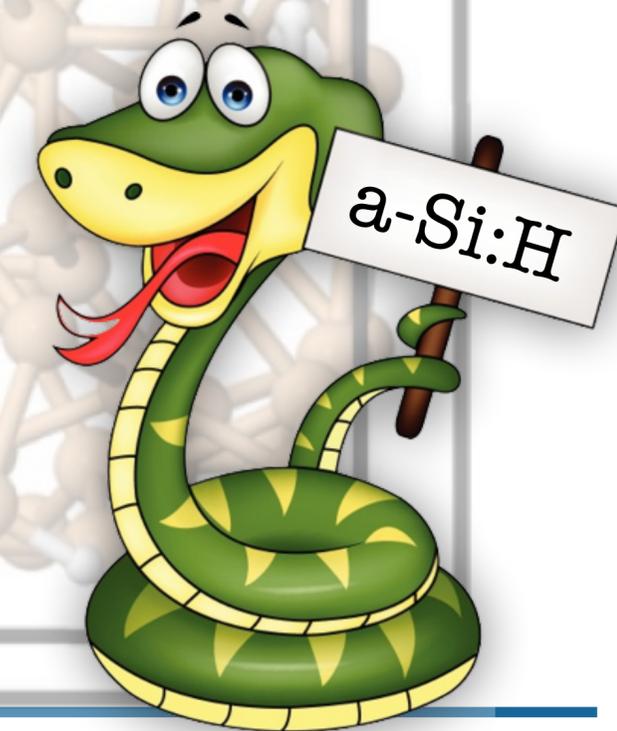




Istituto Nazionale di Fisica Nucleare

HASPIDE COLLABORATION MEETING 09/02/2024



# SUMMARY OF PHOTOEMISSION CHARACTERIZATION TESTS IN PERUGIA

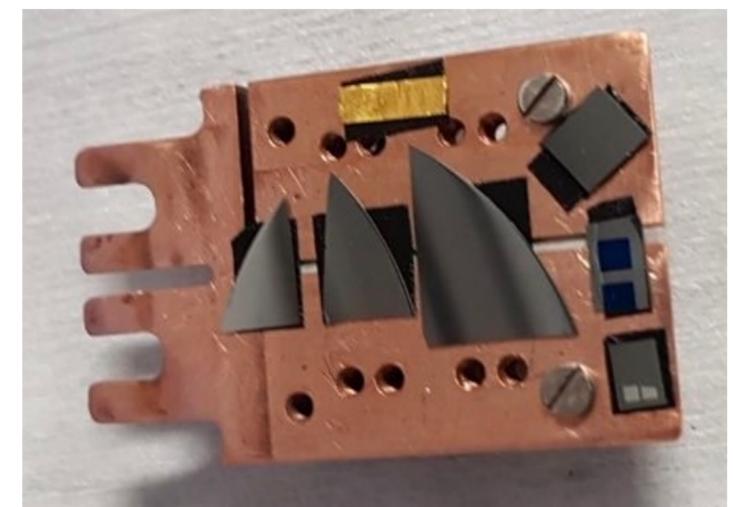
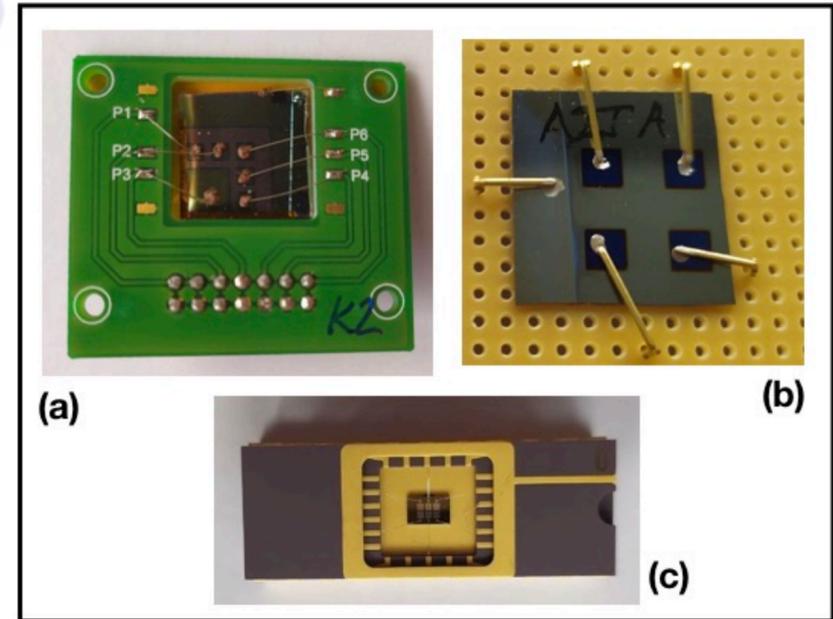
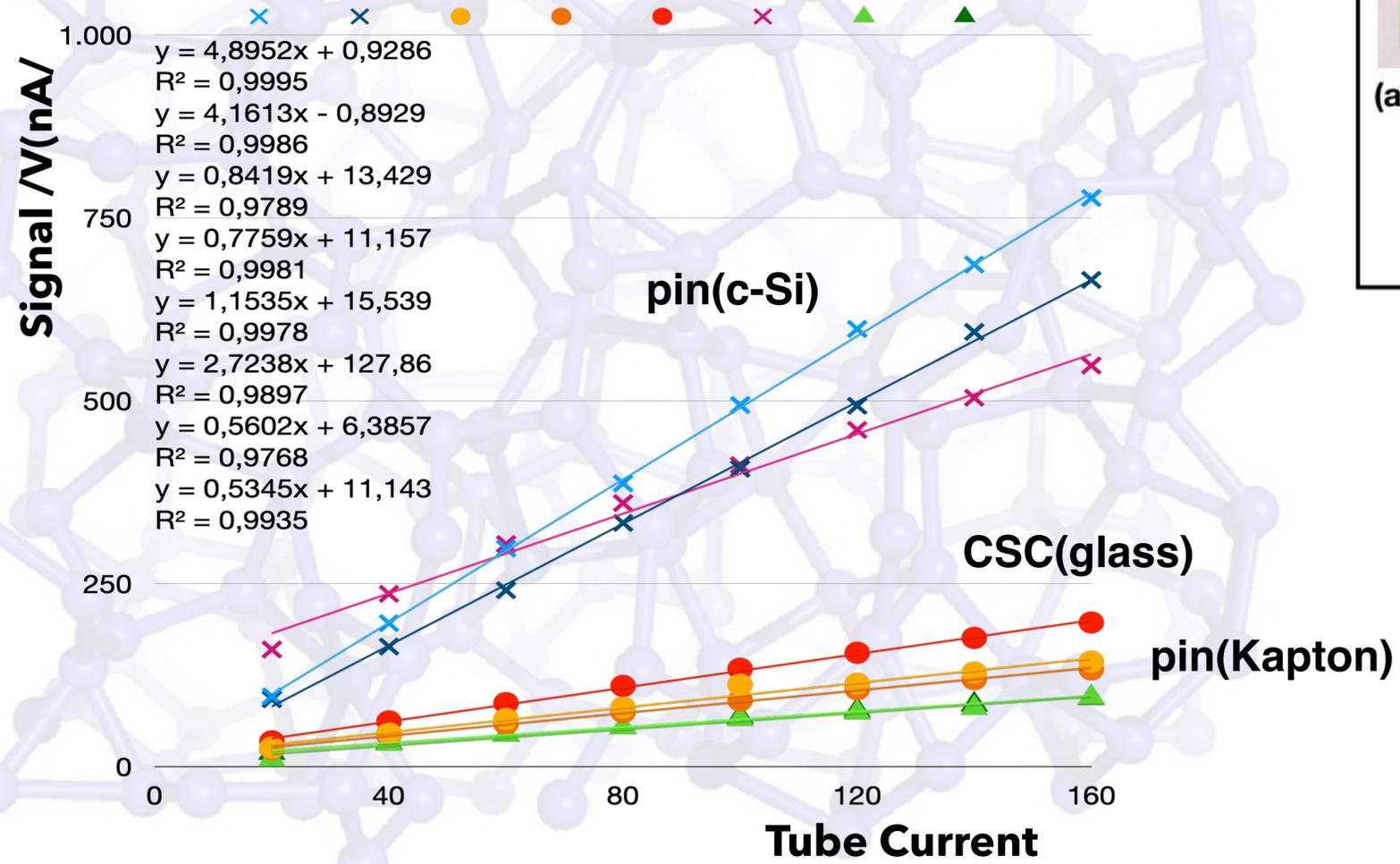
09/02/2024 Peverini Francesca



