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# STUDY OF LITHIUM DOPED SOLAR CELLS

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# Study of Lithium Doped Solar Cells

Third Quarterly Report

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ABSTRACT

In this quarter, electrical differences observed for the different forms of silicon were confirmed and analysed. The physical reason for the differences has not yet been isolated. One cell shipment of 120 cells was made; analysis of these cells is included.

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## 1.0 INTRODUCTION

This program is intended to determine the properties of silicon solar cells doped with lithium, and to study the process parameters giving optimum post irradiation recovery and good cell stability.

More tests were run to explore the differences in cell behavior for identically processed slices of different forms of silicon. No definite physical reason has yet been isolated.

## 2.0 TECHNICAL DISCUSSION

### 2.1 LITHIUM INTRODUCTION METHODS

Again, in this quarter, oil suspensions of lithium were used most. No more lithium vapor tests were run. Tests of lithium evaporation were more encouraging, in that electrically the cells produced were more uniform.

The lithium evaporation boat design was improved leading to more uniform evaporation. However, there was still a problem with leakage of lithium around the front edges of the slice. This leakage could be minimized by a picture frame holding jig leading to a lithium-lean border on the cell back surface, or by evaporating onto a large slice which is then cut to the correct size. It is felt, however, that neither of these solutions is best for long term use. Therefore, present tests are designed to see the extent of the adverse effects of this edge leakage; hopefully, when identification of the factors controlling the leakage is made, this leakage problem can be eliminated.

### 2.2 SILICON GROWN BY DIFFERENT METHODS

As discussed in earlier reports, work has shown that for nominally identical processing, there is a consistent difference in the I-V characteristics of cells made from crucible-grown silicon on the one hand, and the various forms of oxygen-lean silicon on the other hand. Generally, both Isc and Voc are higher for the crucible-grown ingots. In the present tests, slices from a crucible-grown ingot and a float zone refined ingot were co-processed in groups of six slices from each ingot. The co-processing included boron diffusion, application of the antireflective coating, and lithium diffusion. At the time of selection of the cells shipped, cells from each ingot were identified as being simultaneously processed. The conclusion was that despite the similarity of these key fabrication steps, and for two different lithium diffusion schedules, there was still the same type of difference which had been found earlier. A detailed analysis of these cells is given below. (See 2.5)

## 2.3 ETCH STUDIES

In attempts to find some physical reasons for the differences in silicon crystals, more etch pit studies were made. This is in spite of the anomalous fact that for the starting ingots, those grown in the Monex* or Lopex+ method were essentially dislocation free; crucible-grown ingots generally have low dislocation density, whereas float zone refined silicon has high dislocation density.

The boron diffusion method introduced dislocations; but the anomaly is that the observed etch pit density on the oxygen lean silicon is both greater and less than that on the crucible-grown ingots, which show the different behavior.

To date, no conclusive connection could be found between the etch patterns and the cell behavior. For all three forms of silicon the lithium altered the observed etch pit pattern. Instead of well defined pits, the silicon surface was "bumpy", probably from localized alloying of lithium; the density of etch pits was lowered over this uneven surface, but tests have not yet shown whether this was reduced differential etch rate caused by the large decrease in resistivity or whether the lithium did suppress the etch pits.

## 2.4 OXYGEN SKIN STRUCTURE

Lithium cells made from oxygen-lean silicon have generally recovered faster after a given fluence of

*Trademark of Monsanto Chemical
+Trademark of Texas Instruments, Inc.

irradiation, but have often shown more tendency to unstable behavior after the first recovery. On the other hand, cells containing much oxygen have recovered slowly but have been stable in their recovery. The recovery process is dominated by the behavior of the lithium in the bulk of the cell, and the speed of recovery is thought to be governed by the availability of oxygen with which lithium can form Li-O pairs which have lower mobility than Li alone. The instability appears to be controlled by the movement of lithium near the PN junction.

Thus, a hybrid structure in which the bulk of the cell uses oxygen-lean silicon but the region around the PN junction is oxygen-rich shows promise for obtaining fast recovery combined with good stability.

The obvious way to form such a structure is to diffuse oxygen into slices of oxygen-lean silicon, and to form a PN junction and diffuse lithium in the usual way. Tests have begun to check the extent of oxygen diffusion so that cells can be characterized closely as to the extent and concentration of oxygen. Some adjustments in the cell fabrication steps may be necessary. One obvious problem may be lowering of the bulk perfection (and thus the cell Isc) during the oxygen diffusion step. This will be resolved by actual measurement of the change in Isc resulting from the oxygen diffusion.

## 2.5 CELL SHIPMENT DETAILS

One cell shipment of one hundred and twenty (120) cells was made.

Cell Numbers  C5-1 through C-120

Silicon  C5-1 through C5-30
C5-61 through C5-90
Crucible grown, 111 orientation, arsenic doped, resistivity approximately 40 ohm cm.

C5-31 through C5-60
C5-91 through C5-120
Float zone refined, 111 orientation phosphorus doped, resistivity approximately 90 ohm cm.

Lithium Diffusion — Paint-on

C5-1 through C5-60 — 450°C - 40 min.
C5-61 through C5-120 — 425°C - 90 min.
+425°C - 120 min. redistribution.

