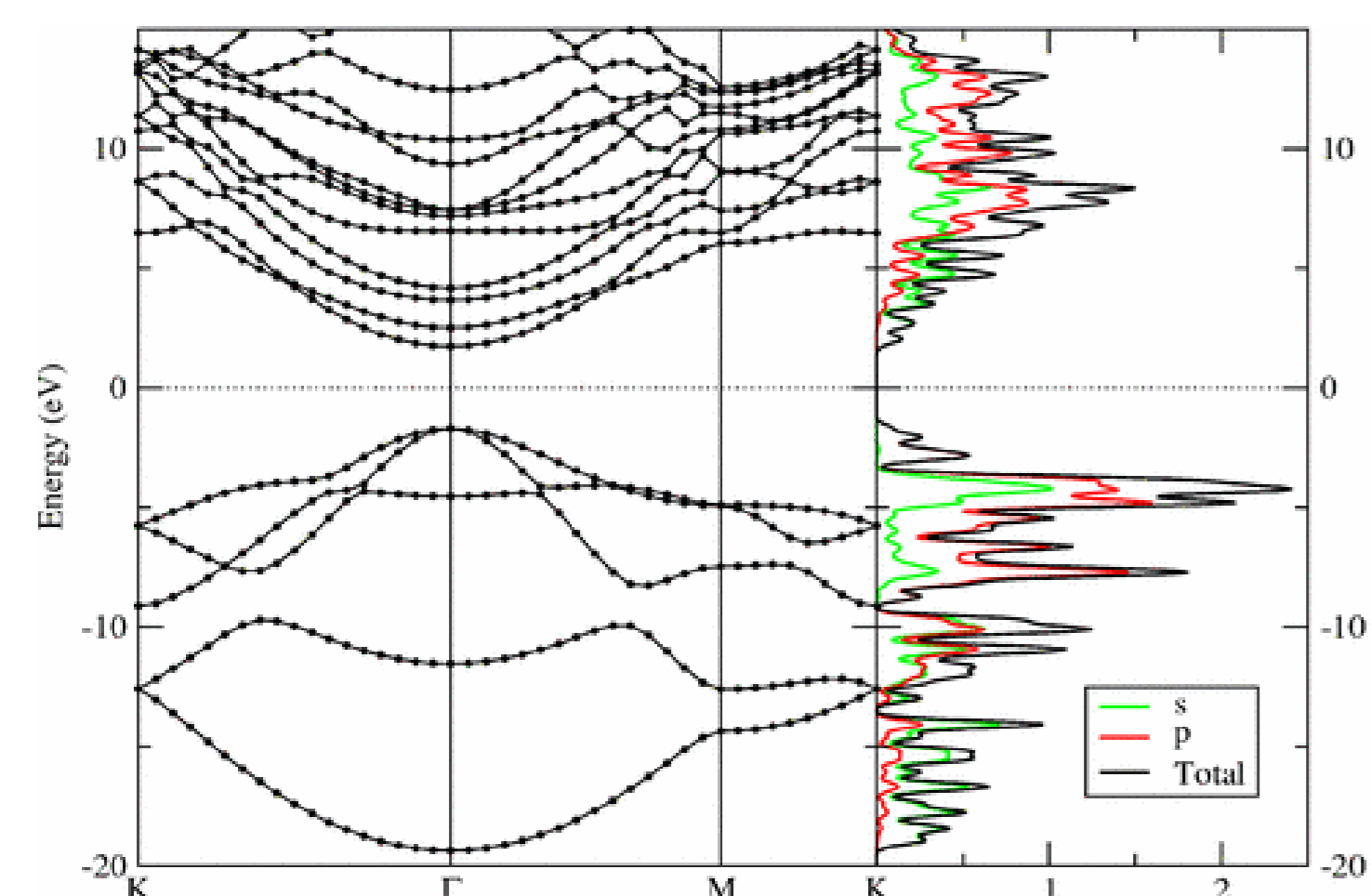
NPG, CVD synthesized on nano-porous Ni template\*  
→ fully free-standing and very high-quality\*\*

