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Sezione di Torino

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REALIZATION OF AN AUTOMATIC SET-UP TO MEASURE ELECTRICAL CHARACTERISTIC OF SOLID STATE DETECTORS

C. Manfredotti[1,2] , D. Crosetto[1], A. Gabutti[1], G. Gervino[1,2], R. Varesio[2]

ABSTRACT

We describe an automatic set-up to study electrical properties of silicon detectors for nuclear research. Particularly, I-V characteristics from silicon junction prototyipe detectors and amorphous samples to test the data acquisition system, are presented.
This set-up joins a low cost to good versatility that makes it very useful in wide application ranges in silicon detector electrical characterization.

INTRODUCTION

In working with solid state detectors (Ref. 1,2,3) particularly of complex type, are usually needs an automatic set-up in order to investigate its electrical properties in general, particularly as for as the I-V characteristics are concerned, since the I-V characteristics may give important informations regarding the mechanisms of the dark current, the possibility of achieving high bias values, etc.

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The apparatus can be used in order to investigate amorphous silicon from the point of view of nuclear detector applications (Ref. 4) and also to study the distribution of gap state density by the Space-Charge Limited Current method (Ref. 5).

In what follows, a detailed description of the automatic data acquisition station which has ben realized is give, toghether with some examples of the obtained results.

DESCRIPTION OF THE AUTOMATIC SET-UP

In Fig. 1 is show the block-diagram of the automatic measurement set-up. We have employed the following instruments:

- KEYTLEY current generator Mod. 20
- KEYTLEY electrometer Mod. 617

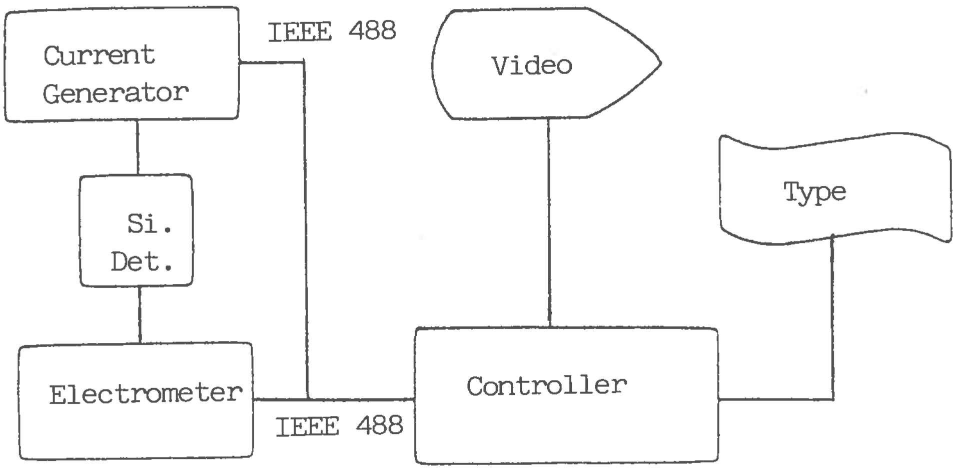


Fig. 1 - Block diagram of the set-up.

Both instruments are programmed by computer using a standard parallel interface IEEE 488. The controller is a CP/M compatible Micro Learn (Ref. 6) connected with a TESAK videous and a graphic printer. The Micro Learn development system consist in two boards based on the STD-BUS: Micro Learn CPU board with a Z-80 microprocessor and Micro Learn Disk Controller board.

The low cost of the boards and the modularity both in hardware (STD-BUS) and in software (CP/M operating system) give the possibility to use these boards in a wide range of applications such as:

- Process control: automation, measuring devices, real time data acquisition, digital control of machine-tools, etc.

- Development system for Z-80 microprocessor
- Instrumentation laboratory controlled by microprocessor (IEEE 488-1978)
- Portable stand-alone instrumentation

The current generator has the following electrical characteristics:

a) Highest value of delivered current for both polarities equal to $101\cdot10^{-3}$ A.
b) Lowest value of delivered current equal to $5\cdot10^{-13}$ A.
c) Lowest incremental step of current, give both manually and by software, equal to $5\cdot10^{-13}$ A.
d) Error in current delivered (it depends upon the range) from 0.005 to 0.4 %
e) Highest voltage value which is possible to have during a measurement at the ends of the tools is 105 V.
f) Lowest voltage step equal to 1 V.

