Hydrogenated Amorphous Silicon Pixel Detectors to Precisely Measure Ionizing Radiation

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1st DRD3 week - 17/21 june 2024

HASPIDE Collaboration in pills….

7 INFN, 9 Universities.

~ 50 researchers

Main Goals

Creation of thin a-Si:H (1 - 10 μm) ionizing radiation detectors deposited over thin plastic supports to be used for:

→ beam monitoring of medical LINACs and other types of accelerators

→ detection of radiation bursts in space, for example Solar Energetic Particles events;

→ neutron detection via ^{10}B deposition over an a-Si:H layer to detect α produced by neutron conversion.

Outline

→ Why a-Si:H

→ Device production

→ Characterization results

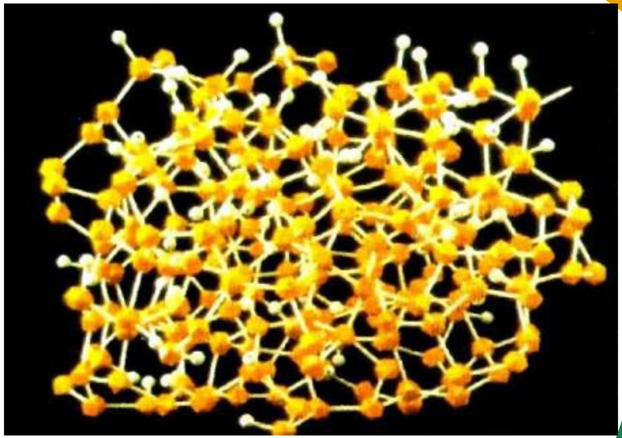
→ Future Developments

Why a-Si:H as material?

→ it is intrinsically radiation resistant;

→ it has a charge collection efficiency ~ half the c-Si;

→ it can be deposited in thin layers (~ 1-100 μm);



→ it can be deposited with any pattern on the substrate (lithography)

→ it can be deposited on different substrates, even flexible ones like mylar and kapton;

→ it is possible a low weight device with a wide area.

How to fabricate a device?

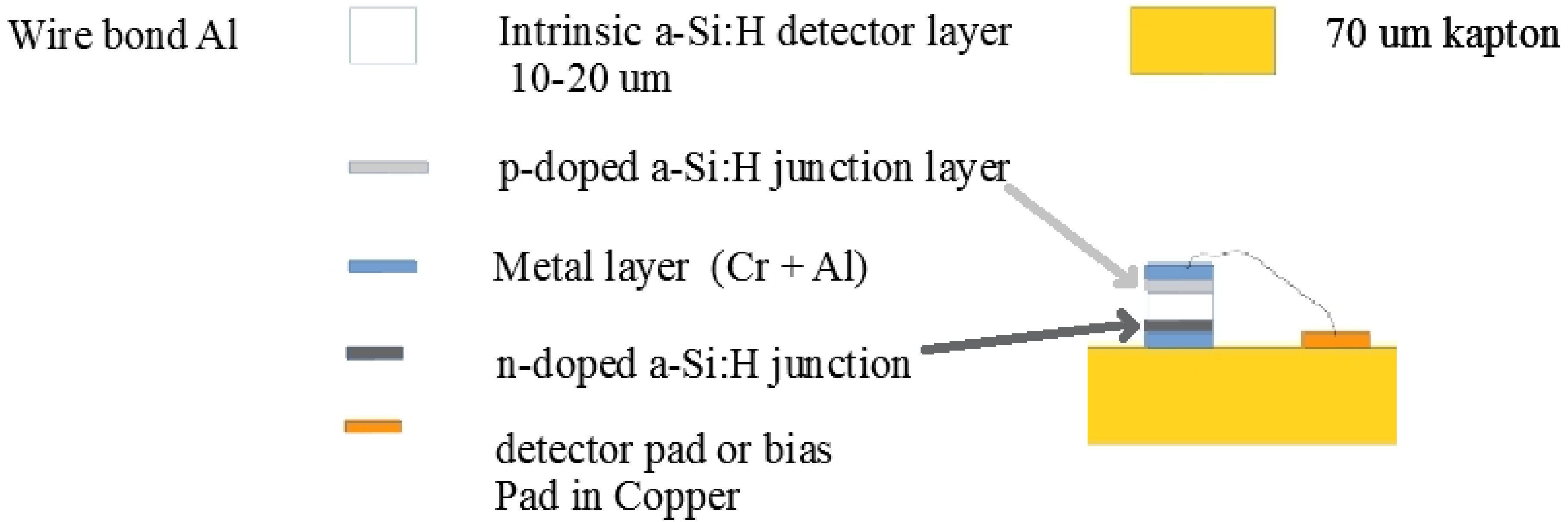
→ Mature protocol for industrial production for different applications like solar cells, flat panels for X-ray imaging...