# SENSORS UNDER TEST

Basic detector configurations will be test to assess the performances of the various prototypes.

- a-Si:H on **c-Si (Reference)**;
- a-Si:H on **c-Si (Device)**;
- a-Si:H on **Kapton (Device)**;



The specific band structure and energy level alignment can impact significantly the device's performance.

# RAMAN SPECTROSCOPY

Sample films were studied using Raman spectroscopy, it allows to measure the concentration of hydrogen in the sample.

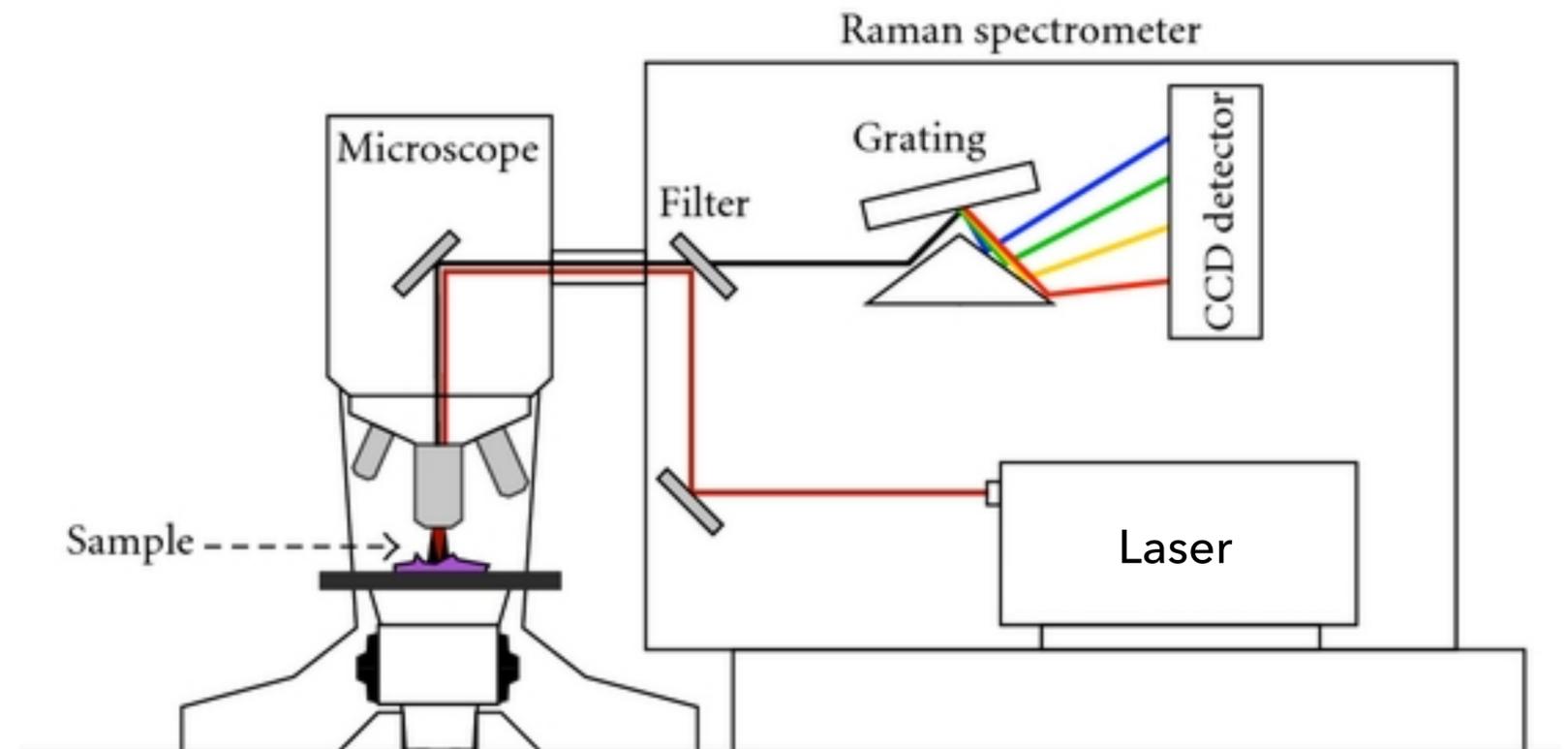
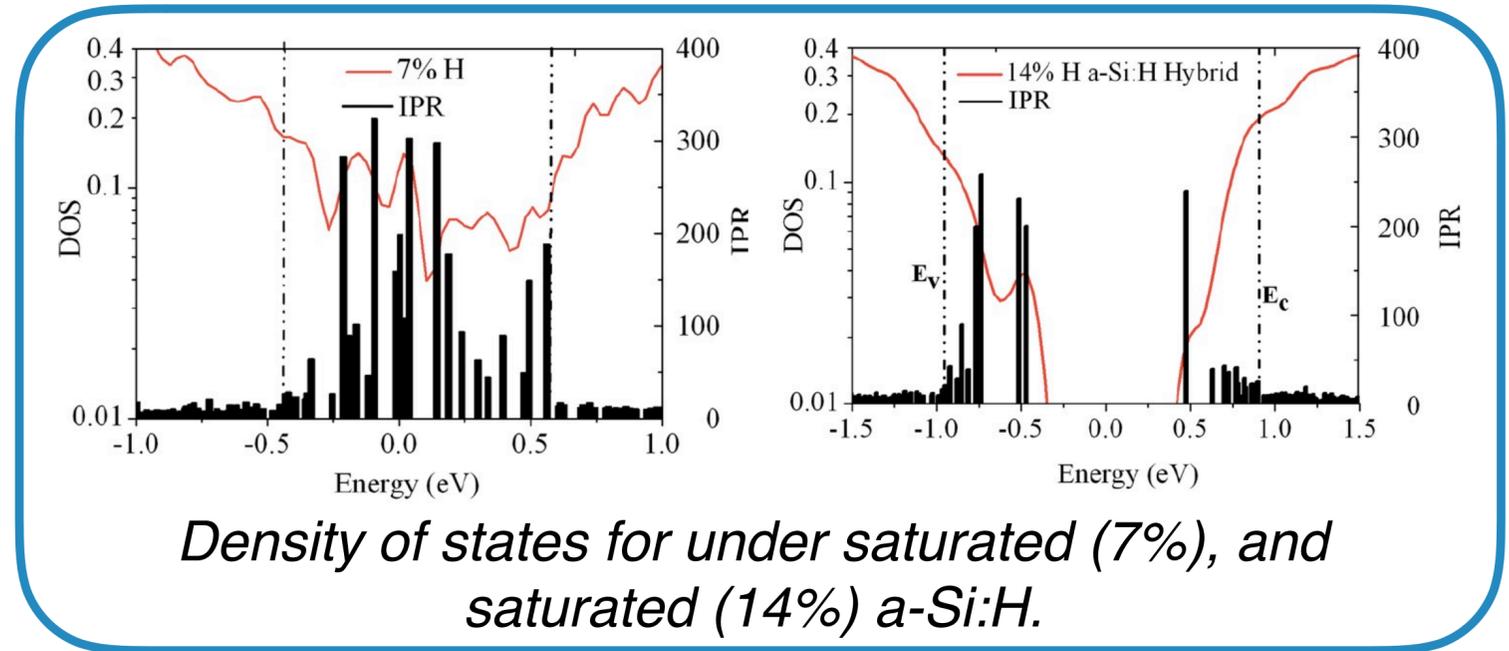


