# CHAPTER VI

## RESULTS AND DISCUSSION

Results of this experiments were shown for nickel-, copper-silicon contacts, solar cells, concentrated solar cells and alpha-radiation detectors respectively.

### 6.1 Results and Discussion of Nickel, Copper-Silicon Contacts

Results of contact resistance and contact resistivity were shown in Table 1 and summarized in appendix E. 1. They were ploted in Fig. 19, 20. The properties of contacts found in this study were summarized in Fig. 19 and Fig. 20. The practical ohmic contact to be good, if its contact resistivity is less than $10^{-3}$ $\Omega$-$cm^2$.[10] Evidently, the previous experimental results assured that the quality of Ni-Si, Cu-Si contacts fabricated by electroplating technique was acceptable by comparing with interporation and extraporation theoretical results.[16] The barrier heights of nickel-silicon and copper-silicon contacts were shown in Fig. 19,20.[10]

Good contacts, however, were obtained with Ni-pSi as shown in Fig. 19. The contact resistivities, $\rho_c$, are the lowest ones ($3.36 \times 10^{-4}$ $\Omega$-$cm^2$ for nonannealing and $2.28 \times 10^{-4}$ $\Omega$ -$cm^2$ for annealing at 120°C for 16 hr). All of $\rho_c$-values decrease after annealing except for the case of nickel and high resistivities p-type silicon contacts.

Fig. 20, the properties of copper contacts were fairly good but these contacts were practically useless in silicon devices, because the copper diffuses rapidly in silicon[11]. Then in this case, the copper induced dislocation in silicon crystal.[12,13]