→ Thin film deposition with several techniques:
- → PECVD (Plasma Enhanced CVD) at moderate temperature (below 300°C) is the most used
- → PLD (Pulsed Laser Deposition) coupled with reactive sputtering at lower temperatures. (HASPIDE R&D)

→ Wide area deposition is possible at lower costs than for crystalline silicon deposition.

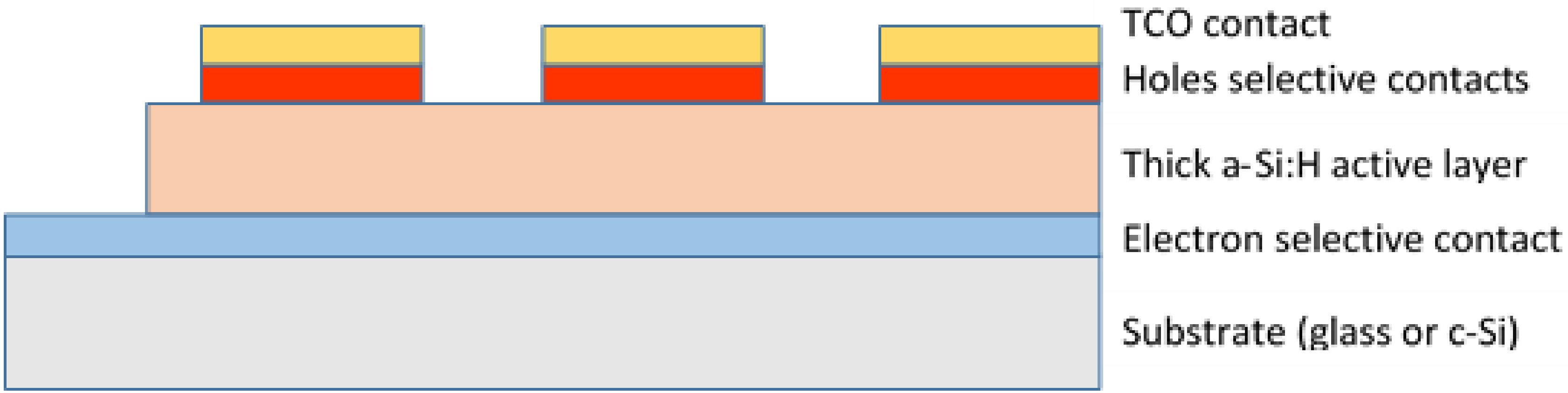
Which contact technique to use?

P-i-n devices: p-doped and n-doped, plus a metal contact on both sides to allow polarization and signal extraction.



Which contact technique to use?

Charge Selective Contacts: thin layers (< 100 nm) with asymmetric charge carriers mobility to create a gradient inside the device.