The amount of hydrogen has influence on the creation of defects and stability of a-Si:H films

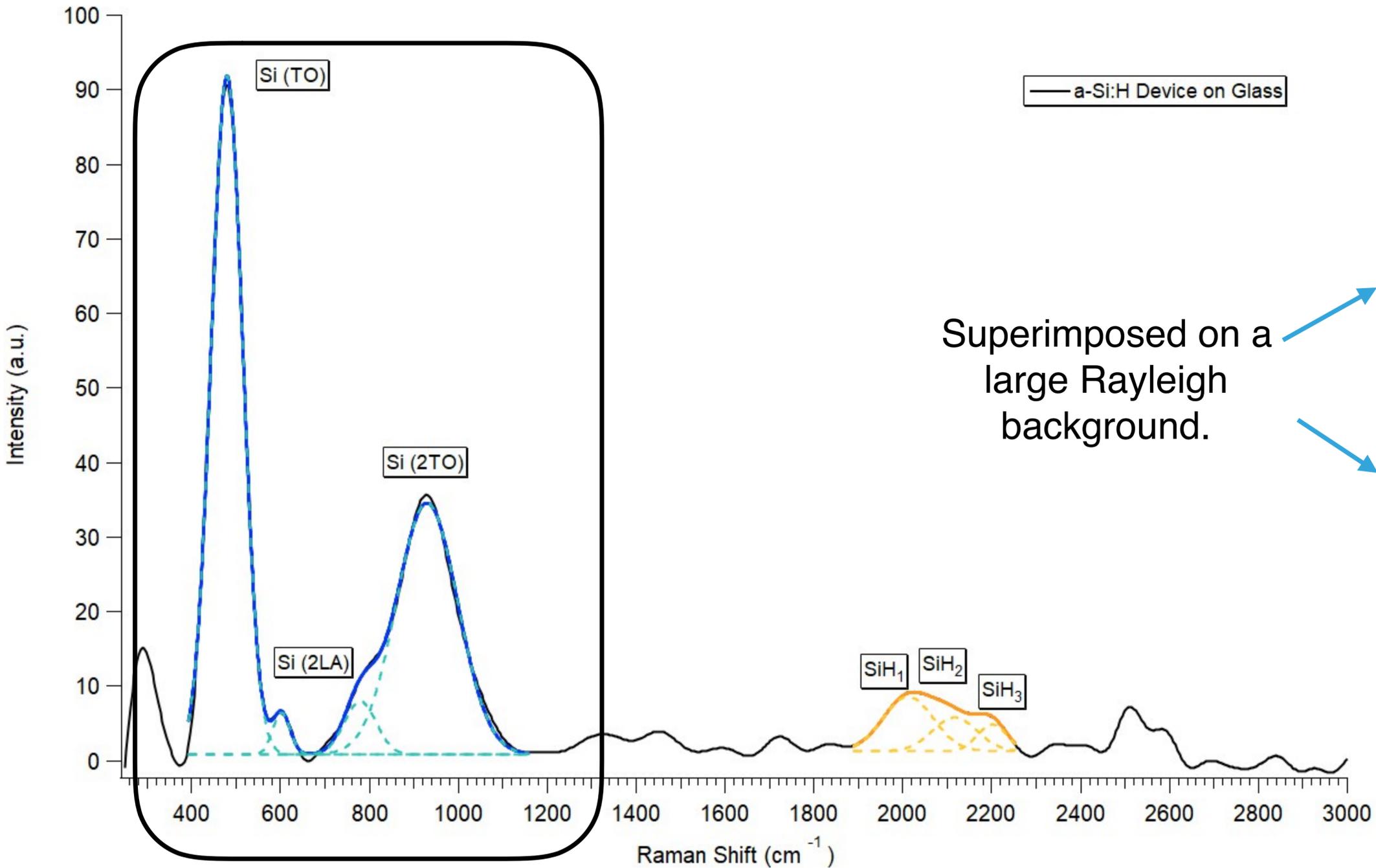
All Raman spectra were measured with the use of Raman spectrometer in the backscattering geometry at room temperature using the **532 nm** line of an Ar<sup>+</sup> laser as a source.