The electrometer is used as a simple voltmeter to measure ΔV at the end of the sample.

Its characteristics are the following :

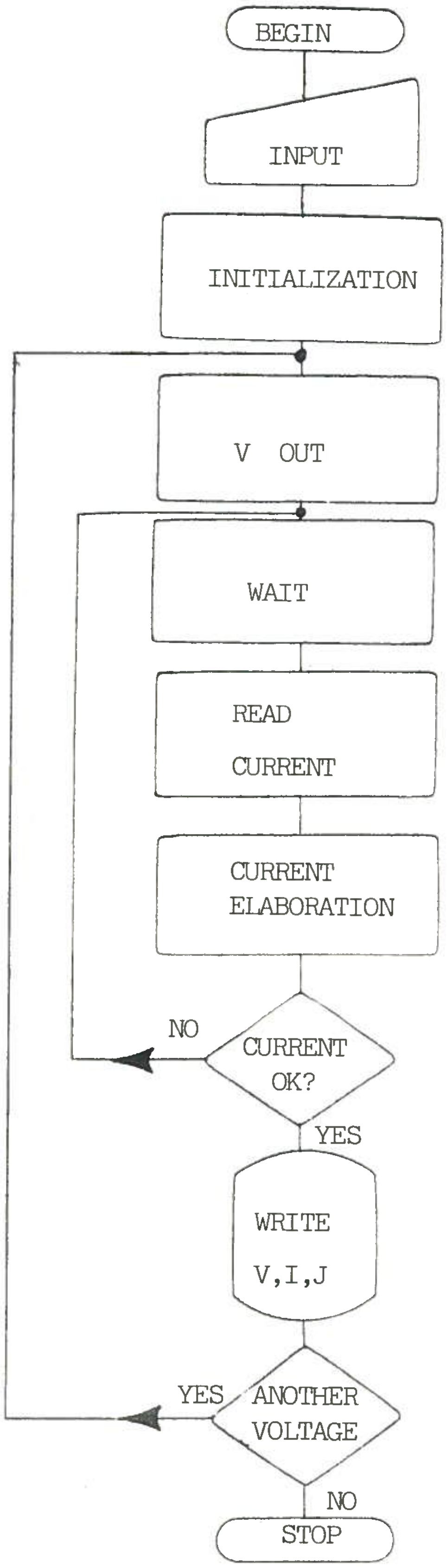
a) Input impedence of about $2\cdot10^{14}$ /20 pF
b) Highest possible voltage to apply in input equal to 200 V.
c) Lowest measurable voltage equal to $1\cdot10^{-5}$ V.
d) Precision of the tool equal to 0.05 %

Among the facilities of Mod. 617 Keytley electrometer there are a memory bank able to store 100 numerical values and we can program the dead time between two contiguos measurements, knowing that this time-value multiplied by 100 is equal to the time employed to fill the buffer of data.

We interfaced the instruments using a IEEE 488 board by ZIATECH, that provided us its management software routine. We have, in this way, a completely automatic measurement system that stores on a disk (floppy or hard disk) the numerical values without the need by any operator. The software of the set-up is organized in a main program writen in fortran and a few routines in assembler which are called by the main program. The assembler routines control the logic state of the wires employed for interfacing the external tools, and they manage the process of hand-shake, the data bus and the control bus.

The flow-chart of the main program, in its general and easier form, is shown in Fig. 2. The input data of every measurement are:

a) Range of negative and positive voltage and the incremental step for both (current step in SCLC measurements)
b) Dead time useful to stabilize the set-up after a current or voltage step, before taking the voltage or the current value



Data input

Interface and tools initialization

Generation of a voltage value

Dead time to stabilize the set-up

Read 100 current value

Calculation of the highest and lowest current value

The measurement is it acceptable?