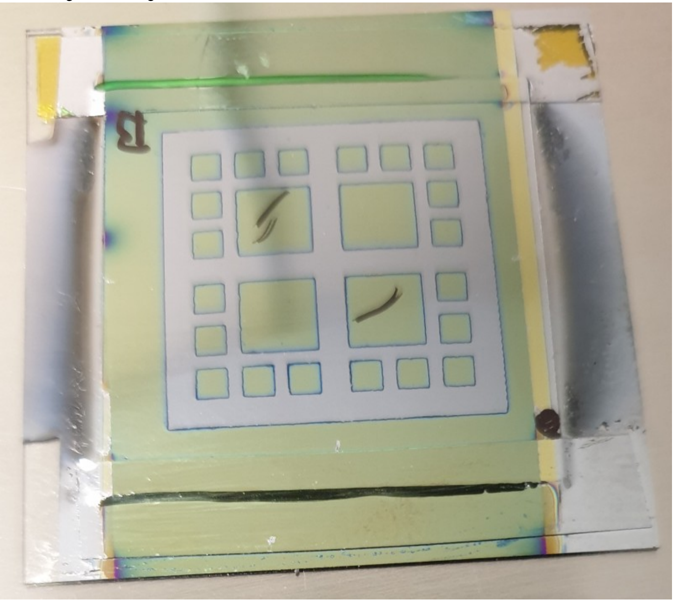


→ ***electron selective contacts: ZnO:Al or TiO_2***

→ ***hole selective contacts: MoOx***

First prototypes

The first batch of a-Si:H depositions on polymmide has been produced (PECVD).
Extensively tested.

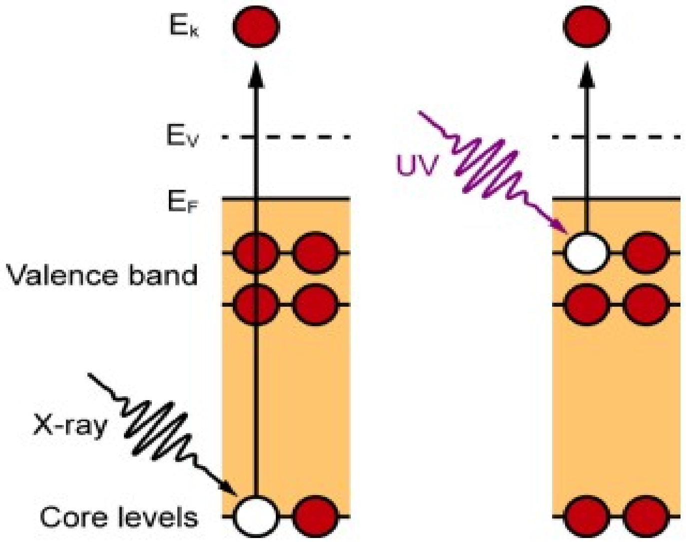


$2x2\ mm^2$ and $5x5\ mm^2$ devices (p-i-n)
Thickness: 2.5 µm.

Polymmide thickness: 25 µm

New batches (under test): CSC + different geometries

Test on device quality



Photoelectron spectroscopy can be used to obtain directly the energy position of gap states.

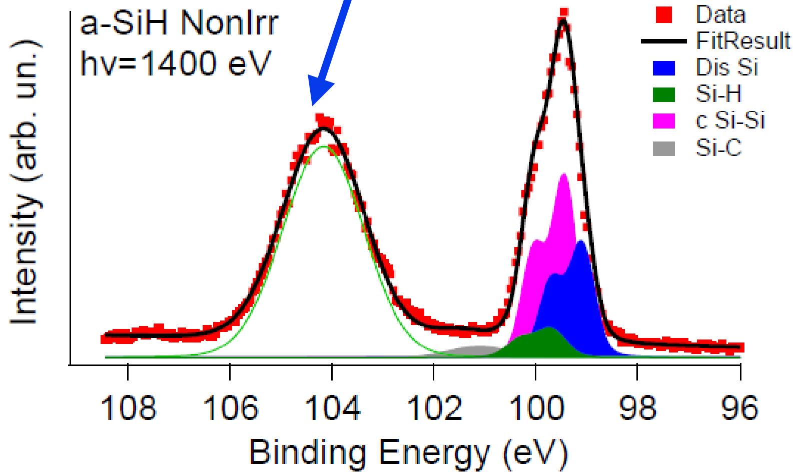
We have used monochromatic X-ray from ELECTRA Synchrotron Circular Polarization (CiPo) and BACH beamlines.