The power of the laser beam reaching the sample was **3-30mW**.

The spectral range of the spectrometer is from **250** to **3500 cm<sup>-1</sup>**. The frequency shifts were **calibrated** using the crystalline silicon emission line (**520 cm<sup>-1</sup>**)



# RAMAN SPECTROSCOPY



Superimposed on a large Rayleigh background.

Example of the deconvolution of the Raman spectrum into Gaussian peaks, broad peaks can be recognised:

- Transverse acoustic
- Transverse optical
- Longitudinal acoustic
- Longitudinal optical

**Vibration of the Si-Si bonds**

The peak at about **480  $\text{cm}^{-1}$** , is indicative of the short-range disorder; an increase in the half-width and a shift in the position toward lower frequencies indicate an increase in **short-range disorder**.

# RAMAN SPECTROSCOPY

You can also see peaks due to scattering on the stretching vibrations of the **Si-H**, **Si-H<sub>2</sub>** and **Si-H<sub>3</sub>** bonds.

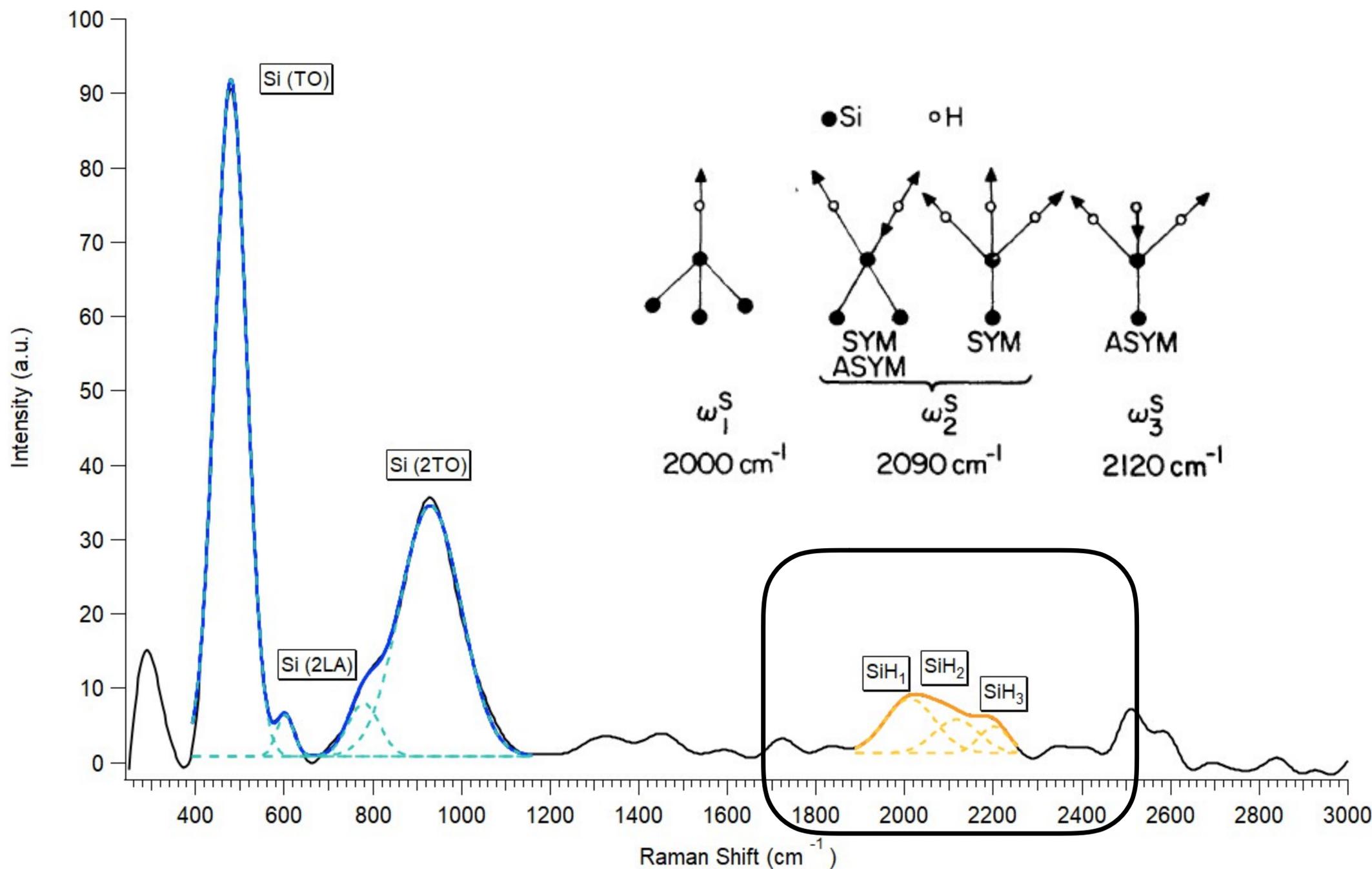
Ratio of the Si-H<sub>n</sub> to Si-Si scattering intensities:

$$\frac{I(\text{SiH}_n)}{I(\text{TO})}$$

↓
↓

Area of the SiH<sub>n</sub> stretching vibrations mode
Area of the transverse optical mode

According to literature, the ratios of Raman **scattering cross-sections** for SiH to SiSi bonds is equal to  $0.40 \pm 0.04$ .