Register on a floppy or hard disk values measurements

Do you want another voltage value?

Fig. 2 - Flow-chart of the menagement program.

c) Highest voltage value, that we can have at the ends of the sample during SCLC measurements, or highest current value during detector charactrization

d) Parameters useful for the off-line analyse of the data (contact surface, box temperature, etc.)

Looking at the flow-chart in Fig. 2, we see that after calculation of the highest an lowest voltage value of a sequence of 100 measurements, if it's true, the following relation for SCLC measurements:

$$(V_{i\ max.} - V_{i\ min}) > \frac{\sum_{1}^{100} V_i}{100} \quad \text{PERC}$$

where PERC is the maxim percent spread admitted, then all the sequence of data is destroyed and the measure starts again after a programmed wait time to stabilize the set-up.

For measurements of I-V detector characteristics we use the equivalent relationship:

$$(I_{i\ max} - I_{i\ min}) > \frac{\sum_{1}^{100} I_i}{100} \quad \text{PERC}$$

We choose an accuracy of the measurements around 3 percent.

The contact with the sample by a SPAD system is assured with two very thin gold surface probes (Fig. 3) . The sample is fixed between two slides of teflon and we connect the probes on the sample surface by a system of micrometer screws, that controls the probe pressure assuring a perfect repetition of the measurements.

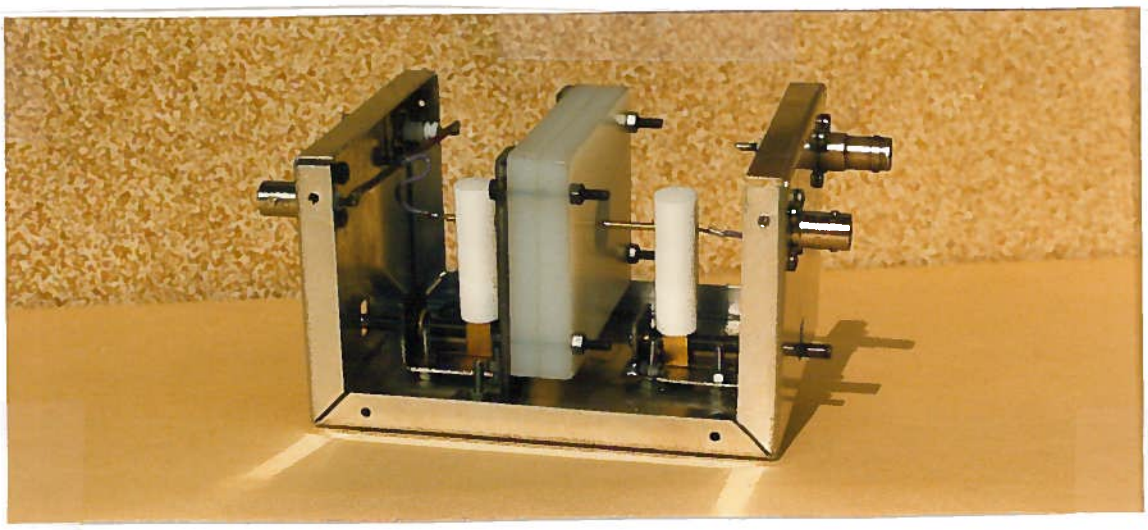


Fig. 3 - SPAD probe system.

EXPERIMENTAL RESULTS

In Fig. 4 it is shown an I-V characteristic of large area silicon junction detector (6 cm^2). We have normalized our results whith unity surface. Investigating the possible way to build solid state detectors, we have realyzed a prototype with a junction made by thermal diffusion of phosphorous on p-type silicon of high resistivity (5-10 KΩ cm). The junction depth is 16 µm and donor concentration is $N_D = 7.7 \cdot 10^{19}$ cm^{-3} measured using spreading resistance tecnique. Electrical stability is reached by surface passivation with a thin film of SIPOS using L.P.C.V.D. deposition tecnique (Ref. 8). We carry out measurements by giving a 1 V. voltage step every 5 minutes, reaching 100 volts as the highest voltage value. The contact between the aluminium electrode of the detector and the probes is ohmic and do not carry in any distorsion in the measures of the reverse current.