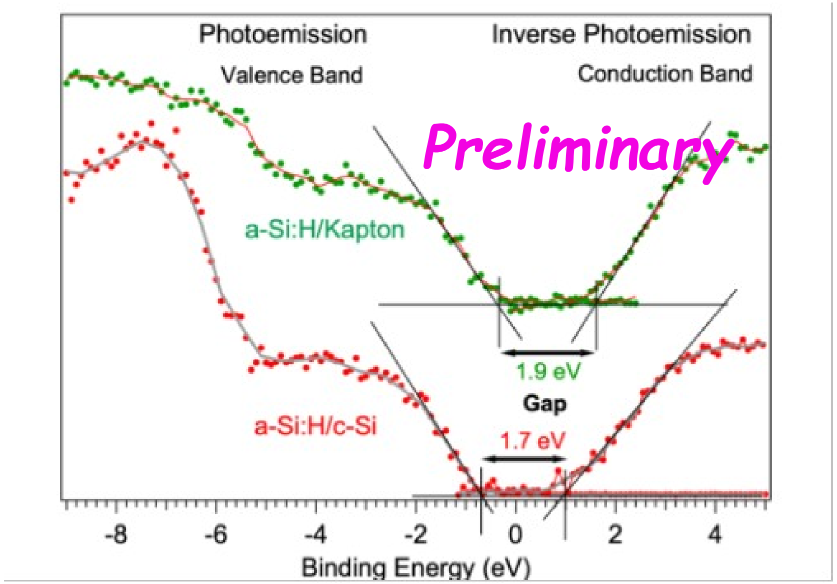
X-rays are capable of ionizing core electrons, while UV photons are not.

Test on device quality: p-i-n

We are capable of identifying several type of bonds.
R&D is going on to correlate it with device sensitivity

