The development of a 3D detector on a hydrogenated amorphous silicon substrate

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Hydrogenated Amorphous Silicon a-Si:H

- The first study on a-Si:H was reported by Chittik et al. in 1969
- Material was obtained by plasma-enhanced vapor deposition (PECVD) of SiH_4 (Silane).
- Substantial progress of the a-Si:H technology were performed when Spear and Lecomber demonstrated that this material could be substitutionally doped (both in n and p-types) this led to the development of various types of electronic devices such as transistors , solar cells memories and eventually, in the second half of the 80', planar radiation detector in p-i-n structures.

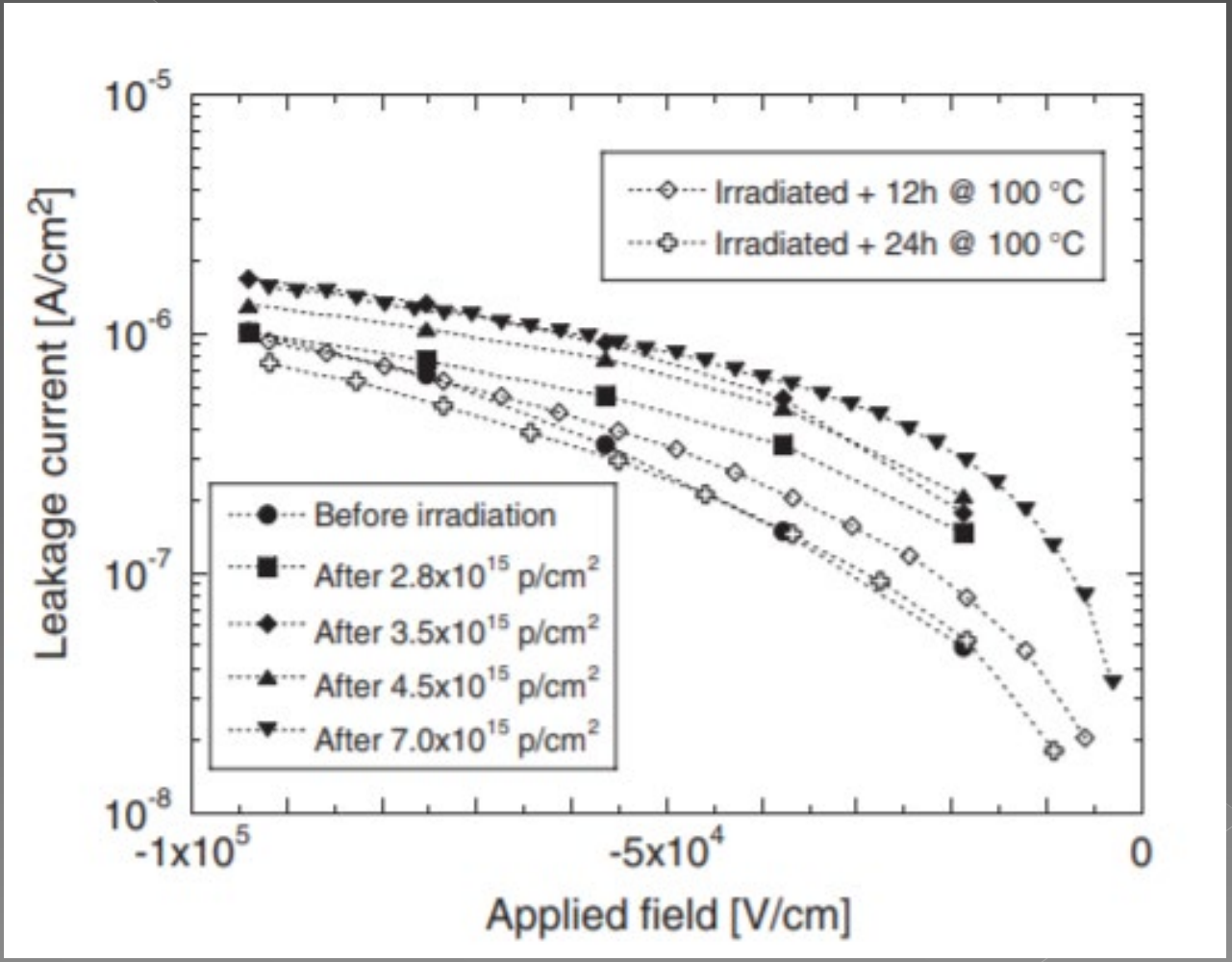
A-Si:H planar detectors pros & cons I

- Pros:
  - Extremely low radiation damage.
  - Low cost production (this technology is currently used in solar cells production)
  - Possible deposition in many different substrate materials