\*Ito, et al., Angew. Chem. Int. Ed. 53, 4822 (2014)  
\*\* Di Bernardo et al., ACS Omega 2, 3691 (2017)

H and D decoration of NPG, by:

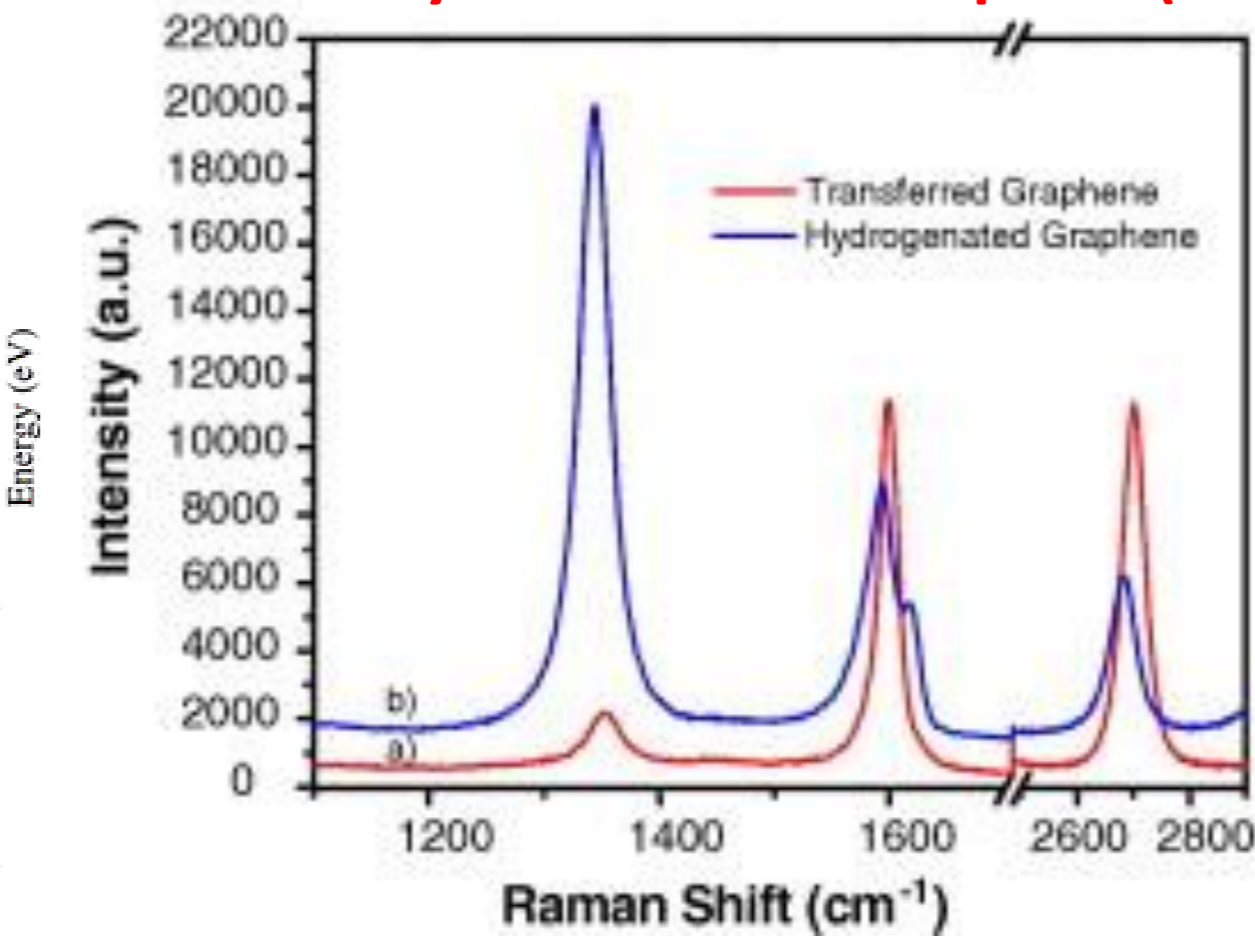
- low-energy (6 eV) ion irradiation
- hot temperature (2100 K) cracked molecule irradiation in UHV