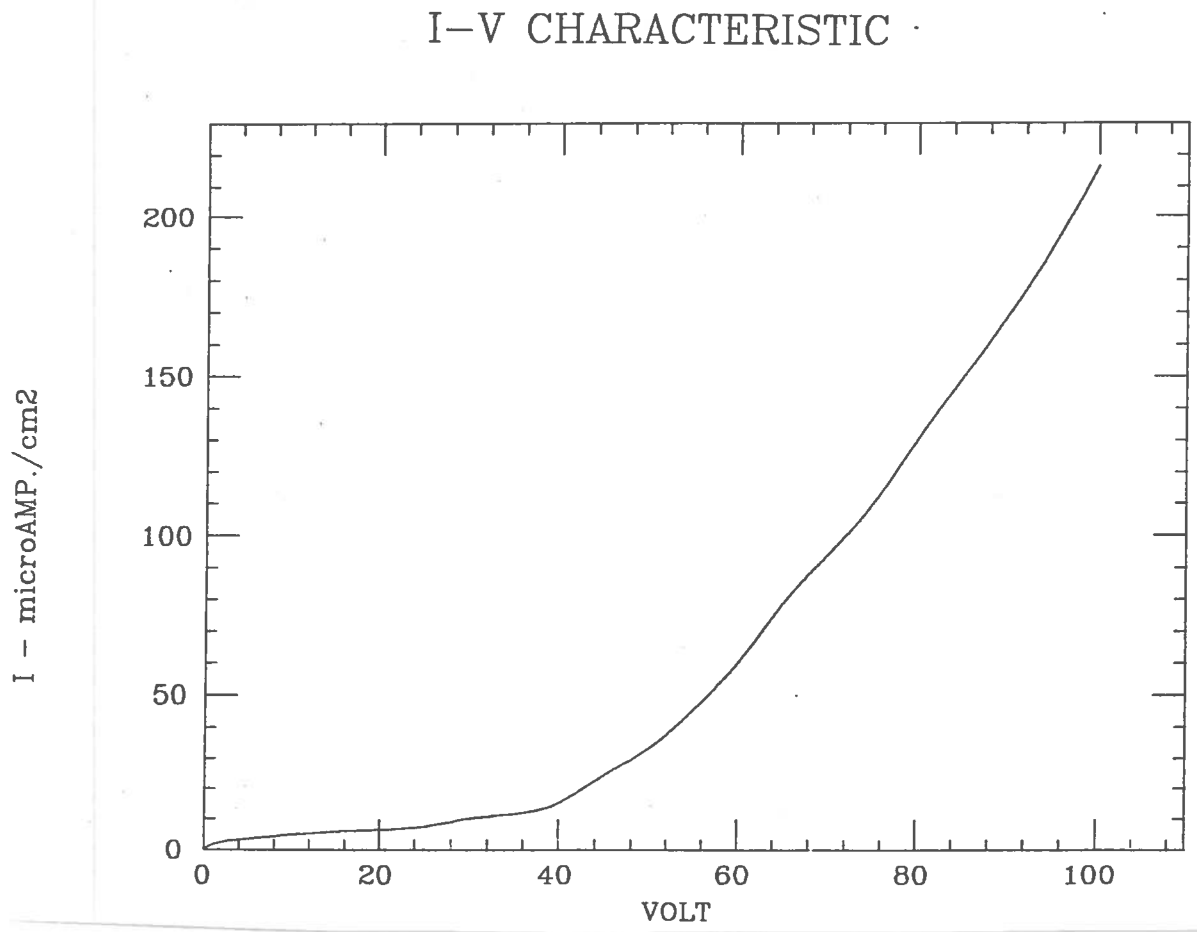


Fig. 4 - I-V characteristic normalized on unity surface of a large area junction silicon detector.