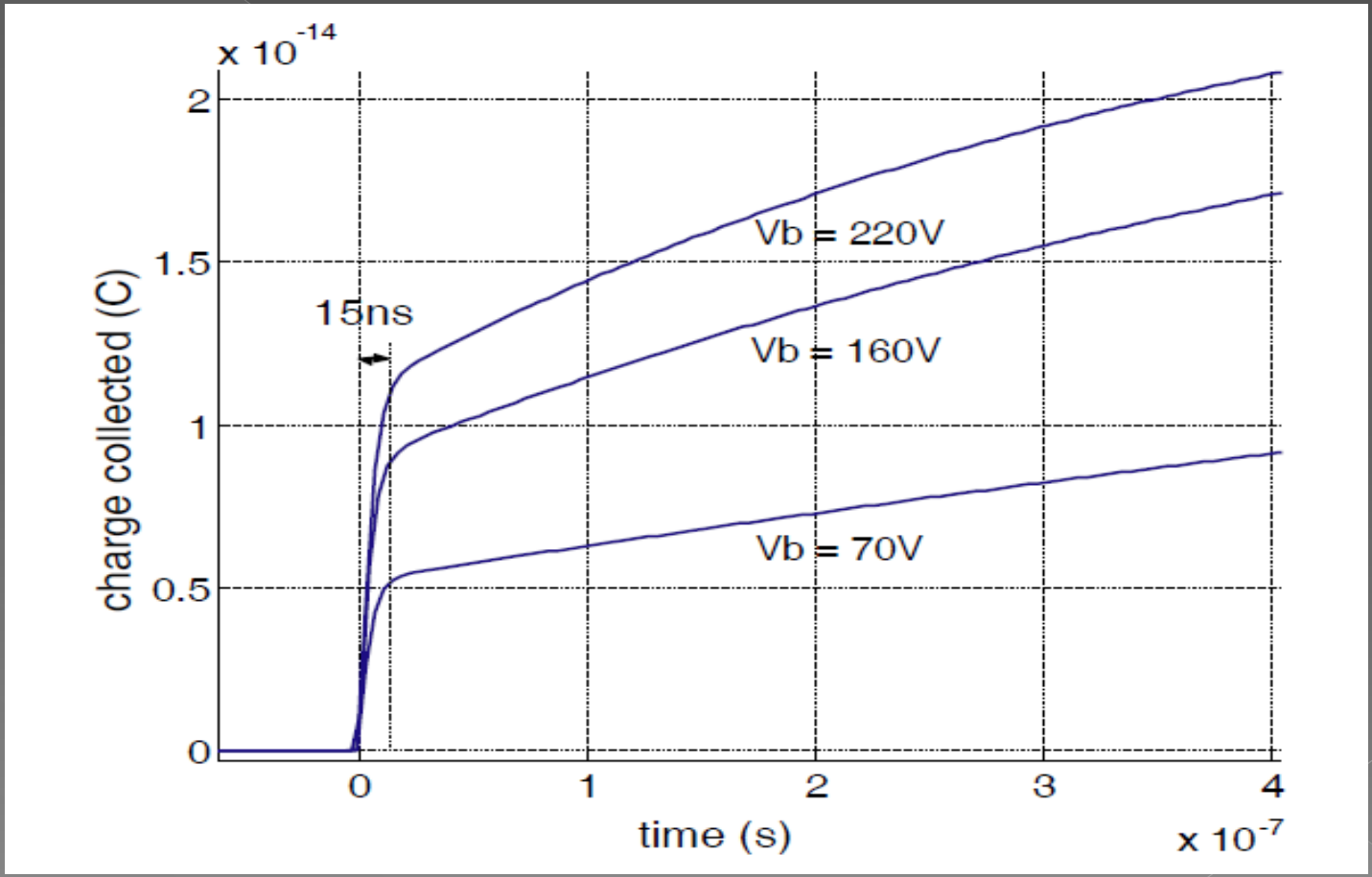
A-Si:H planar detectors pros & cons II

- Cons
  - High depletion voltage (about 1100 V for 50 um thickness)
  - Growth on a non-removable substrate
  - Pretty low charge collection efficiency: 50%(on a 30 um thick detector) energy to create a e-h pair similar to crystalline silicon (3.4-3.5 eV)
  - High leakage current (in the order of few uA/cm^2 on a 30 um detector)
  - Low mobility (from 1 to 10 cm^2 /Vs for electrons 2 orders of magnitude less for holes)
  - Limited thickness of substrates (max 100-150 um)

Displacement damage on a 30 um a-Si:H planar detector



Signal formation on planar a-Si:H detectors