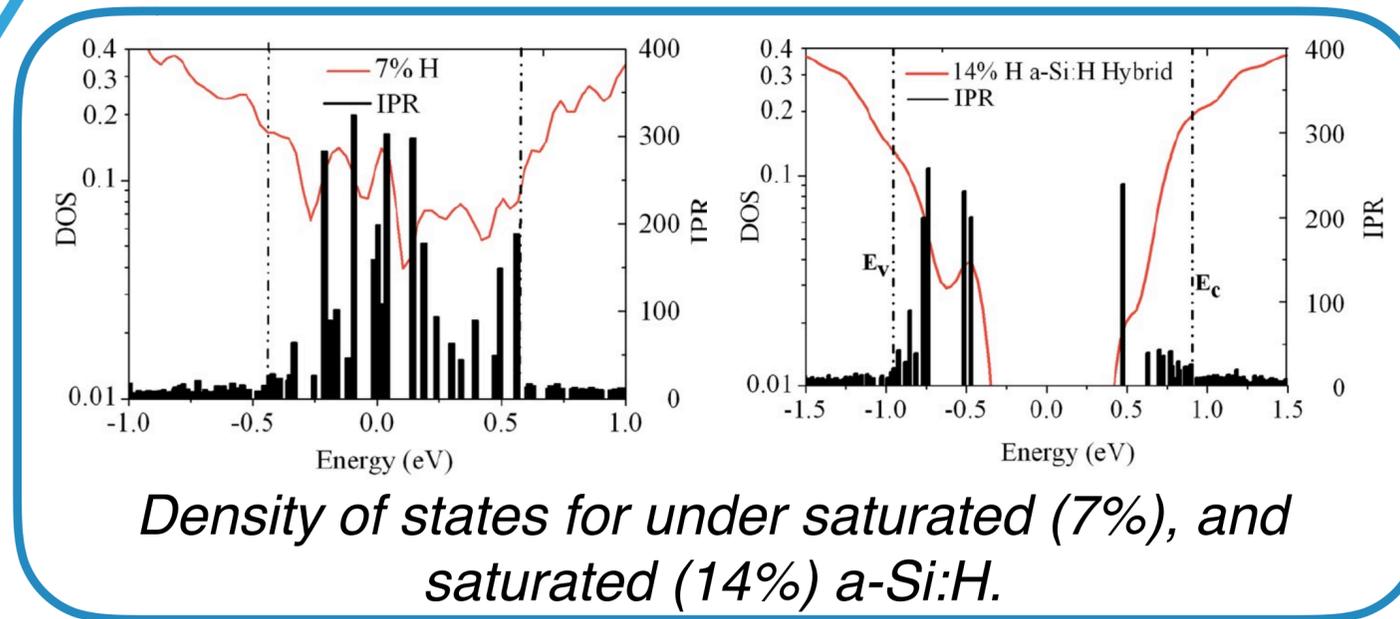


# RAMAN SPECTROSCOPY

Characteristic parameters derived from these spectra

Sample Substrate	TO	2LA	2TO	Si-H	Si-H <sub>2</sub>	Si-H <sub>3</sub> ?	N <sub>H</sub> Tot/ N <sub>Si</sub>
Kapton	460	570	910	1990	2094	2174	~8%
c-Si	472	/	928	2012	2170	/	~10%
Glass	480	602	930	2028	2153	2200	~16%

The quantity of **hydrogen** can influence the bandgap of a-Si:H



Can be used to quantify the **short-range order** in a-Si:H films.  
Surface **roughness** effect?

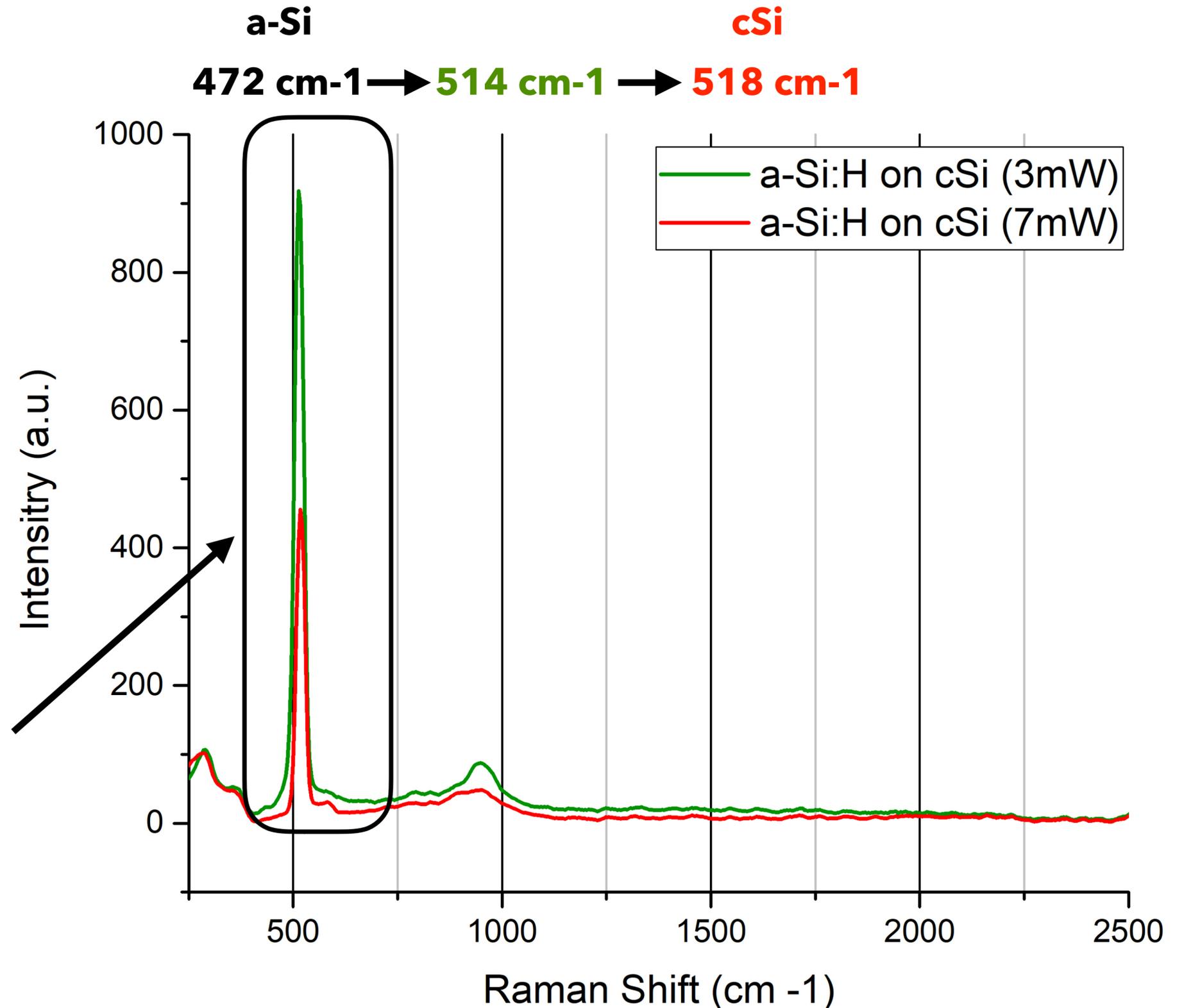
it seems that the detectors deposited on **Kapton** are more amorphous (**more defects**) and with **less hydrogen** content → That might be why Kapton devices have **lower sensitivity**