In Fig. 5-6 we present some experimental results get from amorphous silicon samples with about 1 µm tickness aluminium film; the electrode deposition was obtained by electron beam VARIAN Mod. 3117 set-up.

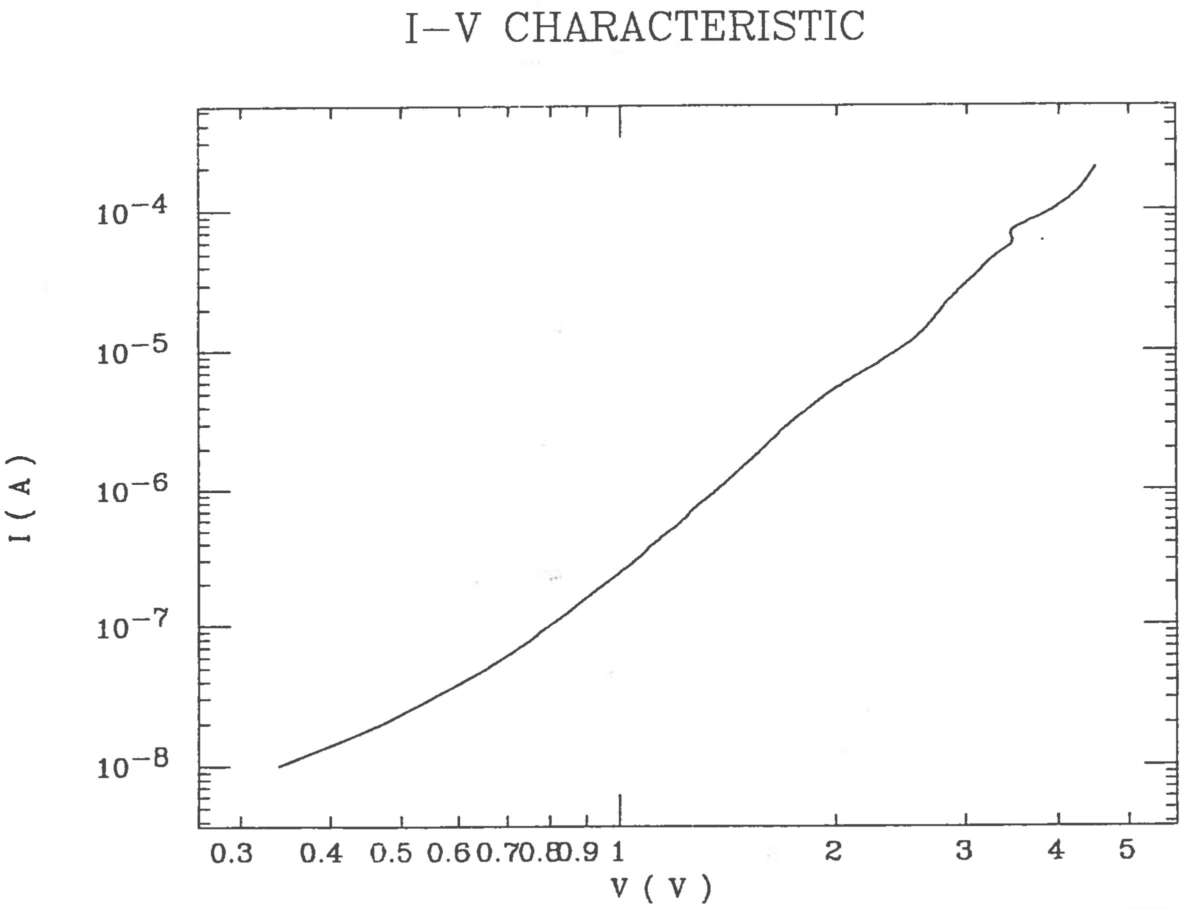


Fig. 5 - I-V characteristic of amorphous silicon film 1400 Å of thickness.

