ON SENSITIVITY OF DETECTORS BASED ON HYDROGENATED AMORPHOUS SILICON (A-Si:H) FOR MEASURING RADIATION BEAMS

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The HASPIDE project wants to explore the possibility to use a:Si-H as a detection material for ionizing radiation of different types.

The demand for radiation-resistant detectors is increasing due to clinical procedures that require high fluxes of particles, new detectors for dosimetry and flux measurement is highly desirable.

The project aims to reach different applications:

- **Clinical Dosimetry** and **Beam monitoring** of clinical and non-clinical accelerators;
- Detection of **cosmic radiation** in space;
- **Neutron** detection;

The project's foundation is the capability already demonstrated to use this material to build devices, such as a detector of ion beam at CNAO.
WHY A-SI:H?

We need a **sensitive** material which should have a **high dynamic range** being at the same time very thin, high **radiation resistance**, adjustable geometry and capability of working both in air and vacuum.

*a-Si:H is an ideal candidate*

The defining property of **amorphous silicon** in contrast to its well-known crystalline form is the absence of long-range order in the atomic positions.

Hydrogen is introduced to help to lift the over-coordination by the formation of Si-H bonds and to saturate the defects arising from Si dangling bonds.

Defects limit the efficiency through the additional electronic states that they generate in the band gap of a-Si.
The project will imply the fabrication of several different detector prototypes to assess the performances (basic physical, electrical and charge collection performances).

- Small arrays of p-i-n diodes with different areas and diode spacings deposited both on c-Si or Kapton;
- Charge selective contacts (CSC);

Different detector configurations differing in thickness and area of the sensitive volume, junction type and deposition substrate, have been tested, to study their behavior both in absence and in presence of a radiation source.
PROTOTYPE CHARACTERIZATION

We can state that we are currently able to produce detector that show a **uniform electronic behavior**, with the same geometric characteristic and deposition substrate.

The **noise level** is uniform for all type of prototypes and is in the order of ten **pA**, this implies detection capability around tens of pA with a reasonable signal to noise ratio.
The second phase of device characterization focuses on the comparison between the different sensors, the aim is to understand if some types are more advantageous than others. Variables: contact type, substrate and thickness.
All these prototypes were initially characterized in Perugia with an X-Ray source.

The values for the signal and noise are extrapolated from the Gaussian fits, the mean value represents the measured current and the sigma value identifies the oscillation.
The first important result that we obtained is the **linear correlation** between **dose rate** and signal, which is an essential feature for all detectors.

The acquired data at the suggests that, for devices with the same construction characteristics, the sensitivity scales with the sensitive volume.
INTERNATIONAL WORKSHOP ON RADIATION IMAGING DETECTORS

SENSITIVITY MEASUREMENTS

<table>
<thead>
<tr>
<th>p-i-n on Kapton</th>
<th>p-i-n on c-Si</th>
<th>CSC on c-Si</th>
<th>CSC on Kapton</th>
<th>p-i-n on Kapton</th>
</tr>
</thead>
<tbody>
<tr>
<td>V = 0.01 mm³</td>
<td>V = 0.0025 mm³</td>
<td>V = 0.13 mm³</td>
<td>V = 0.099 mm³</td>
<td>V = 0.06 mm³</td>
</tr>
<tr>
<td>Sensitivity nC/cGy</td>
<td>9.0±0.4</td>
<td>2.6±0.4</td>
<td>16.71±0.06</td>
<td>8.78±0.03</td>
</tr>
<tr>
<td>Sensitivity nC/cGy (0V Bias)</td>
<td>/</td>
<td>/</td>
<td>1.37±0.01</td>
<td>0.84±0.01</td>
</tr>
<tr>
<td>Normalized Sensitivity nC/cGy mm³</td>
<td>903±40</td>
<td>1040±40</td>
<td>128±1</td>
<td>89±0.3</td>
</tr>
<tr>
<td>Dose Rate (cGy/s)</td>
<td>0.3</td>
<td>0.6</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>y = 2.7082x + 0.3947</td>
<td>y = 6.1934x + 0.3849</td>
<td>y = 0.9204x + 0.1152</td>
<td>y = 2.564x + 0.319</td>
<td>y = 2.6078x + 0.334</td>
</tr>
<tr>
<td>R² = 0.9929</td>
<td>R² = 0.9865</td>
<td>R² = 0.9959</td>
<td>R² = 0.9903</td>
<td>R² = 0.9914</td>
</tr>
</tbody>
</table>
For the sensors deposited on kapton an acquisition test with bias equal to 0V was also carried out.

Using zero voltage bias detectors in medical applications offers advantages in terms of patient safety, ease of operation, compatibility, cost efficiency, and measurement accuracy.

These factors make them a preferred choice.
For the p-i-n type sensors (on c-Si) the sensitivity trend in relation to the applied bias was studied. Sensitivity increases linearly with the applied bias.

Here we can see the sensitivities normalized to the volume of the pins (0.0025 mm³) measured for the various types of detectors.
MEDICAL APPLICATION

The beam profile measurement allows for the determination of the beam's size, shape, and symmetry, which are crucial parameters in various scientific and medical applications.

Four a-Si:H p-i-n diode structure of 2.5µm thickness are fabricated on Kapton substrate. The pad diode area is 2.5x2.5 mm².

70 µm thick Kapton tape placed over the sample for protection of the electrical contact as well as to create a consistent and reproducible build-up layer for dosimetry.

Linac: VERSAHD ELEKTA

6-10MV Xray beams with and without Flattening filter
We can see the uniform electronic behavior of the different diodes used for the measurement.

**Dose profile measurement**
- Field size 10 x 10
- 6MV Photon Beam
- DR=500 cGy/min

Preliminary Data

**MEDICAL APPLICATION**
CONCLUSION

- Different detector configurations differing in thickness and area of the sensitive volume, junction type and deposition substrate, have been tested, to study their behavior.

- We are currently able to produce detector with uniform electronic behavior with noise level order of ten pA.

- We obtained linear correlation between dose rate and signal, we extract the sensitivity for photons.

FUTURE WORK

- As we can see from this preliminary results some configuration seem to work better than others.

- We are carrying out spectroscopic measurements in order to model the way in which the detector’s performance is linked to the internal amorphous structure.

- The next step is to test that the sensitivity does not depend on the type of ionizing radiation.