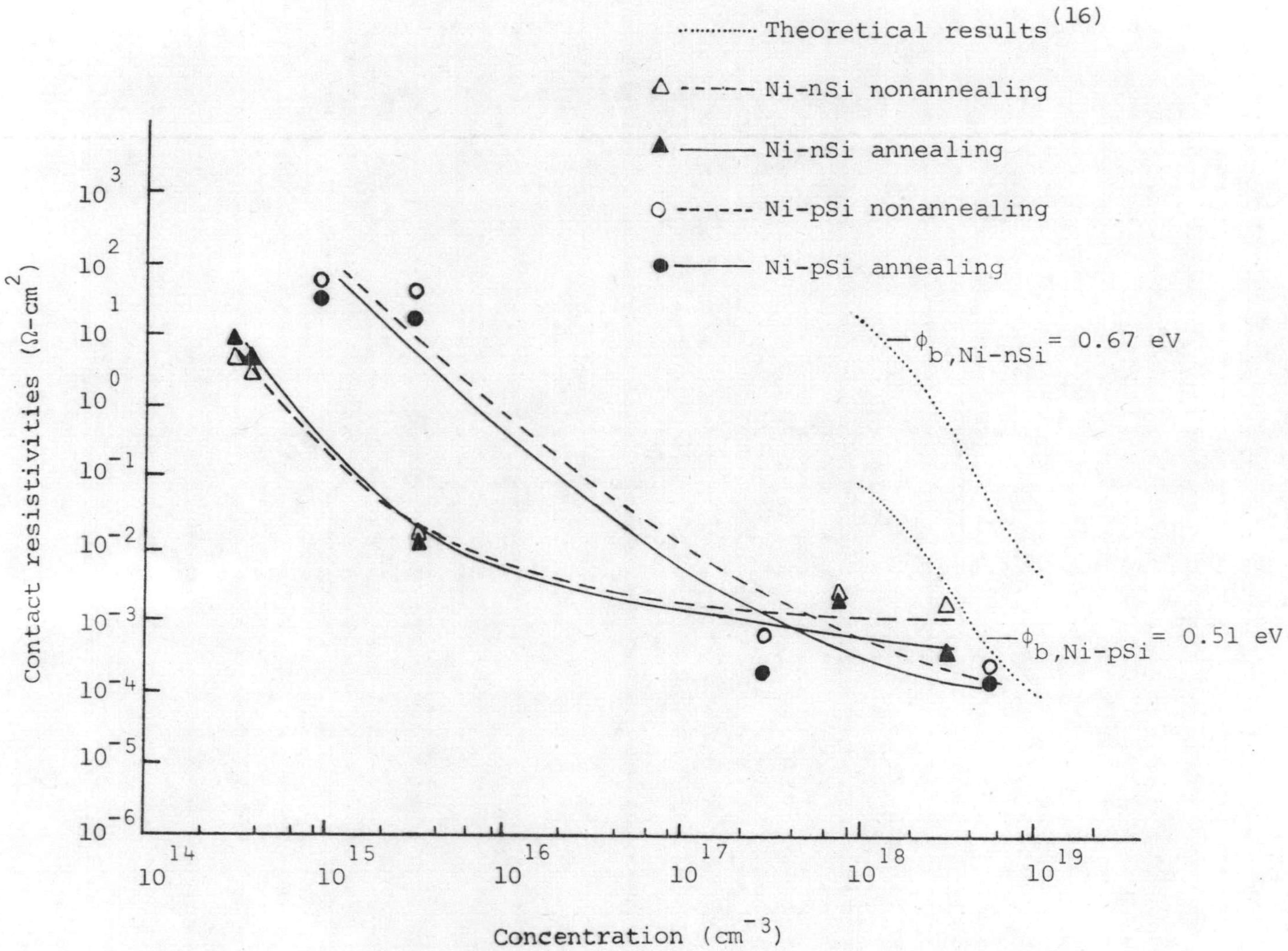



Fig. 19 Contact resistivities vs. impurity concentration for Ni-Si contacts

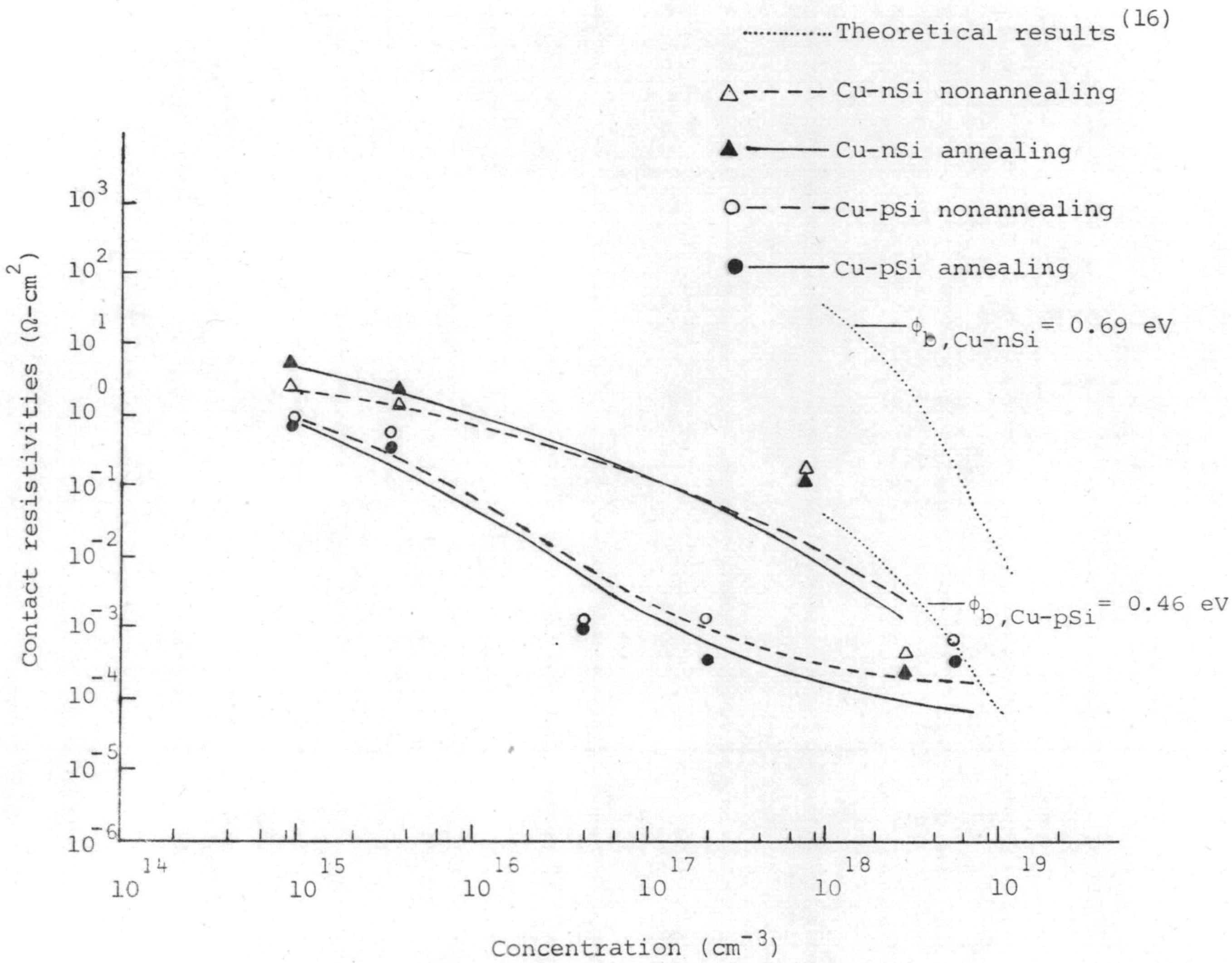



Fig.20 Contact resistivities vs. impurity concentration for Cu-Si contacts

## 6.2 Results and Discussion of Solar Cells and Concentrated Solar Cells

Results of solar cells are compared fabrication of contacts with electroless and electroplating process, which they were shown in Fig. 21,22 and Appendix E.2. They were summarized in Fig. 23.