Reference a-Si:H

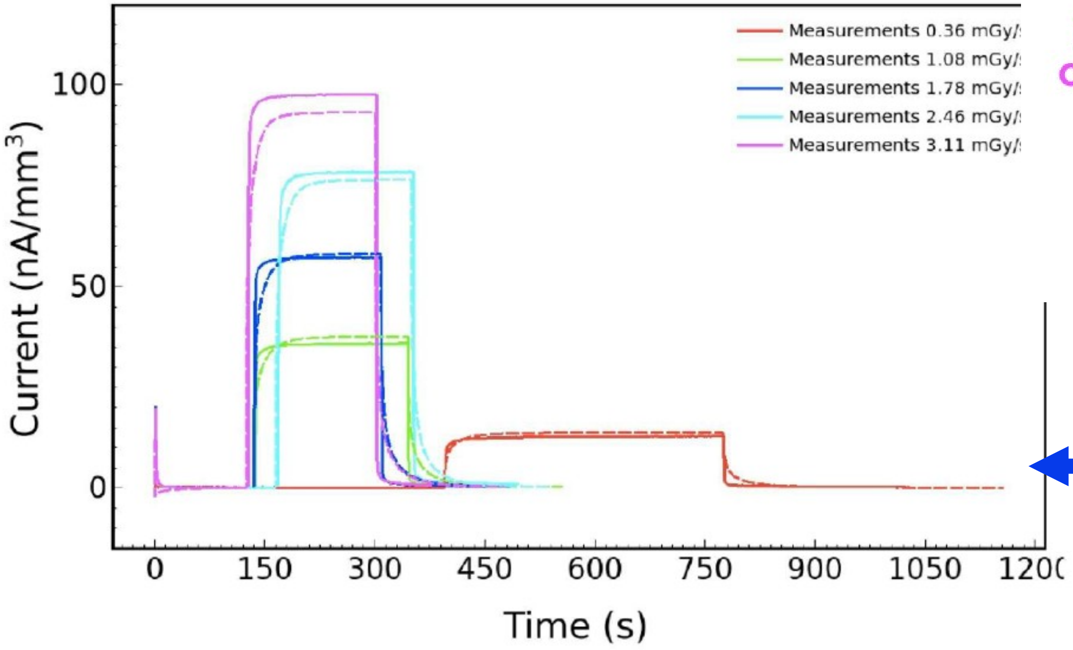


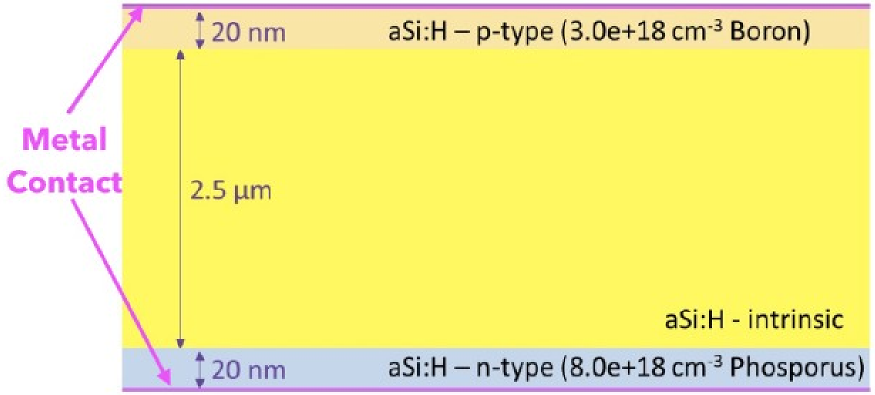


First measurement of band gap (preliminary)

a-Si:H TCAD simulation

We have developed a a-Si:H material description to be inserted in SYNOPSYS TCAD.

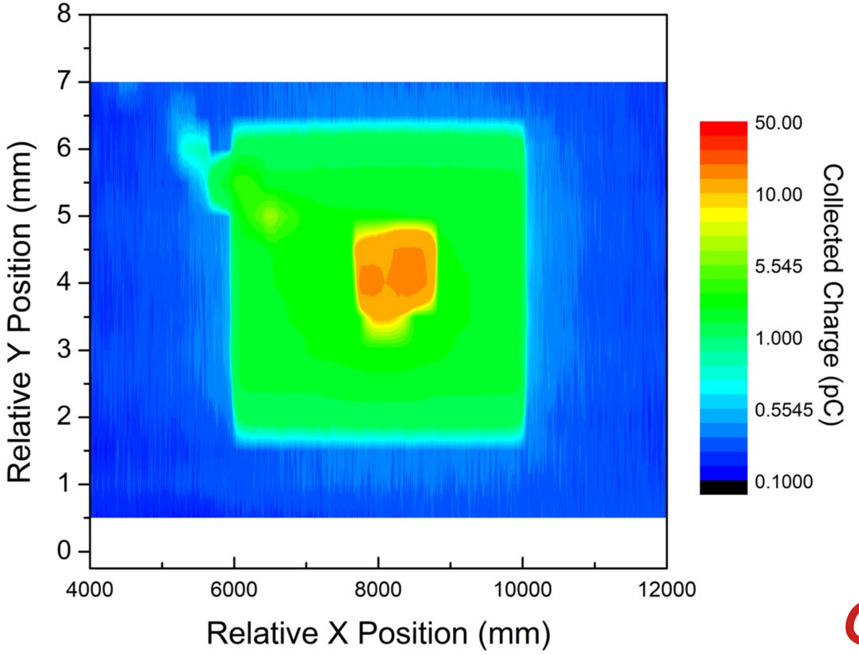


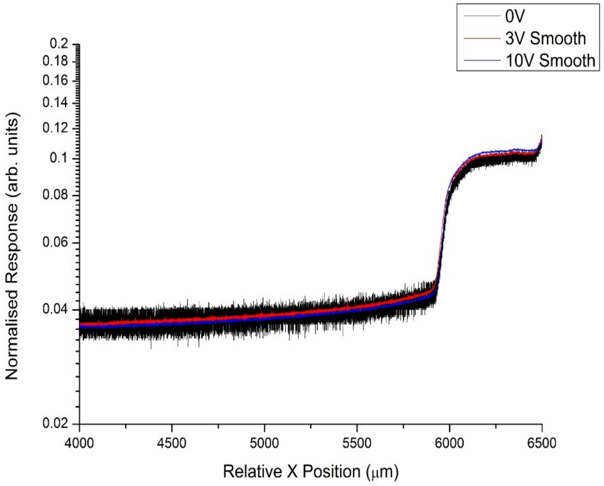


We could now reproduce time-varying evolution of photon beam signal.