# RAMAN SPECTROSCOPY

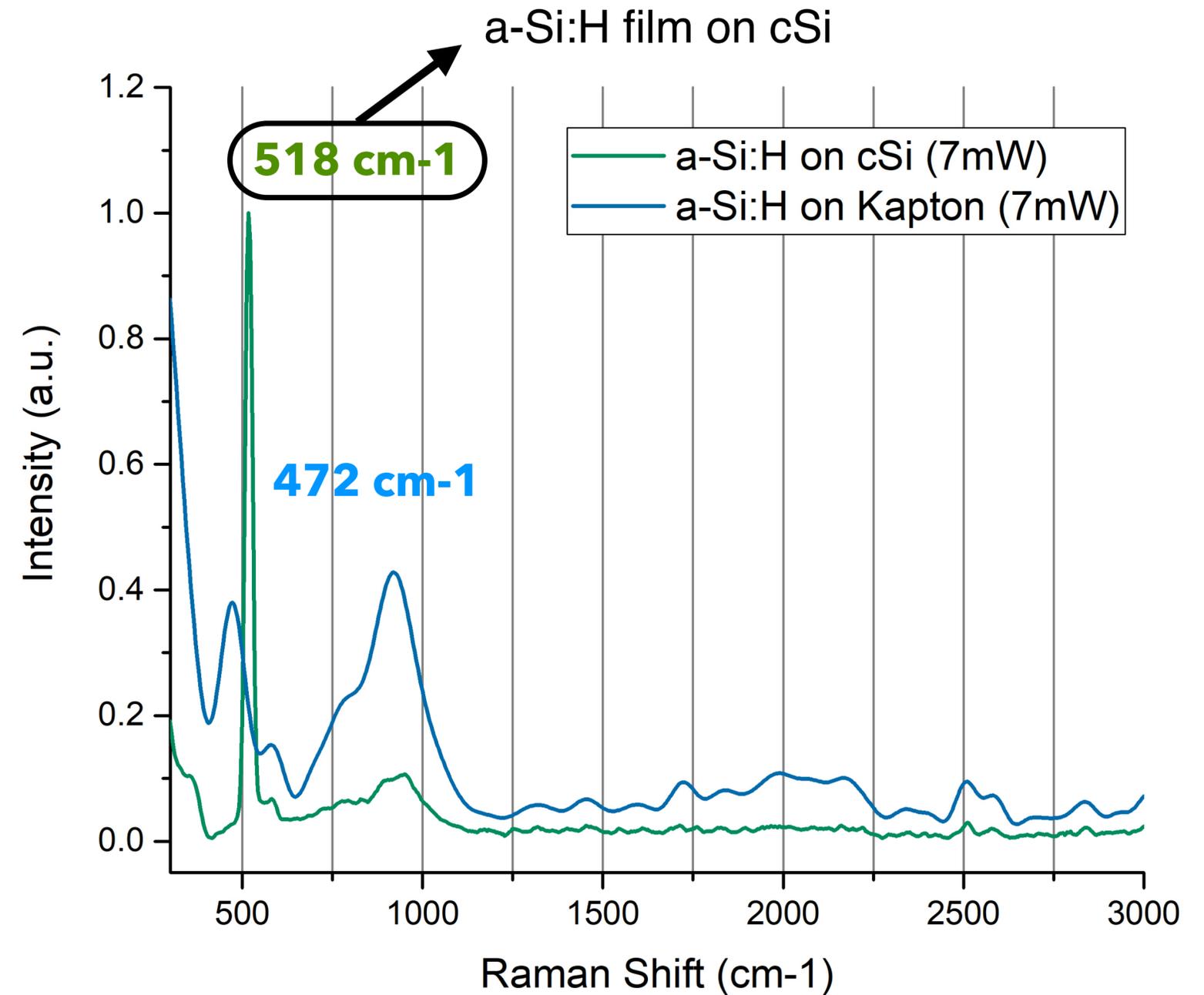
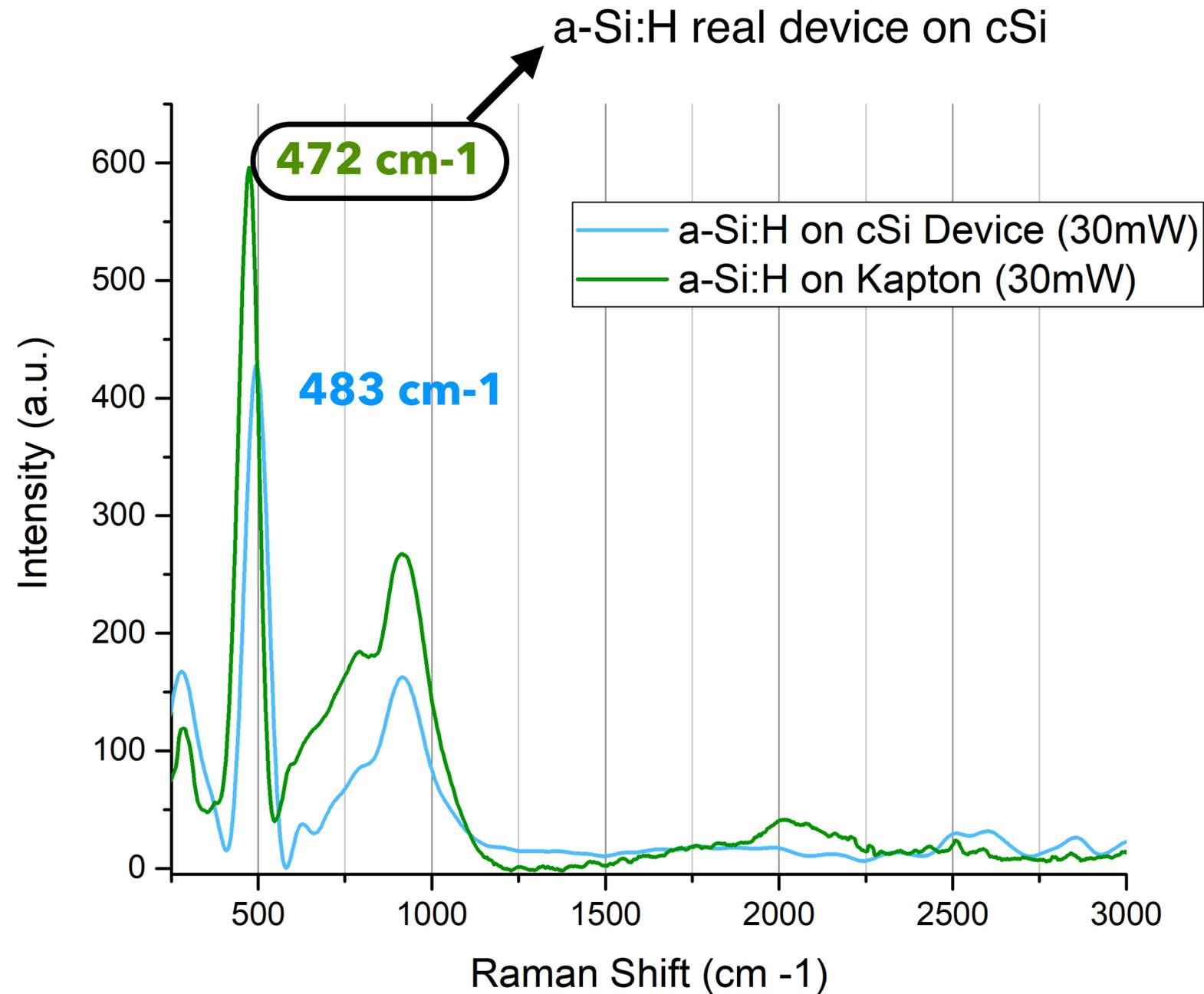
The laser can transform sample from amorphous to **crystalline silicon** by melting the silicon for several nanoseconds.