Results of concentrated solar cells are compared between fabrication of electroplated contact and electroless plated contact which they were shown in table 2 and Fig. 22. The testing equipments of concentrated solar cells were shown in Fig. 24.

Table 2 Photovoltaic parameters of concentrated solar cells (brackets are electroless plated contacts, without brackets are electroplated contacts)

| Suns | $I_{sc}$ (mA) | $V_{oc}$ (V) | $I_m$ (mA) | $V_m$ (V) | F.F. | $P_m$ (mW) | $P_a$ (mW/ $m^2$) | a ($cm^2$) | η (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 47<br>(41) | 0.510<br>(0.510) | 35<br>(32) | .300<br>(.385) | .438<br>(.589) | 10.5<br>(12.3) | 54.3 | 2.7 | 7.16<br>(8.40) |
| 2 | 96<br>(78) | .542<br>(.537) | 78<br>(64) | .385<br>(.415) | 0.577<br>(0.634) | 30.30<br>(26.6) | 140.4 | 2.7 | 7.92<br>(7.00) |
| 5.6 | 262<br>(225) | .550<br>(.540) | 236<br>(192) | .345<br>(.380) | .563<br>(.600) | 81.4<br>(72.9) | 297.9 | 2.7 | 10.08<br>(9.06) |
| 11 | 500<br>(460) | 432<br>(478) | 410<br>(380) | .275<br>(.315) | 0.544<br>(0.521) | 112.7<br>(119.7) | 609.2 | 2.7 | 6.84<br>(7.27) |

Where Suns is the relative intensity, $I_{sc}$ is the short circuit current. $V_{oc}$ is the open circuit voltage. $I_m$, $V_m$, $P_m$ are the parameters maximum power output. $P_a$, a, and η are the input power, active area, and effiency respectively. The efficency can be written as $\eta = F.F. I_{sc} V_{oc} / P_a a$.