Charge Collection area:

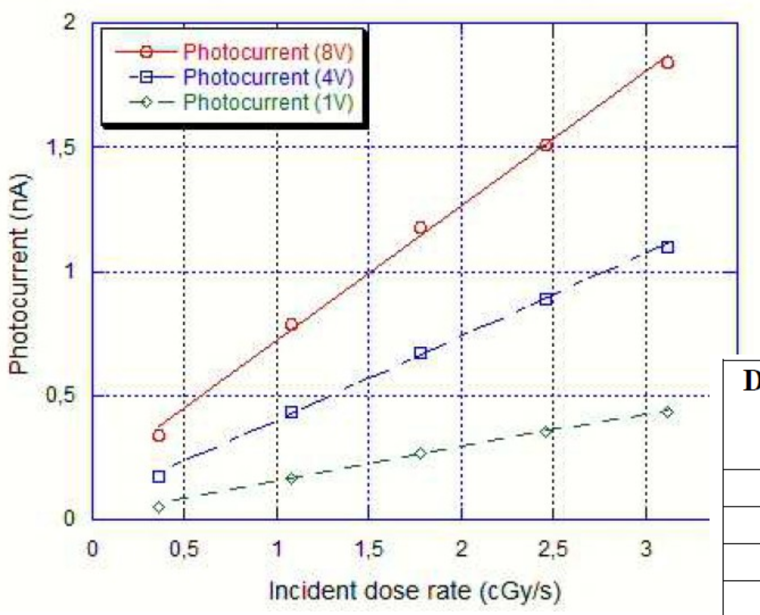
XBIC mapping of the charge collected by a single pixel -10 V bias





Only below contact.

Some results: X-ray.



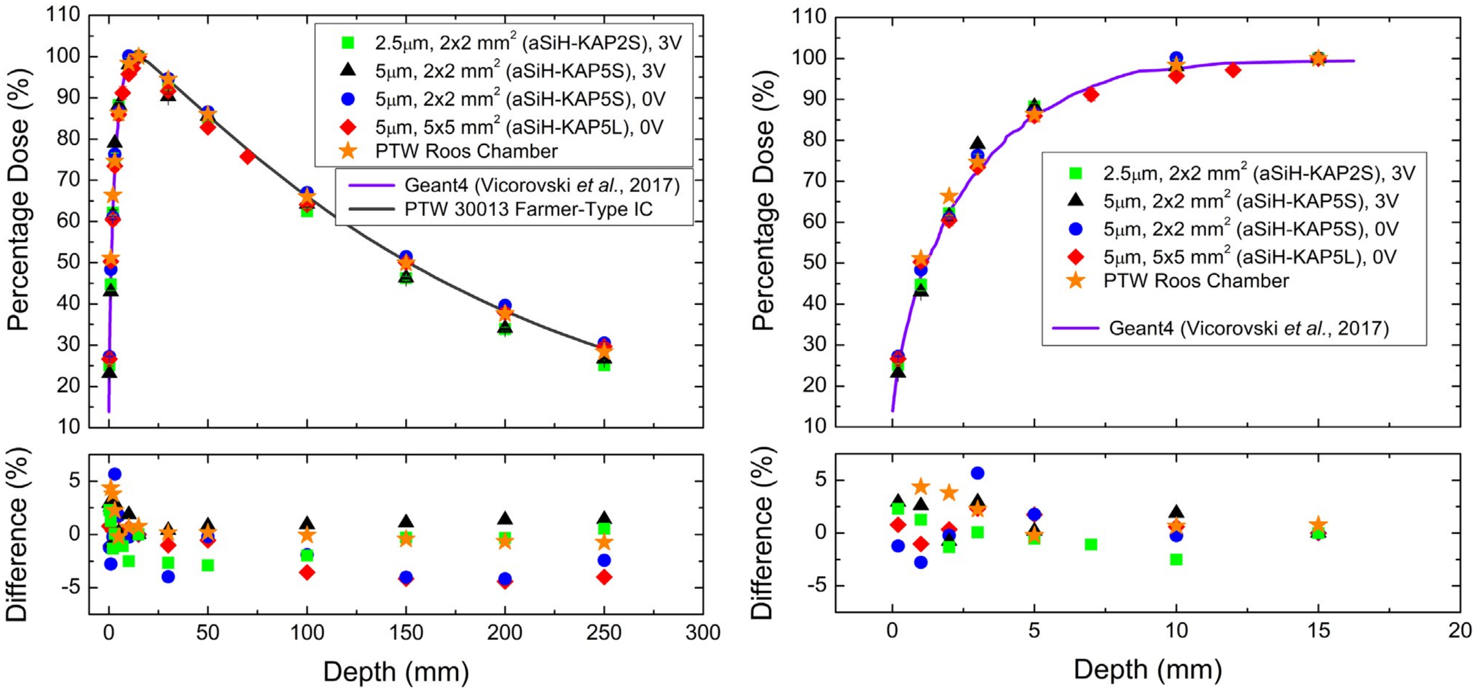
Current vs incident dose-rate (X-ray source) for 2x2 mm device at various bias.