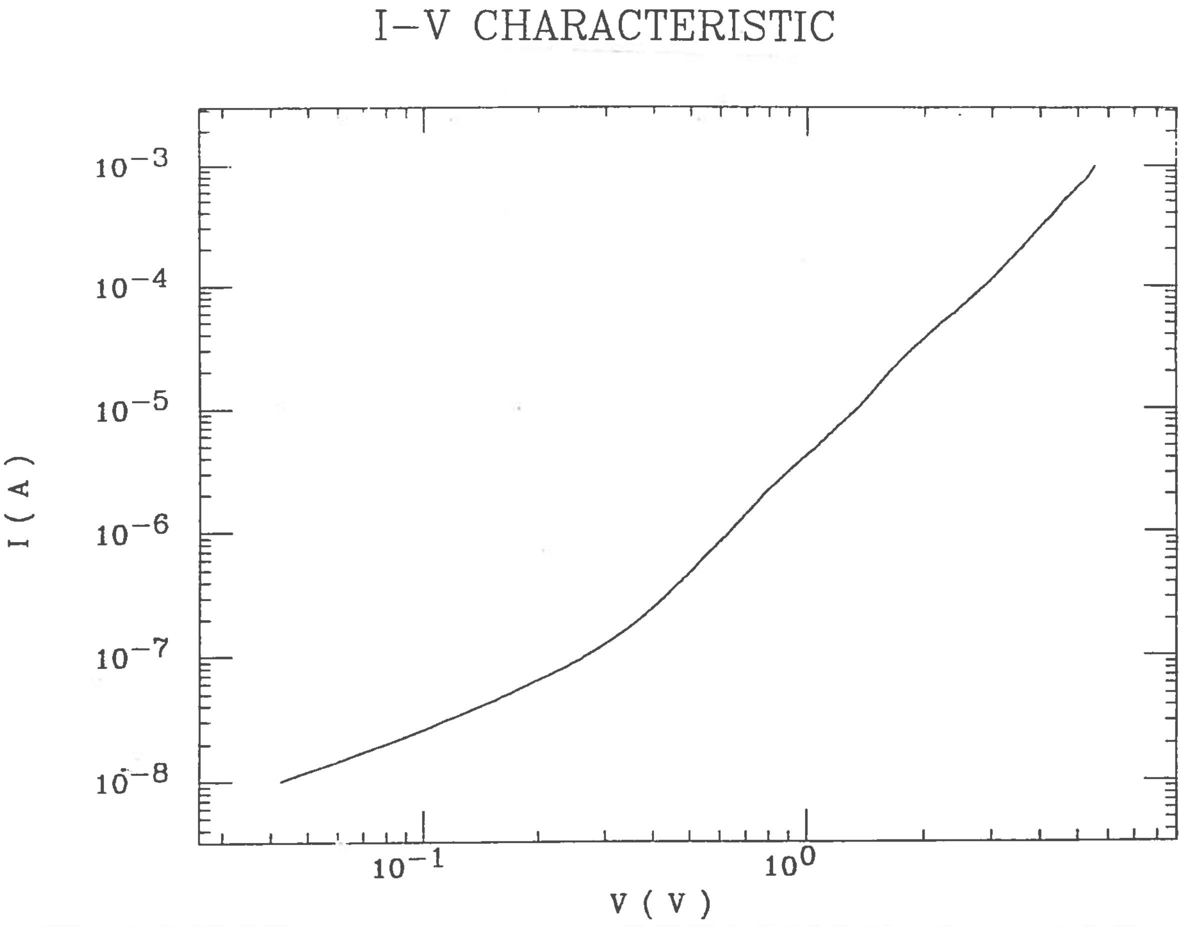


Fig. 6 - I-V characteristic of amorphous silicon film 2000 Å of thickness.

We have choose these measurements because they show better than others the performance of the automatic set-up in a working situation. It's possible, for istance, by this data acquisition system to study the gap state density using SCLC method. We can notice by them a good steadiness and a good agreement of the measurements. This fact is confirmed by the test of agreement (Fig. 7) on the steadiest sample; the convergency of several characteristics is a proof of the goodness of this system.