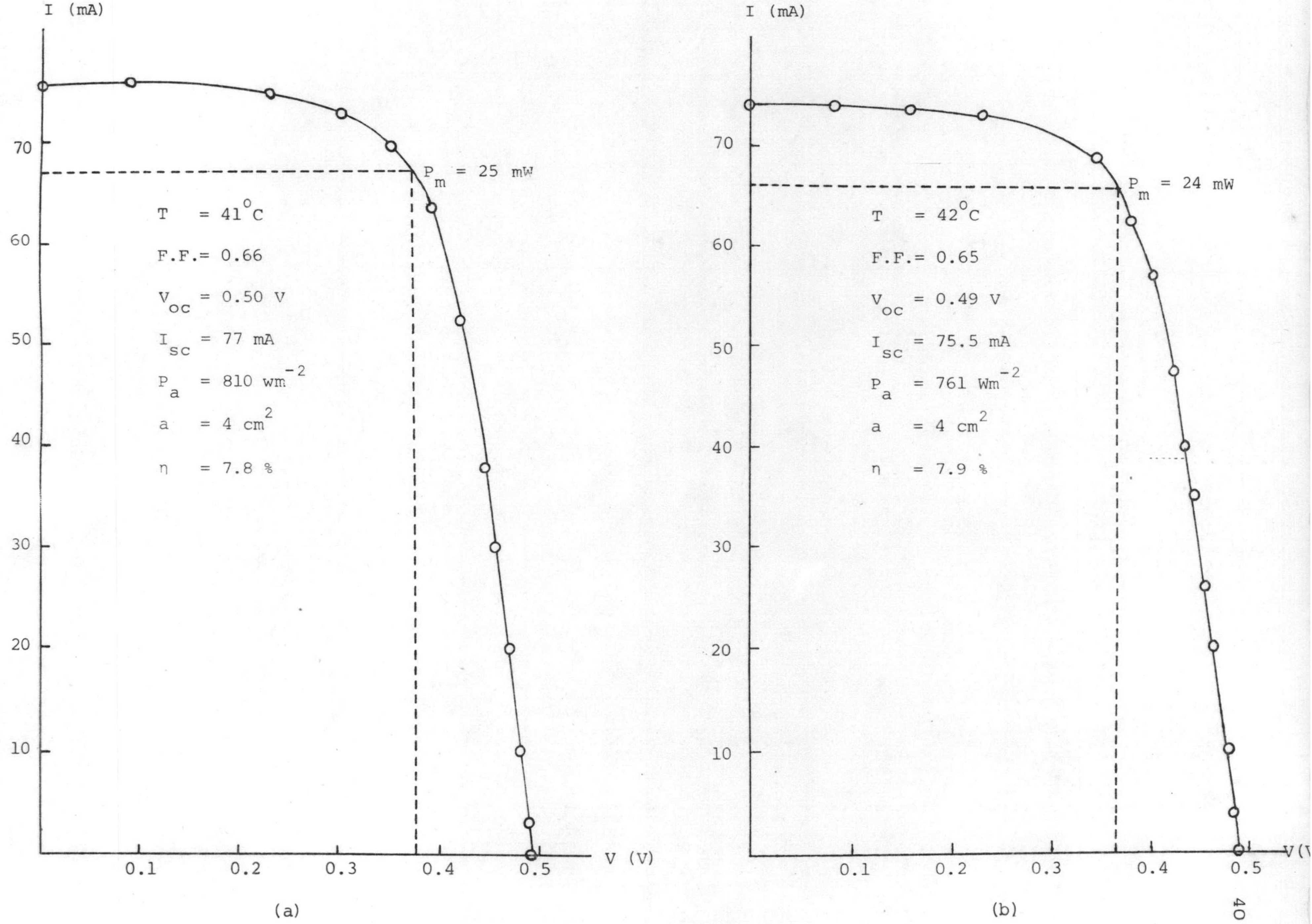



Fig. 21 The I-V chacteristics solar cell curves with electroplating technique.

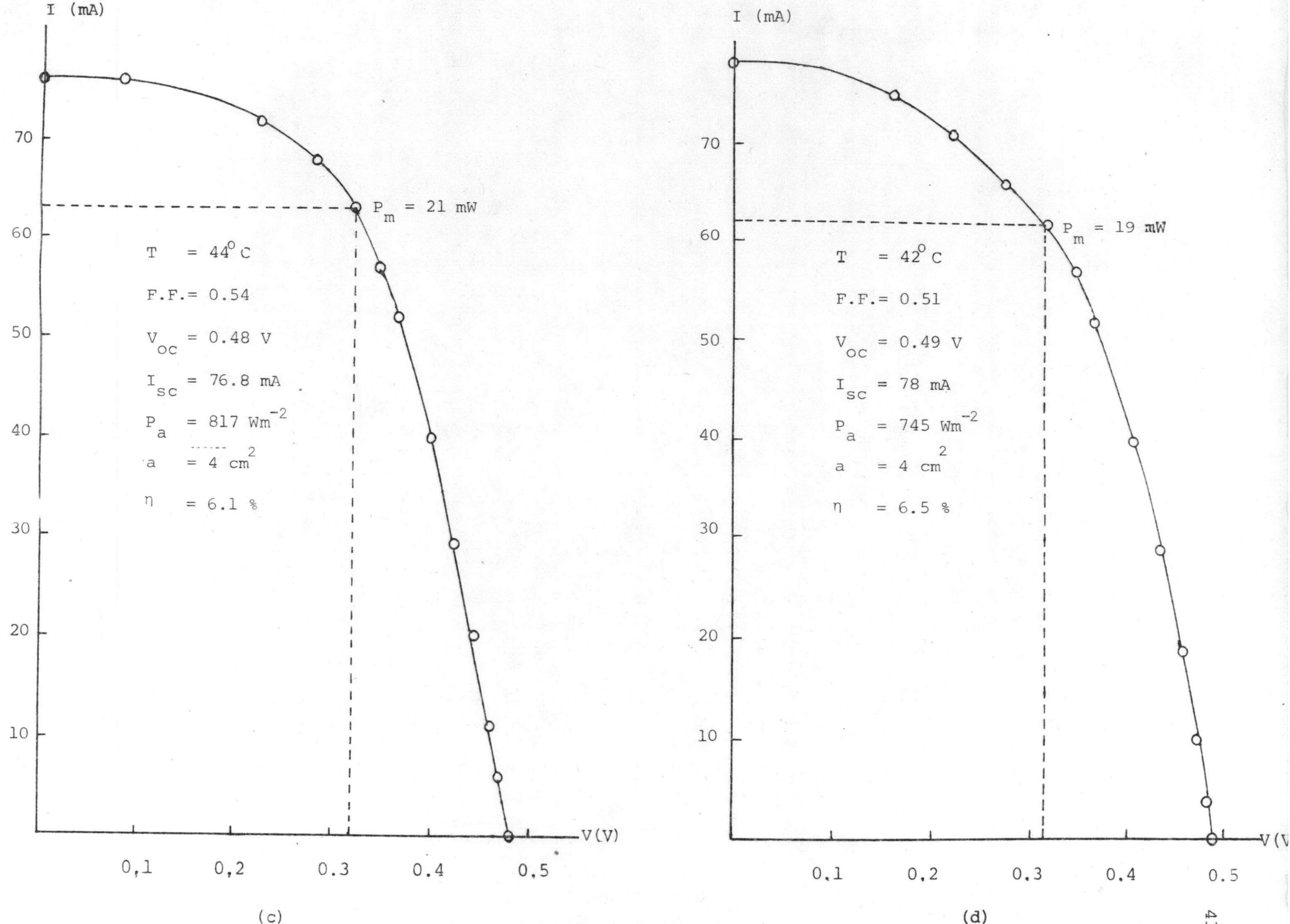



Fig. 22 The I-V characteristics solar cells curves with electroless plating techni