Noise ~ few pA.

Sensitivity for different devices and bias.

Device Area (mm^2)	Bias Voltage	Dosimetric sensitivity (nC/cGy)	Regression coefficient R
5 x 5	0V	0.367	0.99999
	2V	1.283	0.99991
	4V	1.900	0.99975
	6V	2.505	0.99972
	8V	3.027	0.99926
2 x 2	1V	0.137	0.99878
	4V	0.335	0.99961
	8V	0.540	0.99881

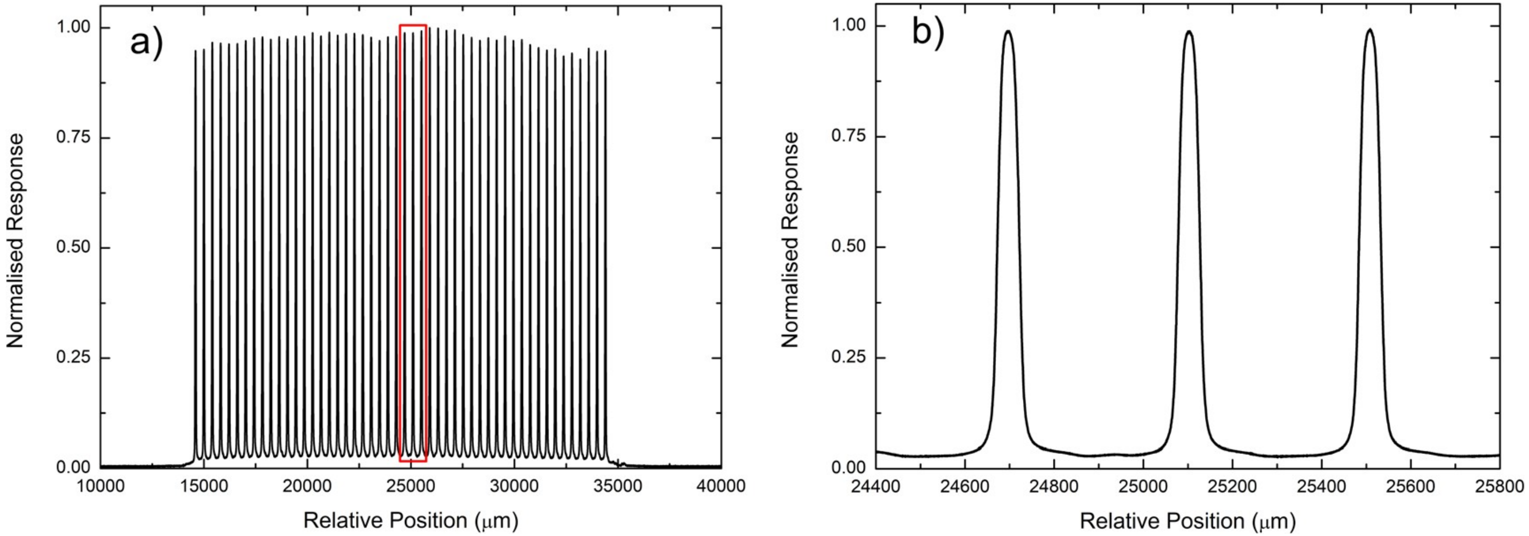
Clinical MV photon beams



Very good results, comparable with reference dosimetry

Synchrotron photon beams

Spatial reconstruction of microbeams (50 μm width)