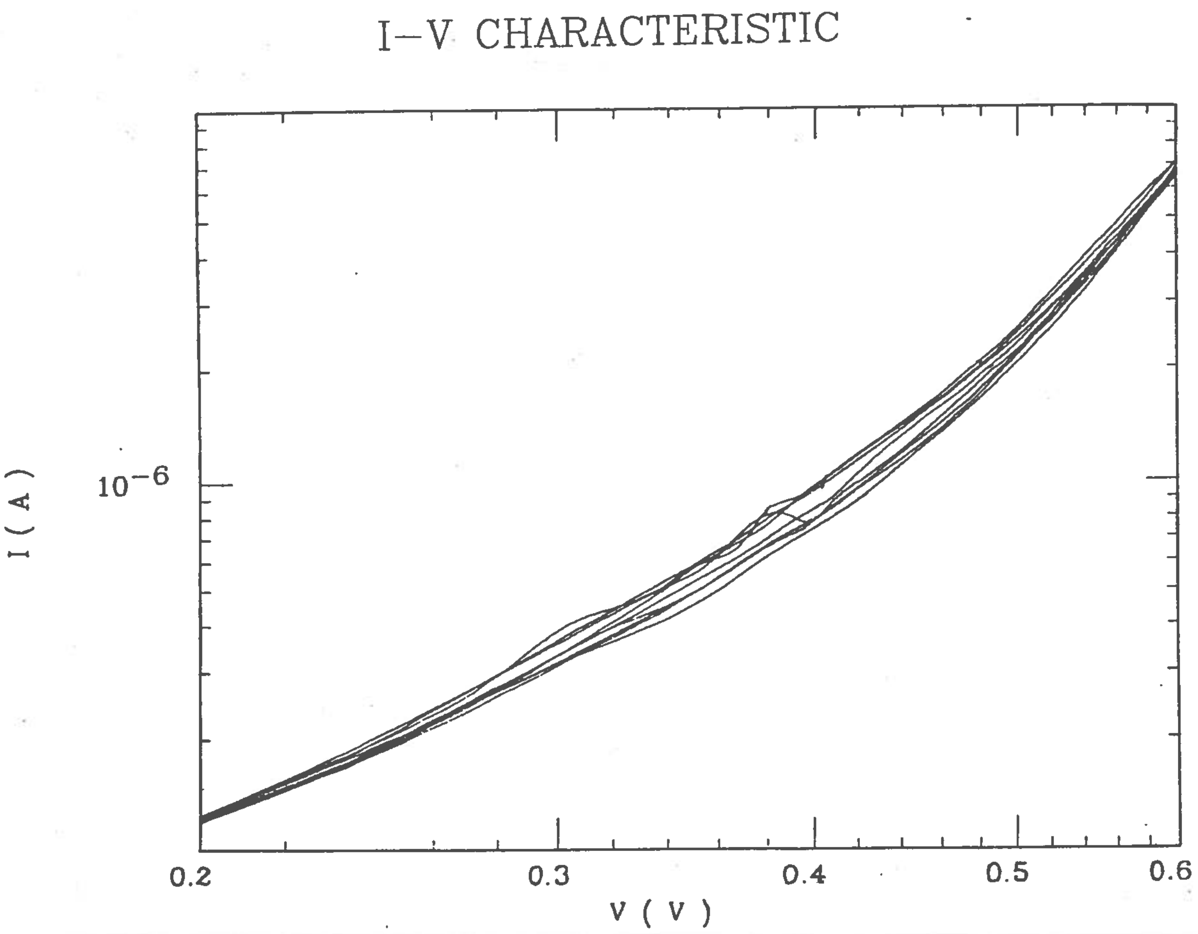


Fig. 7 - Different I-V characteristics taken from the same amorphous silicon sample at different time in the same conditions.

CONCLUSIONS

This project has good performance to get electric characteristics from multistrip silicon detector because it is possible to measure dark current of each strip or strip to strip leakage current.

The facility to get measure at fixed interval of time allows to study the failures by external factors on the semiconductor detector performances. This data acquisition system is a powerful tool to develop high energy physic detectors, for istance, its perfectly measurement repetition is very useful to investigate about the radiation damage with a good accuracy.

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