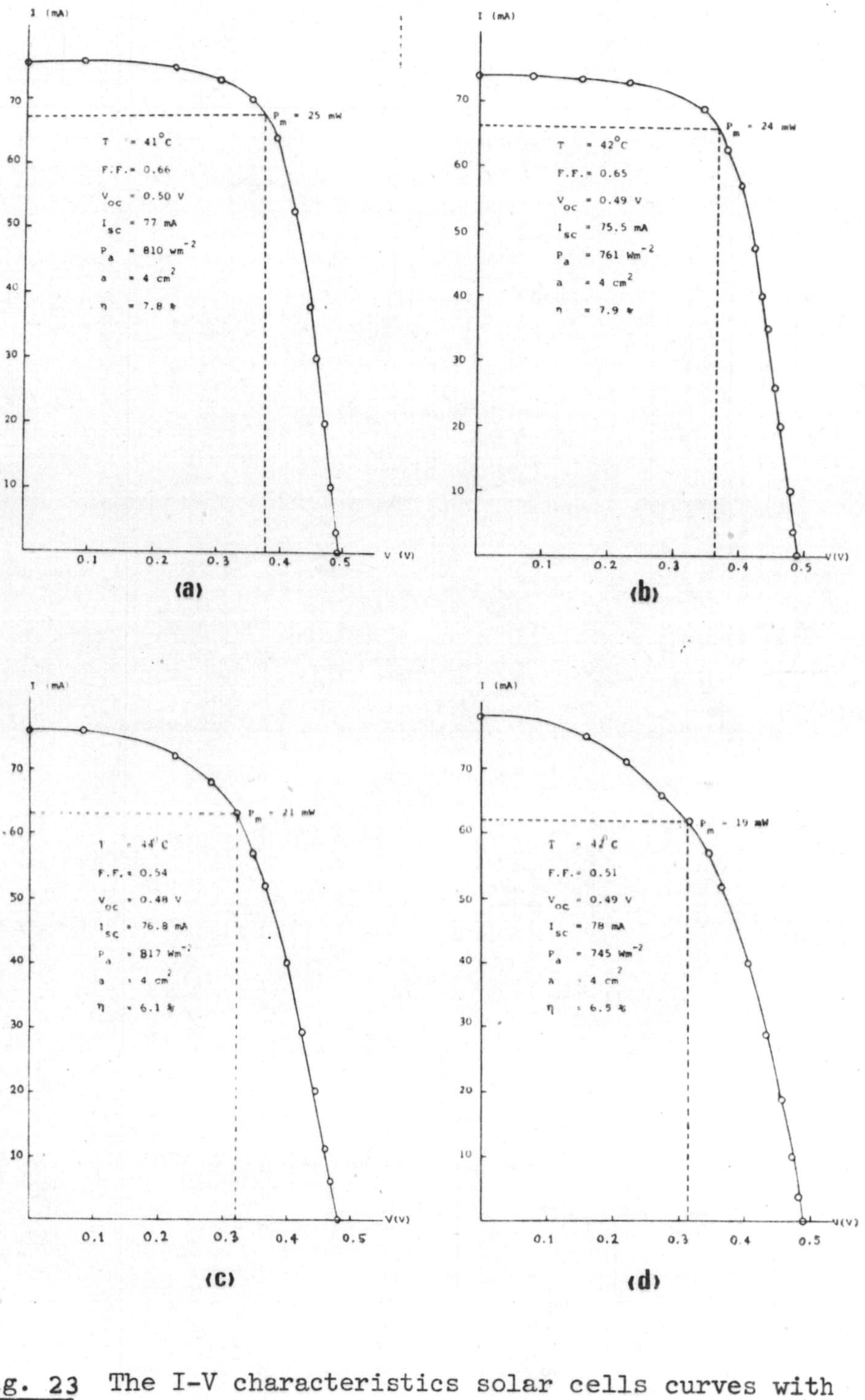
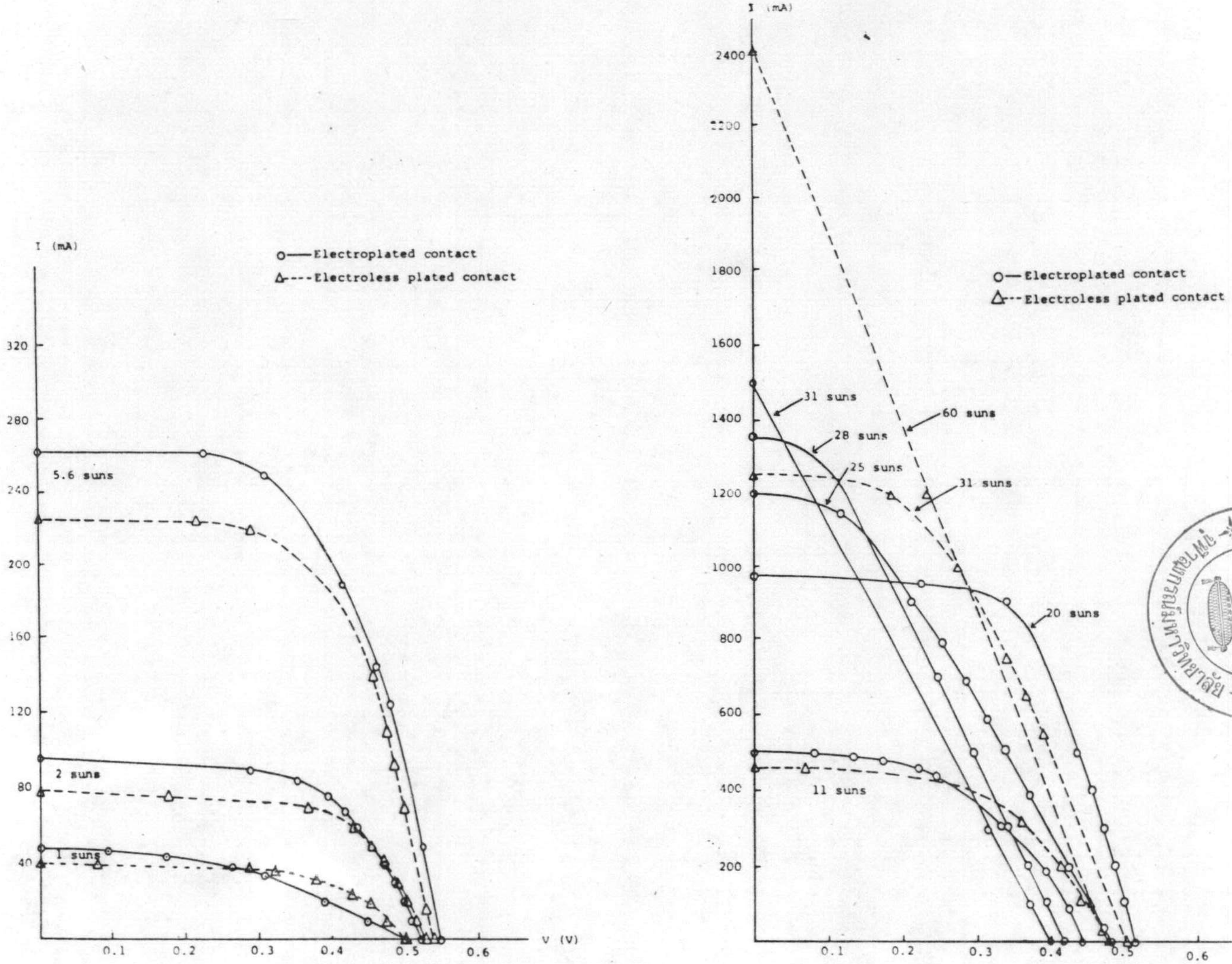