Graphane predicted to be a semiconductor

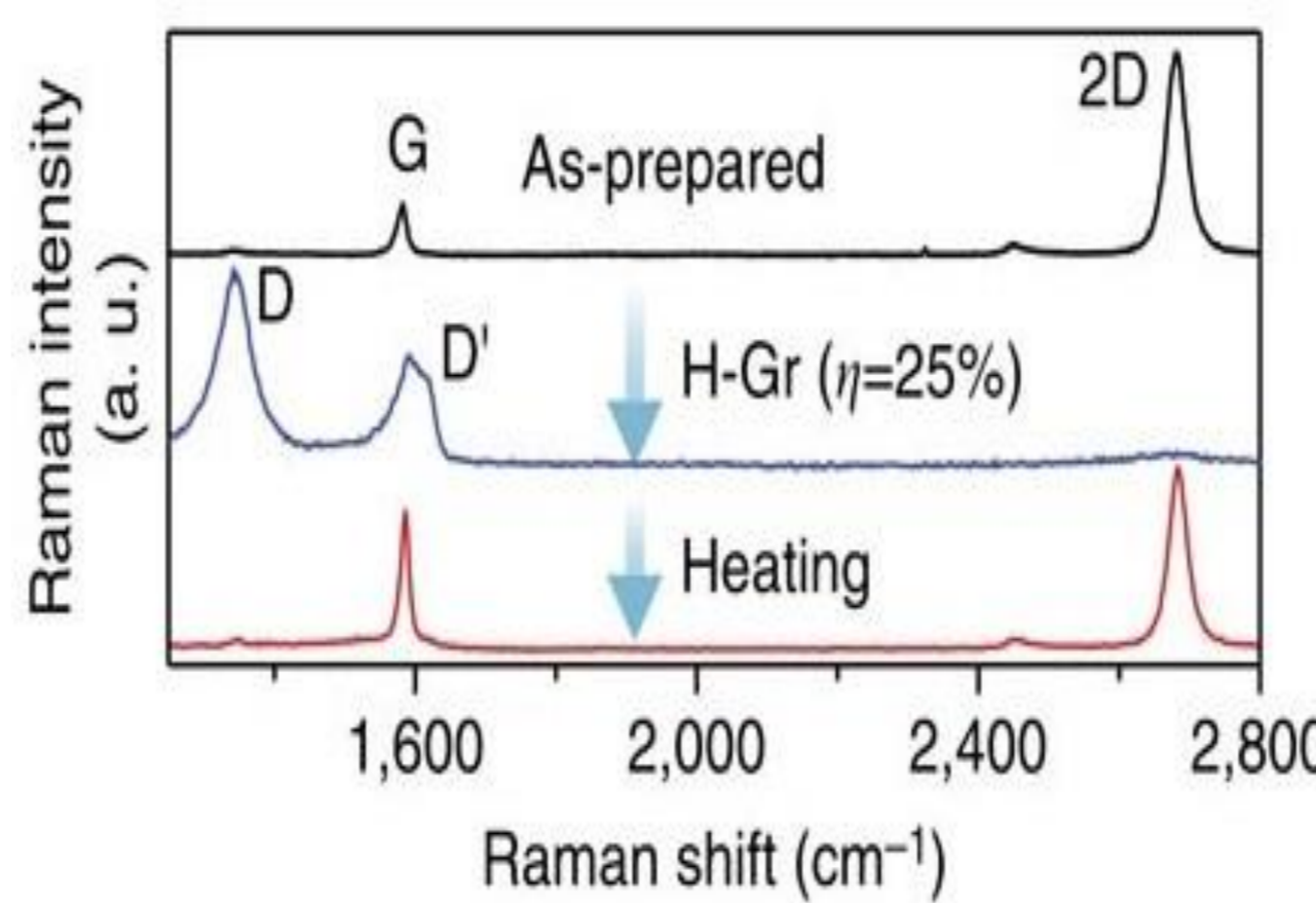


Sofo et al., Phys. Rev. B 75, 153401 (2007)

Previously: H on graphene flakes or supported graphene → high defect-density and low-T desorption (Raman spectroscopy)



