Hydrogenated amorphous silicon is a relatively new material whose doping properties to form p or n layers and therefore produce diodes were first demonstrated in 1976. Since particle detectors are essentially reverse biased diodes the capability of making charged particle detectors exists. The non-doped, intrinsic (i) layer has better transport properties than either the p or n doped layers hence the structure that we, as well as the solar cell manufacturers, use is a p(i)n(p(i)n) layer with metallic contacts, typically chromium or palladium. The main advantage for particle detection is that since a-Si:H is non-crystalline it can be formed in large areas by plasma enhanced chemical vapor deposition (PECVD) techniques on glass, stainless steel or polyimide plastic substrates as shown below in Fig. 1. Deposition rates range from 0.5 - 1 μm/hour at 13.5 MHz up to 4 - 5 μm/hour (new technology at 70 - 110 MHz RF). Additionally large area, thin film electronics is made by the same deposition technology.

The structure of the material is shown schematically in Fig. 2. This has short range order and therefore can permit electric and hole movement provided the trap density (dangling bonds) is kept sufficiently low. Under optimum deposition conditions a large fraction of the dangling bonds attach hydrogen atoms leaving a residual trapped density of 1 - 2 x 10^15/cm^3. With this quality of material we measure electron and hole mobilities of 1 - 1.5 cm^2/Vsec (electron) and 0.003 cm^2/Vsec (hole). a-Si:H is a high resistance material (~10^10 OHM cm) and p-i-n reverse biased diodes can tolerate electric fields ~ 3 - 5 x 10^3 V/cm corresponding to a bias voltage of 30 - 50 V/cm. Under these conditions the mean free paths of electrons and holes > 100 μm.

For charged particle pixel or strip detectors we have two options: (1) make the i layer ~ 50 μm thick. In such layers, we have measured that a minimum ionizing electron produces ~70 e,h pairs/μm and hence in such a p-i-n diode we can collect ~2500 e,h pairs or ~1800 electrons if we use a short < 50 nsec collection time. As we show below for small pixels (200 μm) this signal can be amplified with thin film transistors (TFT) amplifiers made of a-Si:H or Polysilicon deposited directly underneath the detector layer (Fig. 3a).

(2) Make the i layer ~ 1.5 - 2 μm thick and place a suitable scintillator on top of the p-i-n diode. a-Si:H is a very efficient detector (~80%) of visible light. In order to minimize amplifier noise the detector capacitance can be kept low by use of interdigitated metal electrodes (Fig. 3b). For such layers we collect over 80% of the e,h pairs at 50 nsec resolving times. The signal amplitude then depends on the scintillator thickness.

We measured the response of a-Si:H p-i-n diodes up to 50 μm thickness from 860 MeV alphas, 2 MeV protons and from 1.5 - 2 MeV electrons (MIPS) from a collimated beta source. These measurements showed that a MIPS produces ~70 e,h pairs/μm of a-Si:H which is consistent with a measured value of ~5.5 eV. In Fig. 4 below we show signals from 1 - 2 MeV electrons on various thicknesses of a-Si:H. We also measured charge collection from photodiode light sources to determine mobilities mean free paths, and signal collection time for electrons and holes. The calculated values are shown in Fig. 5.

Fig. 3 Schematic coupling of a-Si:H detector pixels or strips to thin film electronics. Each metal pad is coupled to an individual charge sensitive amplifier. (a) Thick (50-70μm) a-Si:H detector. (b) Thin (1.5-2μm) a-Si:H detector coupled to scintillator.
In Figs. 3a, 3b we show that the large area pixel arrays can be readily coupled to distributed thin film electronics. Fig. 6 shows the general structure of a-Si:H or polysilicon T.F.T. Table 1 below shows some of the properties of these T.F.T. that we have measured or calculated from their dimensions. We also exposed these T.F.T to fluences up to $5 \times 10^{14}$ 1.5 MeV protons and found less than 5% increases in noise and leakage currents.

![Diagram of TFT structures](image)

**Table 1**

<table>
<thead>
<tr>
<th>Insulator</th>
<th>L (µm)</th>
<th>W/L</th>
<th>E_in (V)</th>
<th>Rm (Ω)</th>
<th>Freq Limit (MHz)</th>
<th>Noise** (# of e)</th>
<th>Radiation Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-Si:H TFF</td>
<td>Si3N4</td>
<td>4</td>
<td>0.3-0.8</td>
<td>1-60</td>
<td>3-200</td>
<td>1-10</td>
<td>50 - 400</td>
</tr>
<tr>
<td>900°C poly Si</td>
<td>SiO2</td>
<td>4</td>
<td>0.3-0.8</td>
<td>1-60</td>
<td>3-200</td>
<td>10-700</td>
<td>N: 60 - 500</td>
</tr>
</tbody>
</table>

We have designed prototype charge sensitive amplifier arrays assuming the use of either the 4 µm gate length a-Si:H or 10 µm gate length polysilicon. For detector layers 50 µm thick with capacities ~ 0.1 pf, we estimate that S/N > 10 can be achieved for minimum ionizing particles. For the scintillator - a-Si:H alternative considerably higher S/N can be achieved depending on the scintillator thickness.

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**References**

The publications listed below contain extensive references.