Fig. 23 The I-V characteristics solar cells curves with electroless and electroplating techniques.

(a),(b) electroplating contact

(c),(d) electroless plating contact




(a) (b)

Fig. 24 The I-V characteristics concentrated solar cells curves with electroless and electroplating techniques. (a) low illumination (b) high illumination

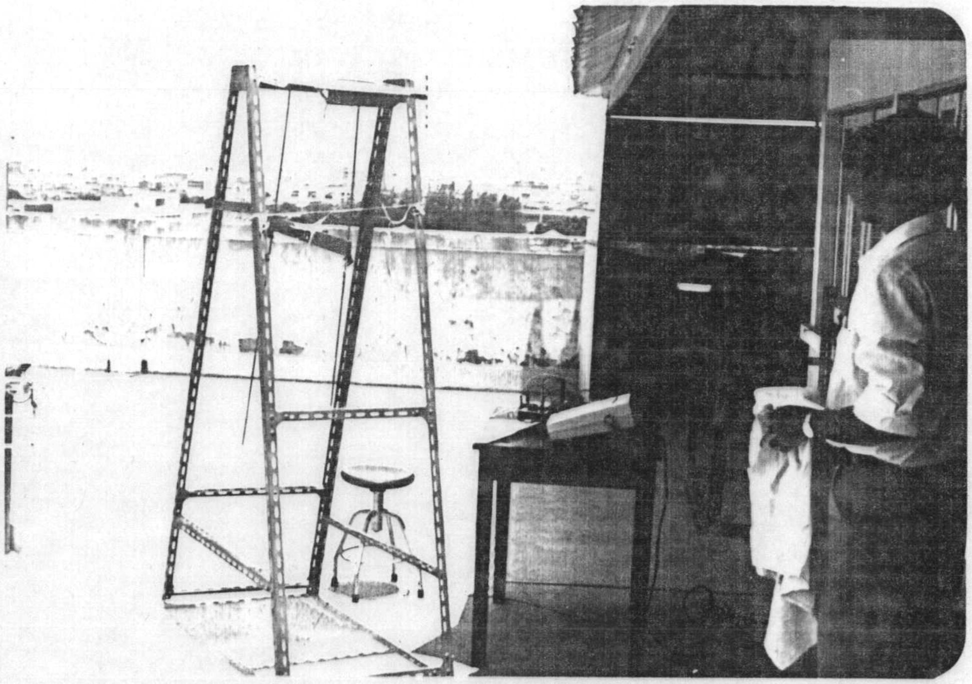


Fig. 25 Measurement the concentrated solar cell

The electrical tests were performed in order to plot the I-V characteristics of the finished solar cells as shown in Fig. 23. I-V characteristics for the solar cells were tested under 1 sun (~AM.2) illumination. The experimental results were shown that the solar cells using electroplated contacts were better than the solar cells using electroless plated contacts (Fig. 23). Namely, the quality of cleaning was more important for electroplated contacts than that of electroless plated ones. If there were some stains (dirt, scum, photoresis,dust, ect.) on the wafer's surfaces, electroplating would be inhibited but this was not the case for electroless plating.

I-V characteristics of concentrated solar cells (Fig. 24 ) at low illumination level (1-6 suns) looked like the solar cells.

The experimental results (Fig. 24) showed that the concentrated solar cell using electroplated contact had good efficiency at low illumination level (1-6 suns). Beyond this range, its efficiency decreased rapidly so that if could be used upto 25-28 suns only. On the other hand, the concentrated solar cell using electroless plated contact had lower efficiency in the range of 1-6 suns. But its efficiency did not decrease so rapidly beyond this range of illumination that it could be used upto 31 suns.

### 6.3 Results and Discussion of Alpha-Radiation Detector

The alpha-radiation detector performance was tested in order to measure its energy resolution. The alpha-radiation sources were Mixed source ($Pu_{239}$, $Cm_{244}$ , $Pu_{238}$) and Americium ($Am_{241}$) source (Fig. 26,and 27). The space between detector and the source is 1 cm.

A fairly good result for an alpha-radiation detector with the active area about 1.54 $cm^2$ was shown in Fig. 16. The main alpha particle groups were resolved, and the resolution measurement was about 277 keV. full width at half maximum. By comparing with the one previously fabricated,[9] the electroplating technique was able to improve the performance of the detector and its reliability.