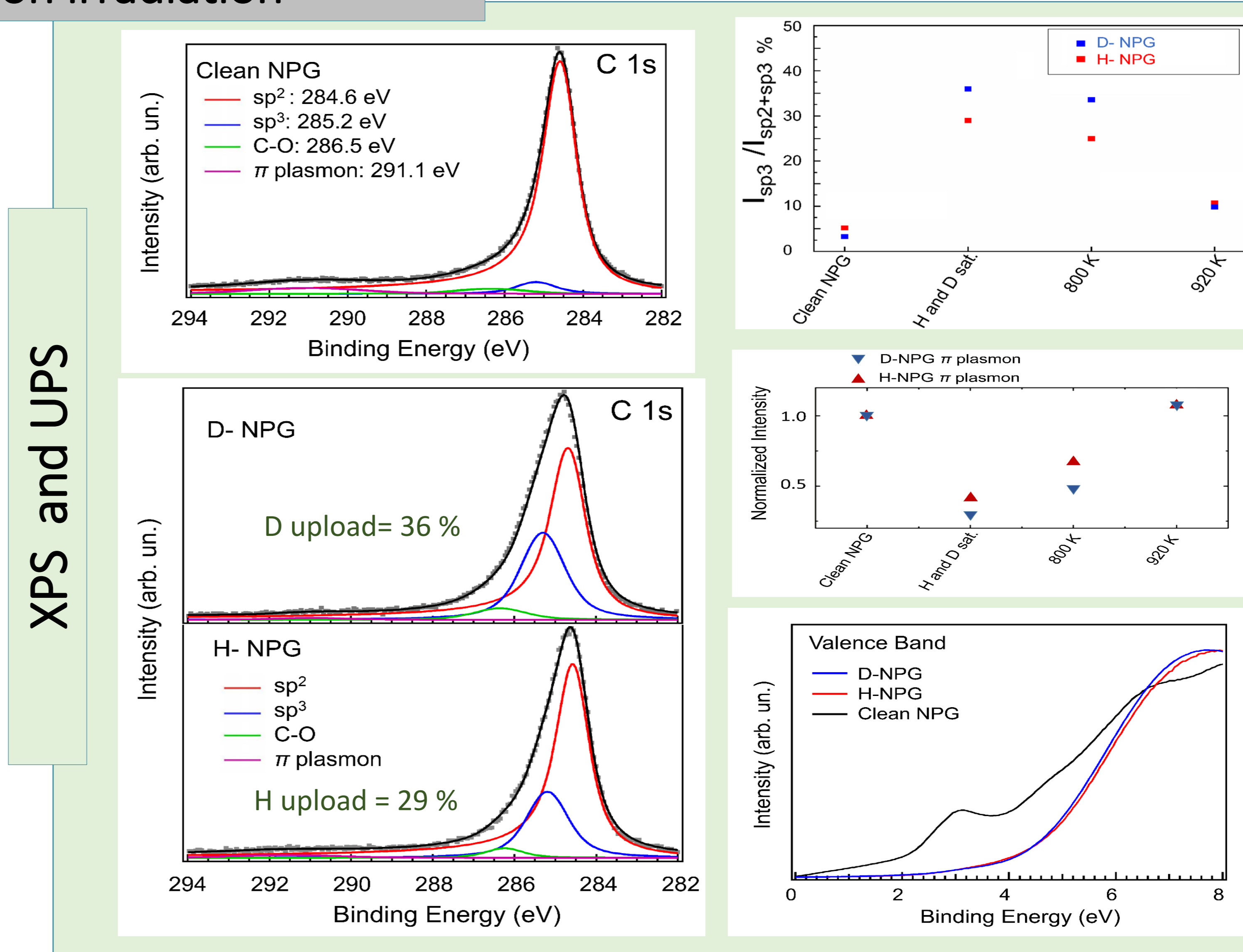
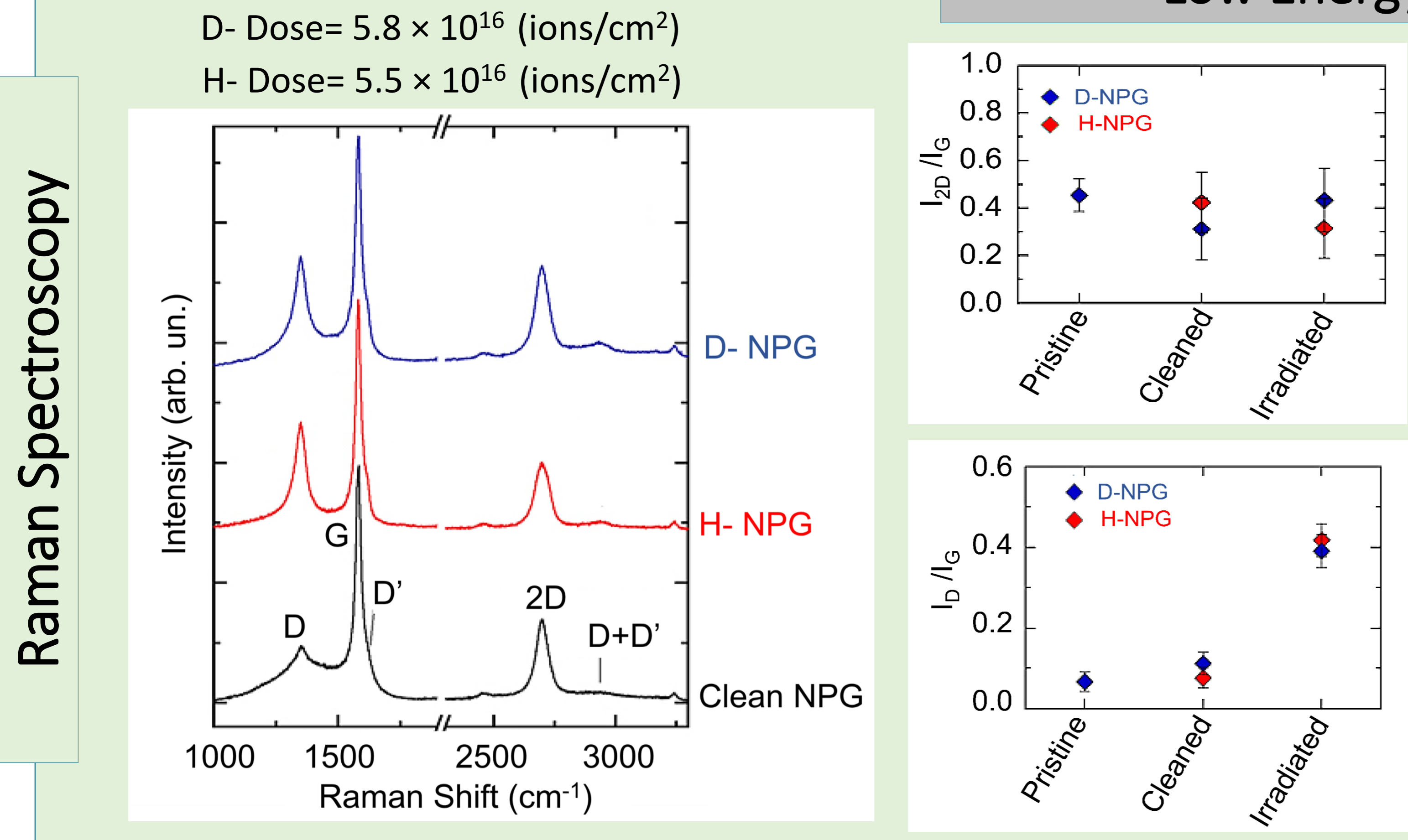
Burgess et alii, Carbon 49, 4420 (2011)



