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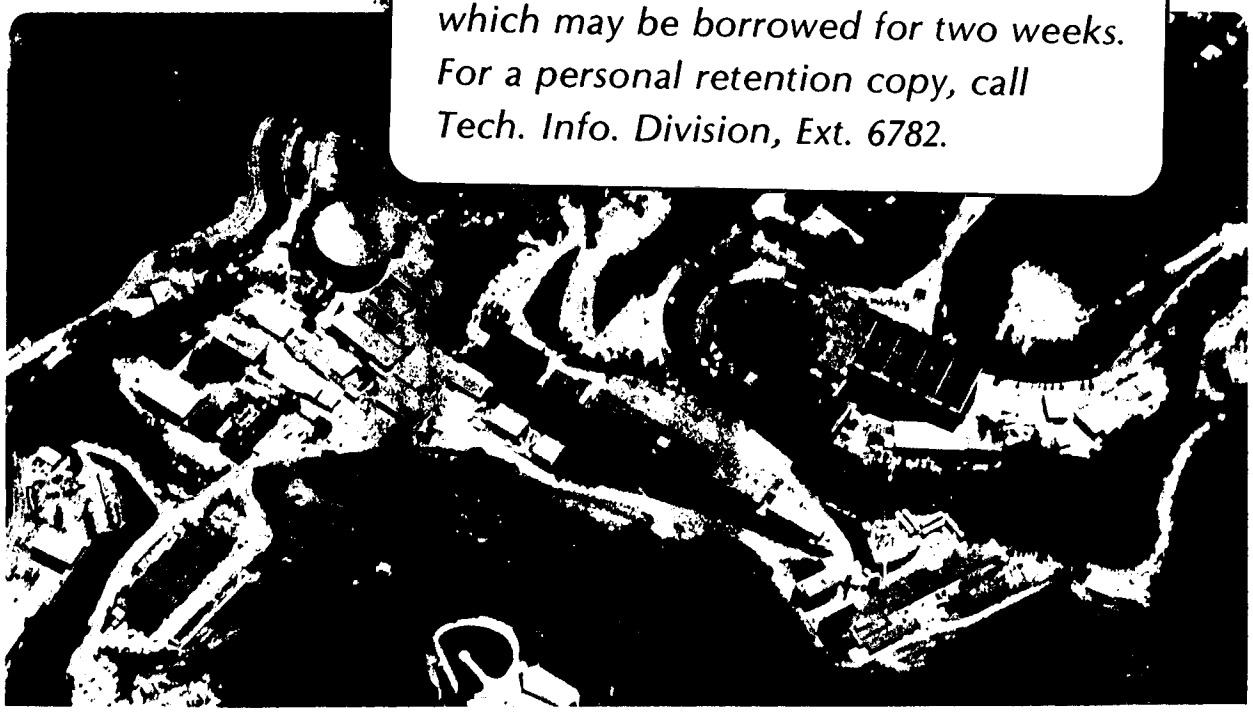

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# Large Area Non-Crystalline Semiconductor Detectors

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## Summary

The properties of various non-crystalline semiconductors are considered for use as position sensitive detectors. Amorphous silicon and conducting plastic can be doped to form NP depletion regions similar to those in single crystal silicon, but without the limitation of single crystal size. Chalcogenide glassy materials such as Te-Se-Ge compounds as well as some metallic oxides such as the Vanadium oxides have switching and memory properties. They could serve as x,y location identifying devices when triggered by amplified pulses from a parallel plate or multistep gas filled detector stage in order to resolve the multitrack ambiguity for x,y readout schemes.

## I. Introduction

Single crystal semiconductor detectors have been widely used in Nuclear Physics research as energy measuring devices. For $\gamma$ spectrometry in the few KeV to MeV energy range, back biased NP junction Germanium single crystals of ultra-pure germanium have given the highest energy resolution of any device. Position sensitive detection of charged particles has been done with back biased NP junctions in silicon crystals with a plated metallic grid to give the position information. In high energy physics these devices have come into use as vertex detectors in colliding beam accelerators, with spatial resolutions in the few tens of microns range.

All of these applications of silicon and germanium semiconductor detectors are limited to small area usage by the fact that they are slabs of single crystal material. Larger area devices could be made by use of a mosaic of crystals at a high cost and with a great deal of electronic complexity. Furthermore, if the events which traverse the crystal have a high multiplicity, the usual multi-track ambiguity from crossed grid detectors is still present.

We propose to develop the properties of three classes of non crystalline semiconductors for uses as radiation detectors, which would not be subject to the above mentioned limitations. These are (a) Amorphous silicon; (b) semiconducting plastics and (c) chalcogenide - Metallic oxide compounds.

Both amorphous silicon and semiconducting plastics - primarily polyacetylene - can be doped by suitable materials to form N or P type layers and thus create a depletion region by back biasing in the usual manner. Since both of these materials are non-crystalline, the limitations as to size do not apply; however, the difficulty with the multi-track ambiguity still remains.