3D technology on a-Si:H

- Possible advantages:
  - The depletion potential applies on the intercolumnar distance and not on the thickness of the detector
  - The shape of the electric field in a 3D detector may have some benefits also on the charge collection time
- Never attempted before
- Noise reduction test at cold temperature (e.g. -30°C)

Baseline detector structure

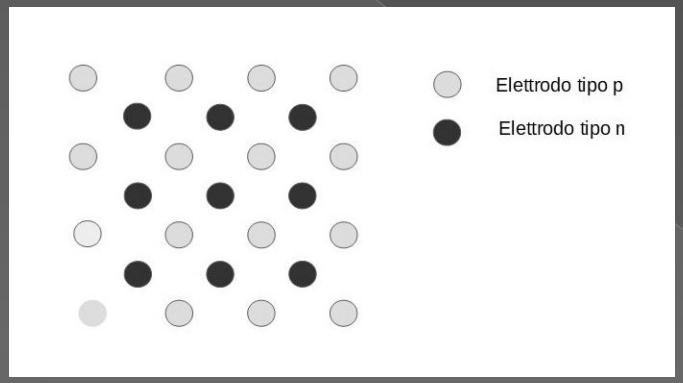
Technological options for doping the electrodes

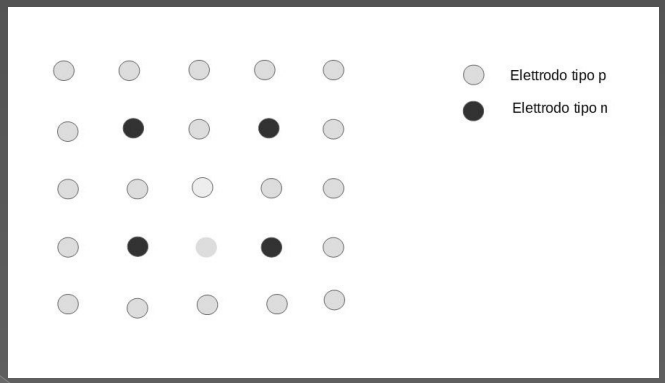
- Option 1: Selective layers of metal oxide deposited via ALD
- Option 2: Ion implantation and low temperature activation (250 °C or below)