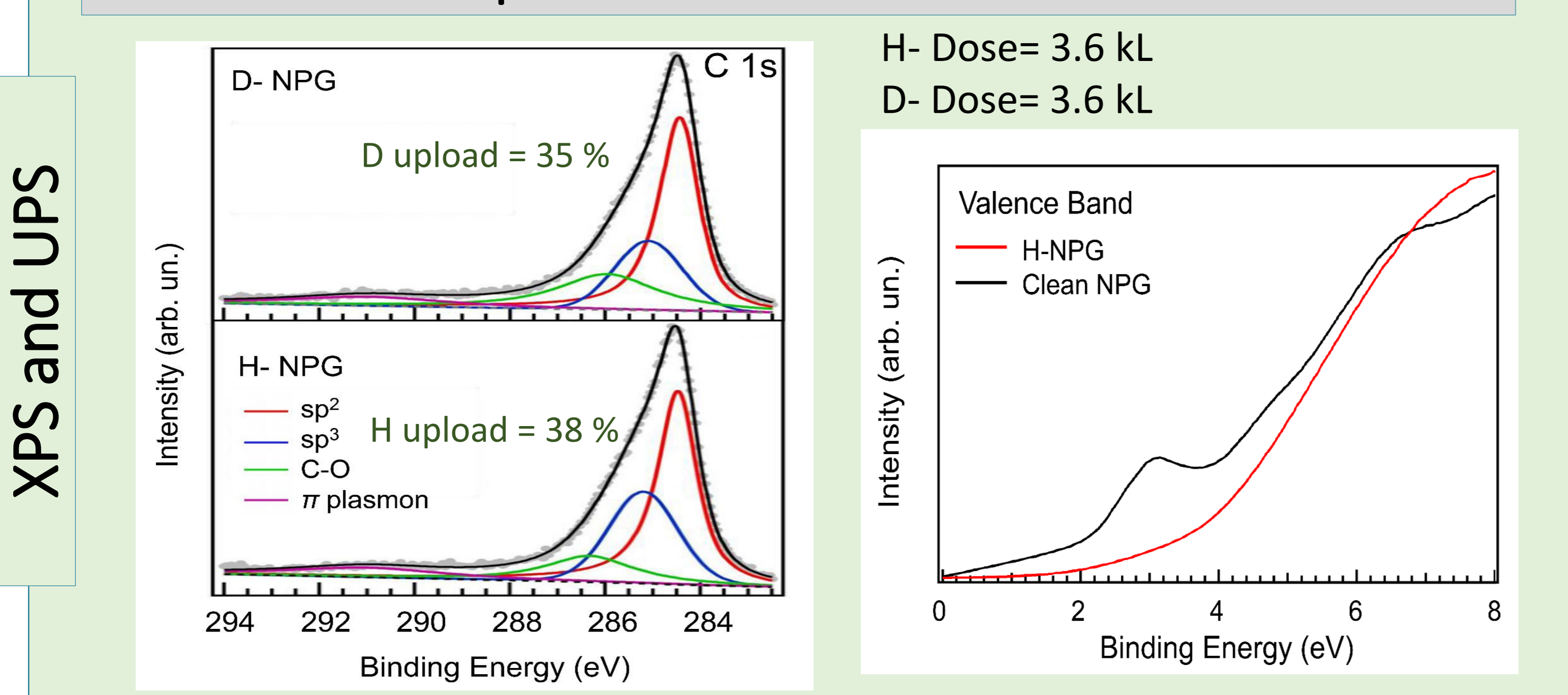
Son et alii, Nature Commun. 7, 13261 (2016)

## 2. Experimental results

### Low Energy ion irradiation



### Hot temperature atomic H and D in UHV



## 3. Summary

- XPS reveals the high H and D up-load in free-standing *graphane* through the sp<sup>3</sup>-distorted component in the C 1s core level, pointing out H-C and D-C covalent bonding; such functionalized samples show high thermal and chemical stability [1-2].
- Low-defect and non-destructive H and D functionalized free-standing *graphane* is obtained (Raman spectroscopy) [1-2].
- UPS shows a band-gap opening (>3V) after H- and D- functionalization of NPG, indicating semiconducting response [2].
- Such results pave not only the way toward fabricating semiconducting *graphane* on large-scale, but it may also represent a guidance for tritium functionalization of graphene for futuristic advanced detectors for the β- spectrum analysis [3].

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### REFERENCES

- [1] Abdelnabi et al., Nanotechnology 32 (2021) 035707
- [2] Abdelnabi et al., Nanomaterials 11 (2021) 130
- [3] Betti et al., J. Cosmol. Astropart. Phys. 2019 (2019) 047

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