Amorphous silicon can be deposited in large areas by various proccesses such as the decomposition of Silane-$S_iH_4$[1]. Doping with trivalent and pentavalent impurities can be done by vacuum deposition, or by sputtering techniques. The mobility of the elecrons and holes in this material is appreciably slower than in the single crystal silicon,[2] and thus there may be serious limitations to the resolving time of such layers if they are more than a few microns thick. Multiple layers can presumably be made in order to have a sufficient stopping power for detection of minimum ionizing particles. Amorphous silicon, being non-crystalline is less susceptible to radiation damage than its crystalline counterpart.

The development of conducting plastics has occurred primarily during the last few years. Among the various types[3] the most promising at this point is Polyacetylene which can be made by vacuum techniques[4] in layers up to a few m.m. thick. Doping with trivalent and pentavalent impurities for PN junctions formation can be done by electrolytic methods[5] or by deposition from the gaseous phase.[6] One present difficulty with the conducting Polyacetylene is that it is unstable in the presence of oxygen; this difficulty can, however, be readily resolved by encapsulation with thin mylar sheets.

A third approach to large area solid state detectors is to use the switching properties of some chalcogenide (Se-Te-Ge-Si) and metallic oxide compounds. These materials switch from a high resistance state to a low resistance state; some under the action of an electric[7] field and some at a critical temperature[8]. The Vanadium Oxides $V_2O_3$ and $VO_2$ for example switch at temperatures of 140°K and 68°C respectively. Some of the Se-Te-Ge-Si chalcogenides have been used as electronic latches in prototype computer memory arrays[9]. These devices can be made in large areas by vacuum deposition, sputtering and similar techniques. The temperature switching components are slower than the electronic switching compounds (10-100 $\mu$sec compared to 1-20 nsec).

The switching compounds have the following useful features

(a) They are readily made and there is some commercial background on their use
(b) They are more radiation resistant than the semiconducting plastics
(c) The switching properties and their memory can be used to resolve the multi track ambiguity when x,y crossed grid arrays are used.

Figure 1 shows the voltage current relation for typical electronically switched chalcogenides. Since traversal of a semiconducting layer by a charged particle will not produce a net potential difference across the layer, these materials could be used in conjunction with a gas filled chamber and serve as a memory at each node of an orthogonal grid of wires or plated strips similar to a glow chamber memory device[10].

Figure 2 shows the configuration of an argon or neon filled chamber (with a suitable quenching gas), either working as a parallel plate chamber or in a multistep chamber configuration. The pulse of electrons ($10^7$ to $10^8$ electrons) can be drifted onto a plated layer of chalcogenide material, causing switching at locations where charged particles traversed the chamber. A readout scheme in which the $n^2$ locations are sampled is shown in Fig. 3. Each x line is pulsed sequentially to switch off any conducting elements on that line. The corresponding y locations are read out in synchronism. The speed of such a readout can be as short as 10-20 n/sec per x wire, which is appreciably faster than the corresponding glow memory device.

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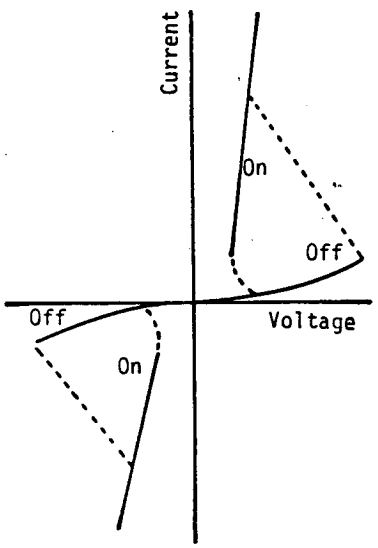


Fig. 1. Current voltage characteristic of a chalcogenide glass switch.

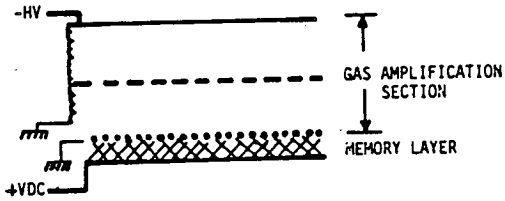


Fig. 2. Schematic of proposed detector. The gas amplification scheme shown here is a multi-step avalanche chamber.

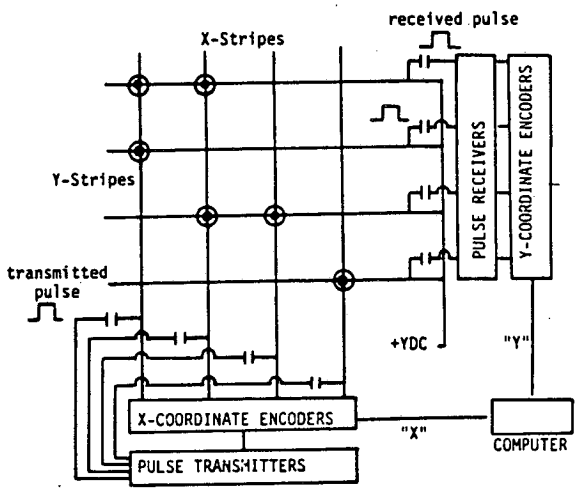


Fig. 3. The correlated x-y readout scheme. The circles represent memory elements which have been switched on by the passage of a charged particle at that location.

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