The distribution of possible states for amorphous silicon leads to a broad Raman band centered at  $480\text{ cm}^{-1}$ , while crystalline silicon exhibits a **sharp peak at  $520\text{ cm}^{-1}$**

Laser power increase, as well as the position of the peak shifts to the higher wavenumber values, suggesting that the crystallinity of the treated film increases and the crystalline grains are getting larger.

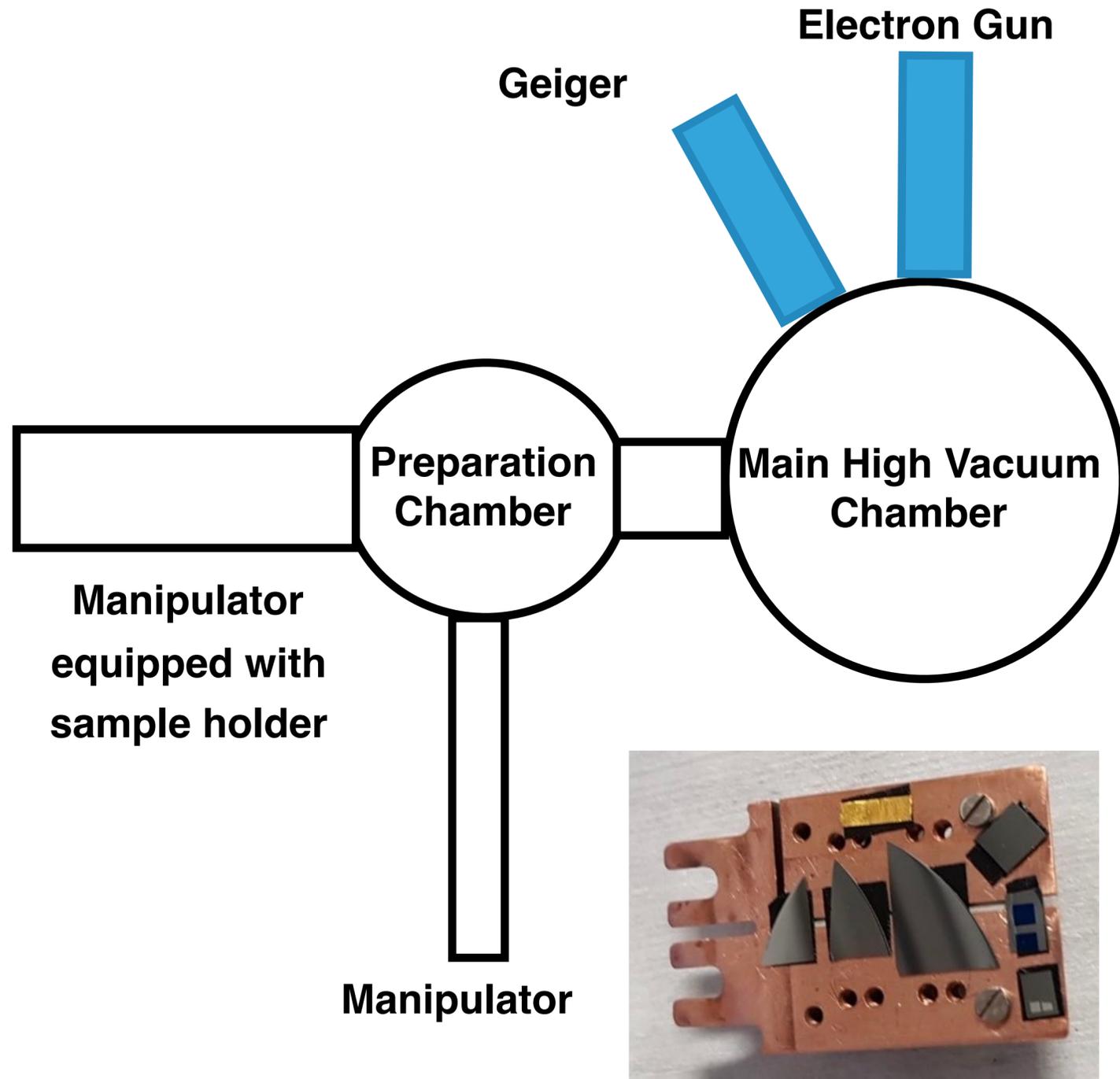


# RAMAN SPECTROSCOPY



Amorphous silicon deposited on c-Si ([assembled to form a detector](#)) has greater laser resistance, comparable to that of the device deposited on kapton, both can achieve higher laser intensities (30 mW) than aSiH/cSi film.