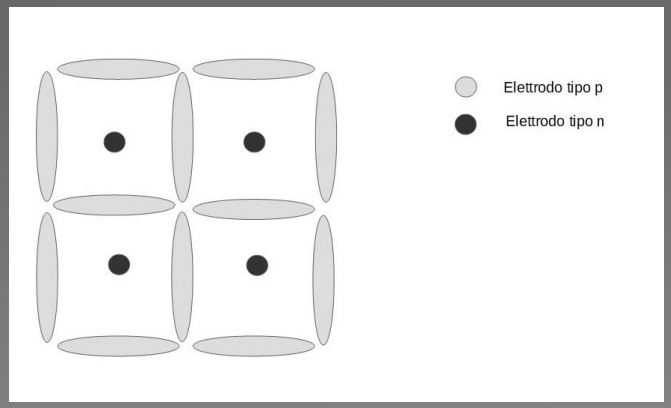
Prototype development

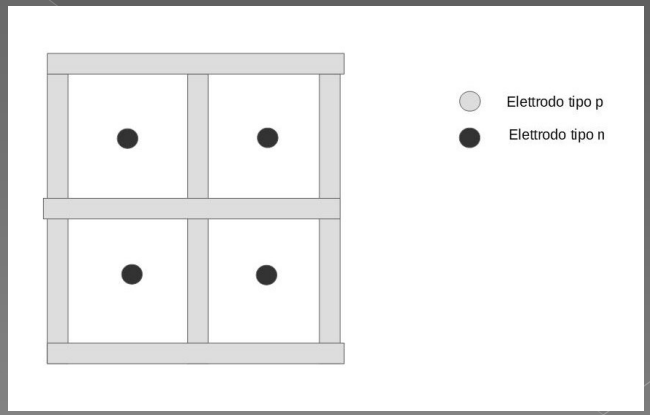
- Phase 1: construction of planar diodes with option 1 and 2 doping techniques.
- Phase 2: Construction of basic 3D structures in order to test the two proposed doping techniques.
- Phase 3: Contruction of 3D detectors in various configurations.

Possible detector configurations



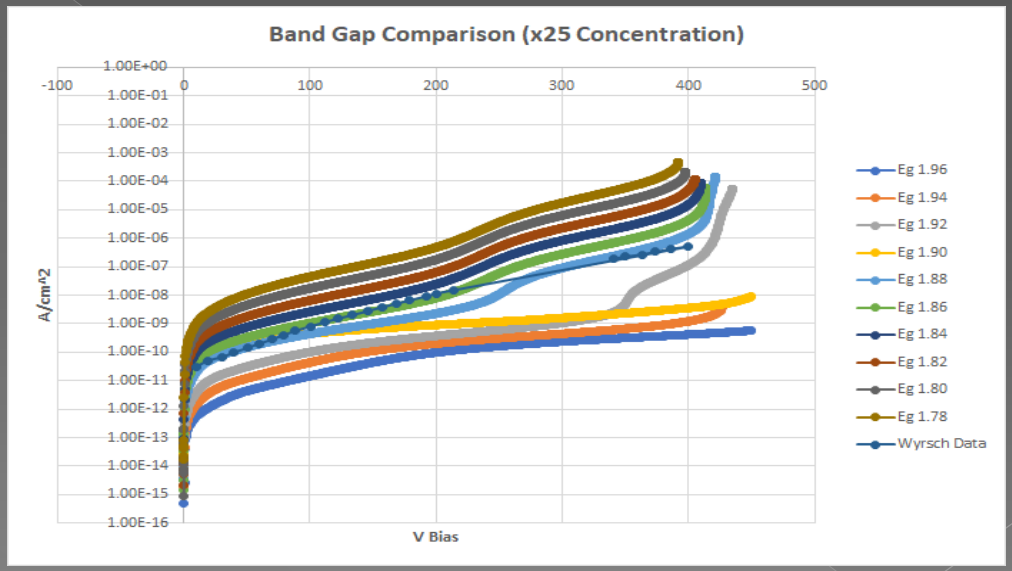






Side development

We need of a simulation model for a-Si:H for SYNOPSYS.



Timeline of the 3 years program

- We are defining the design of the various devices in the phase 1 prototypes
- Soon we will begin to make depositon of the a-Si:H for the phase 1 prototypes
- Completion of production of the phase 1 prototype by September.
- Testing of the phase 1 prototype and beginning of definition of the phase 2 prototype by the end of 2019
- Construction of phase 2 prototype by mid 2020.
- Testing of phase 2 prototype and design of the phase 3 prototype by the end of 2020
- Production and testing of the phase 3 prototype by the end of 2021

The future of 3D a-Si:H detector

- Construction of a actual pixel detector bump-bonded with a readout chip.
- Deposition of a-Si:H directly on the readout chip and construction of the 3D detector on the deposited substrate.