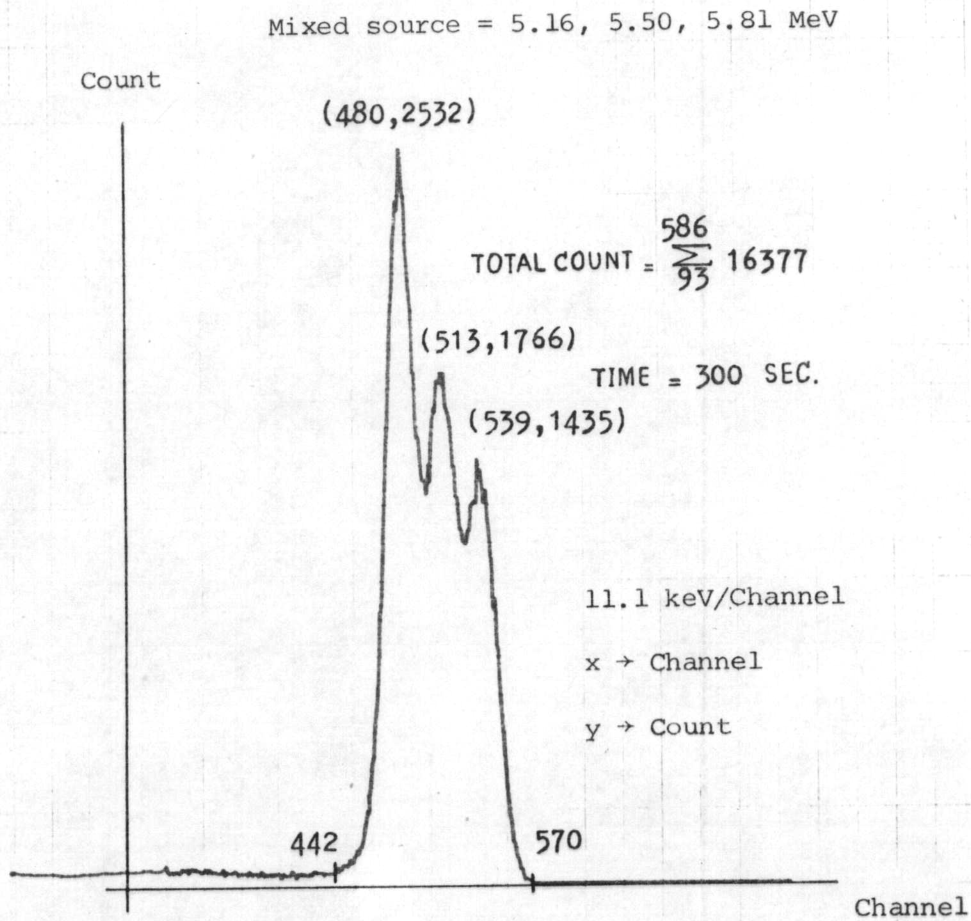



Fig.26 The response of 7500 Ω-cm α-radiation detector with Mixed source at zero bias room temperature.

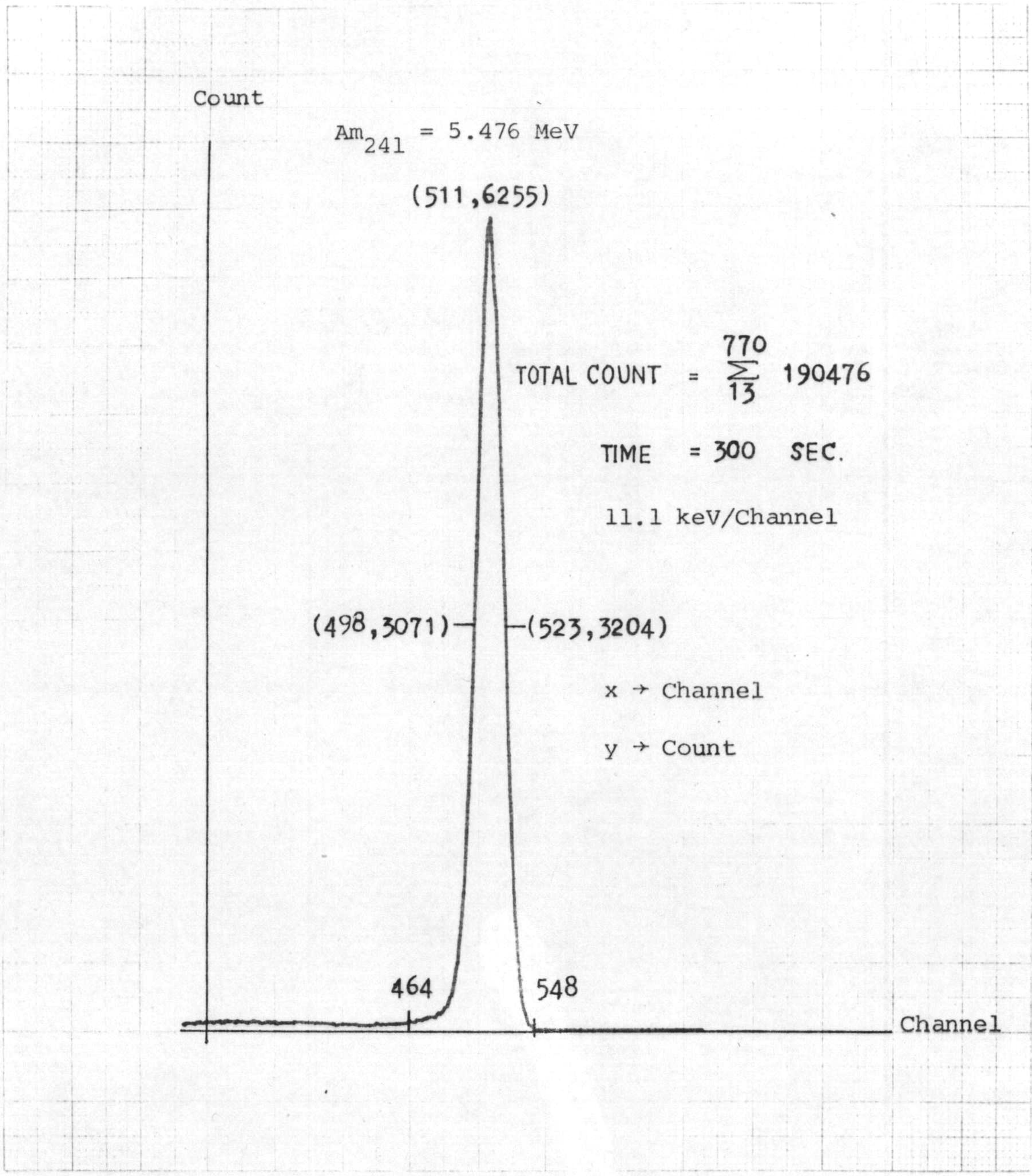



Fig. 27 The response of 7500 Ω-cm α-radiation detector with $Am_{241}$ source at zero bias to room temperature.