# IPES SPECTROSCOPY

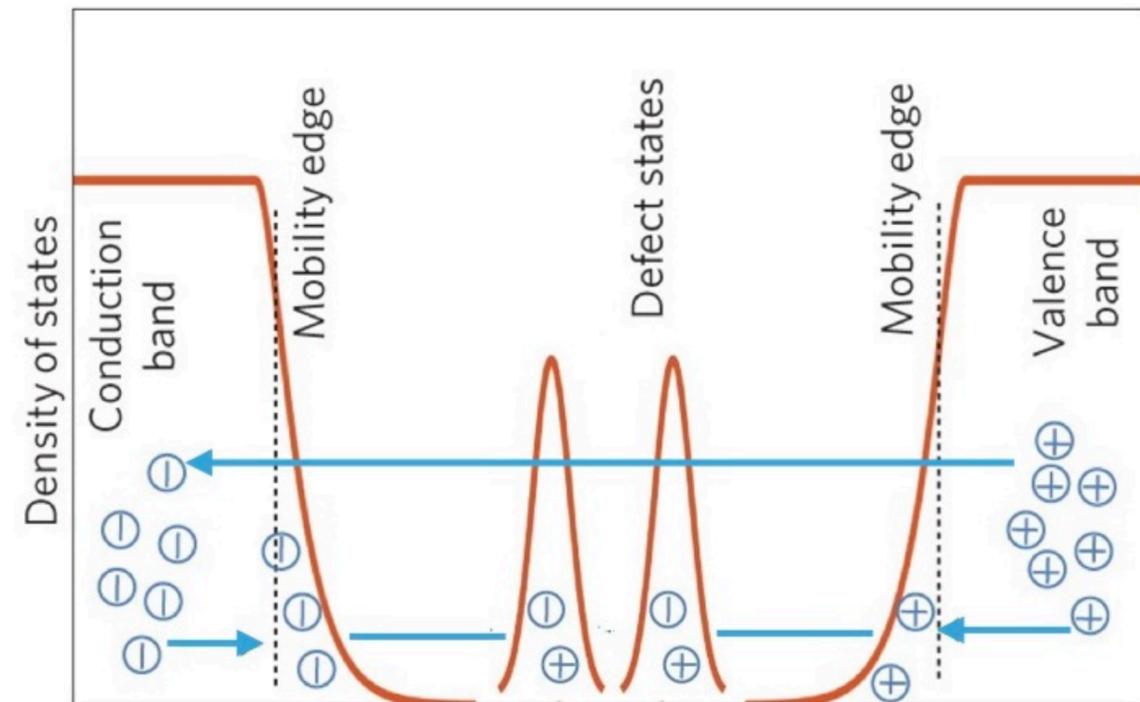


## IPES Inverse Photoemission

A beam of electrons of defined energy and momentum impinge on the surface sample, coupling with **unoccupied electronic states** above the vacuum level, and radiatively decaying into their lower-empty states. Emitted photons are collected through a Geiger-Müller detector.

It is a complementary technique to photoemission spectroscopy; together they allow us to estimate the **gap** and quantify the **defects**.

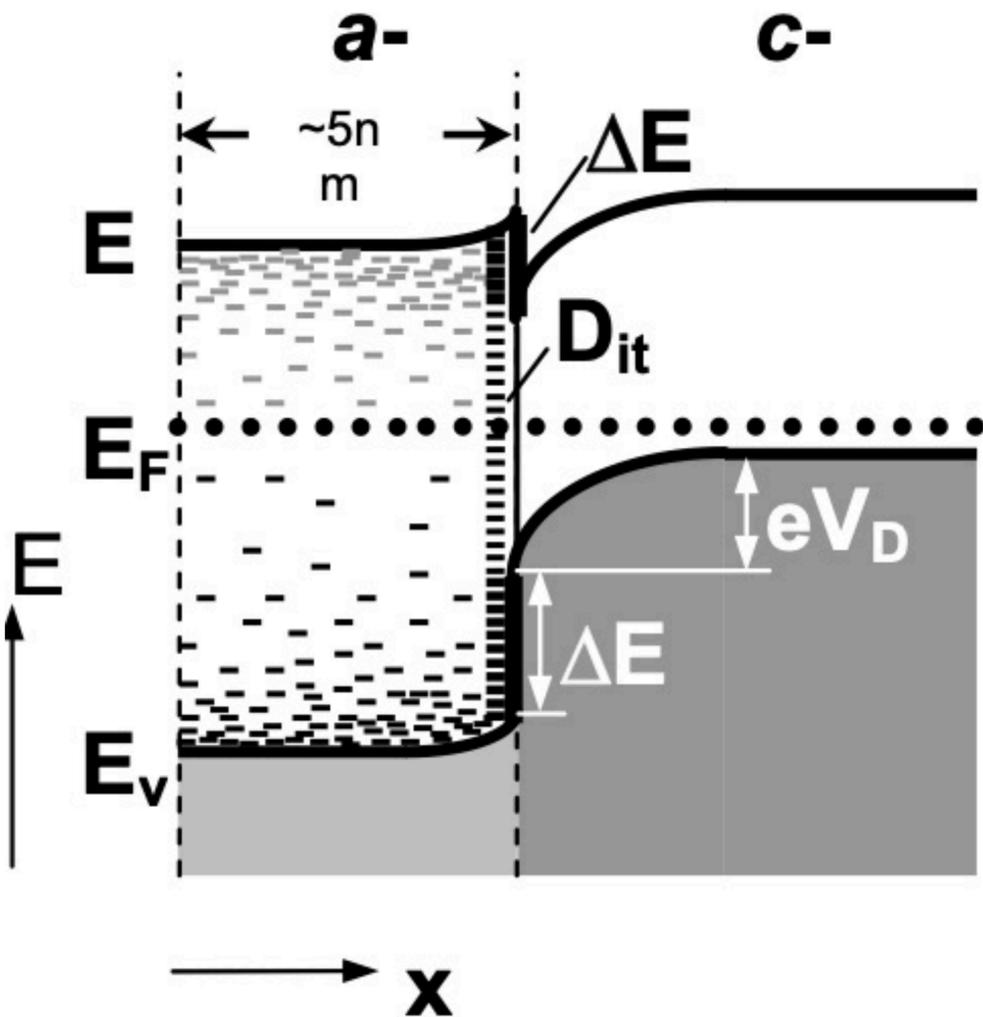
IPES



XPS

# IPES SPECTROSCOPY

a-Si:H has a direct band gap in the range **1.5–2.0 eV**, depending on growth conditions and hydrogen content. The electronic structure of the heterojunction is characterized by unsymmetrical band offsets at the conduction and valence bands.



We measure  
 ~ **1.7 eV (Kap)**  
 ~ **1.9 eV (cSi)**