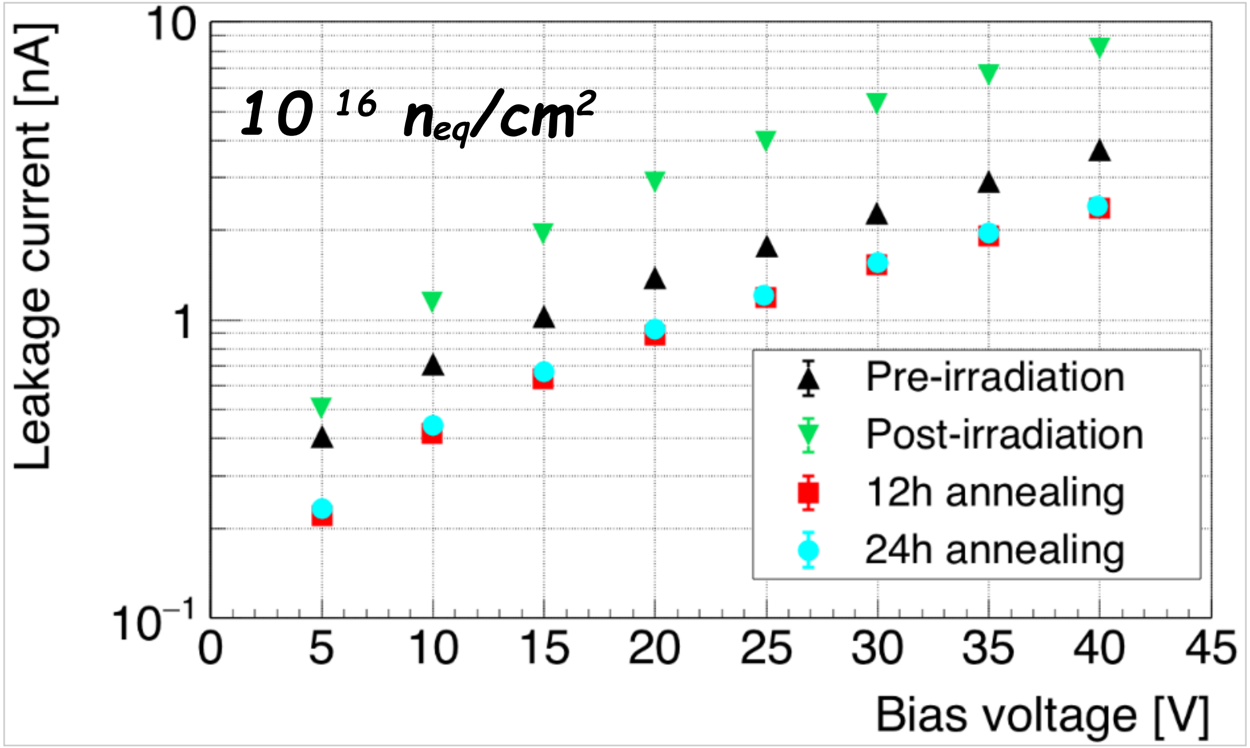


Very good results, comparable with reference dosimetry

Device radiation resistance

Neutron irradiation at Ljubliana facility p-i-n device

Leakage current recover after 12 h annealing @ 100°C



Future developments

1) Beam monitoring:

→ response to electron, proton and ion beams (ongoing)

→ single ion detection (using chip developed for PANDA readout)

→ very high dose-rate (like FLASH therapy) tens kGy/pulse

Future developments

2) Device fabrication:

→ creating matrix of diodes to monitor in transission beam exit from accelerators

→ studying the possibility of 3D electrodes for thicker a-SI:H devices.

→ study device performance with different contact techniques.

Future developments

3) Miscellanea:

→ *test of a readout chip (current mode) in 28 nm technology*

→ *study response of devices deposited on bendable (and bent) substrates like kapton.*

→ *realization of pixellated transmission device to measure at the same time spatial distribution and flux (dose-rate)*

Thanks.