NOTE: Boron and lithium diffusions were simultaneously performed on split lots, half CG, half FZ. The resultant cells showed the same differences as the averages given below:

| CELL NO. | Isc (mA) | $I_{450}$ (mA) | Voc (mV) |
|---|---|---|---|
| C5-1 to C5-30 | 62 | 59.5 | 605 |
| C5-31 to C5-60 | 54 | 49 | 570 |
| C5-61 to C5-90 | 69 | 64.5 | 585 |
| C5-91 to C5-120 | 62 | 49.5 | 540 |

Analysis of all the starting slices in the four groups is given in Figure 1 ($I_{450}$ distribution) and Figure 2 (Cumulative percentage.)

## 3.0 CONCLUSIONS

There is still a need to understand the effects of different methods of silicon crystal growth. The control of lithium introduction methods has increased.

## 4.0 RECOMMENDATIONS

In the next quarter, effort will continue to understand silicon effects. Attempts will be made to fabricate cells with an oxygen rich skin for irradiation testing.

## 5.0 NEW TECHNOLOGY

None to report this period.

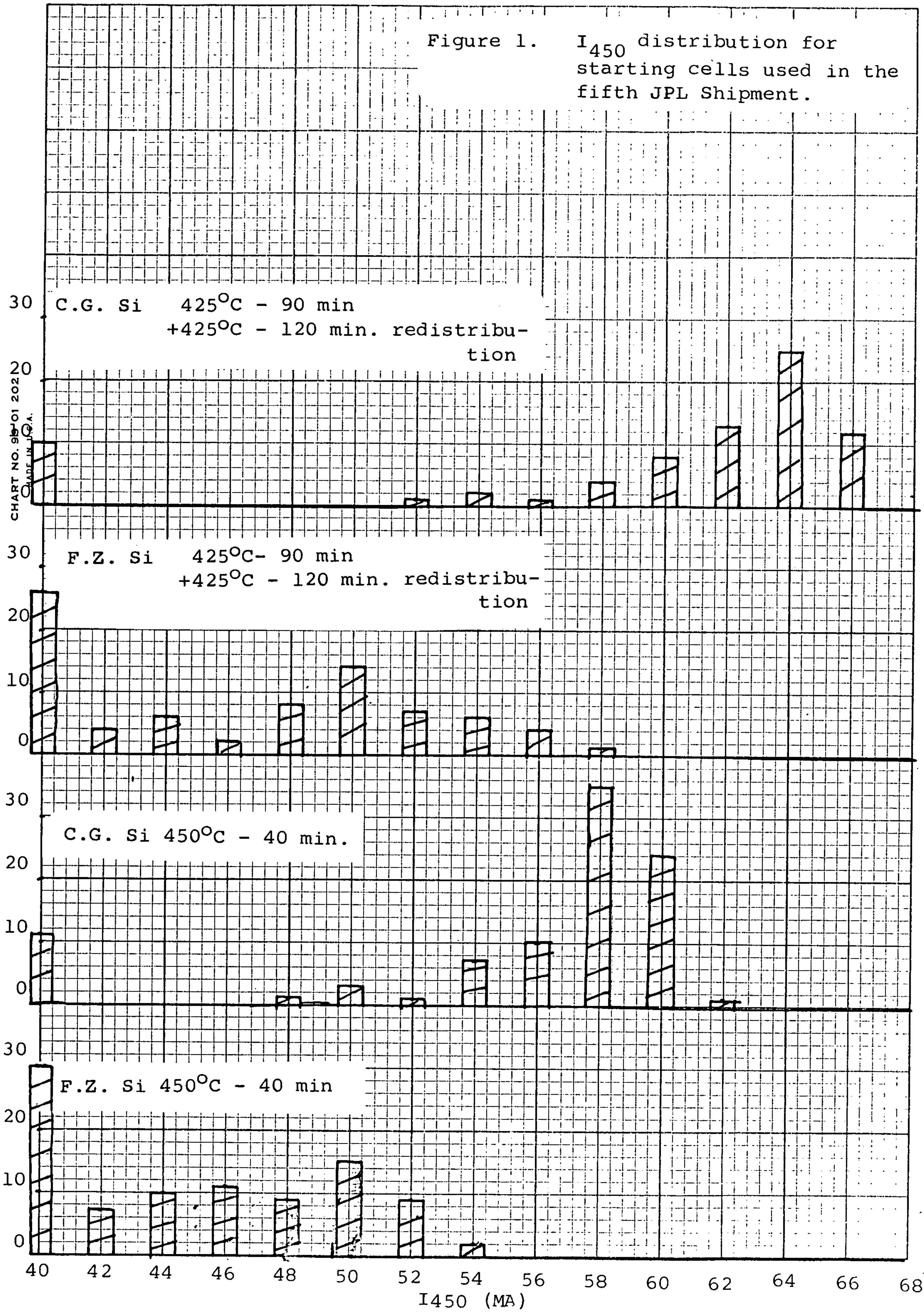
Figure 1. I450 distribution for starting cells used in the fifth JPL Shipment.
C.G. Si 425°C - 90 min +425°C - 120 min. redistribution
F.Z. Si 425°C- 90 min +425°C - 120 min. redistribution
C.G. Si 450°C - 40 min.
F.Z. Si 450°C - 40 min
30
20
10
0
40
42
44
46
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62
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I450 (MA)
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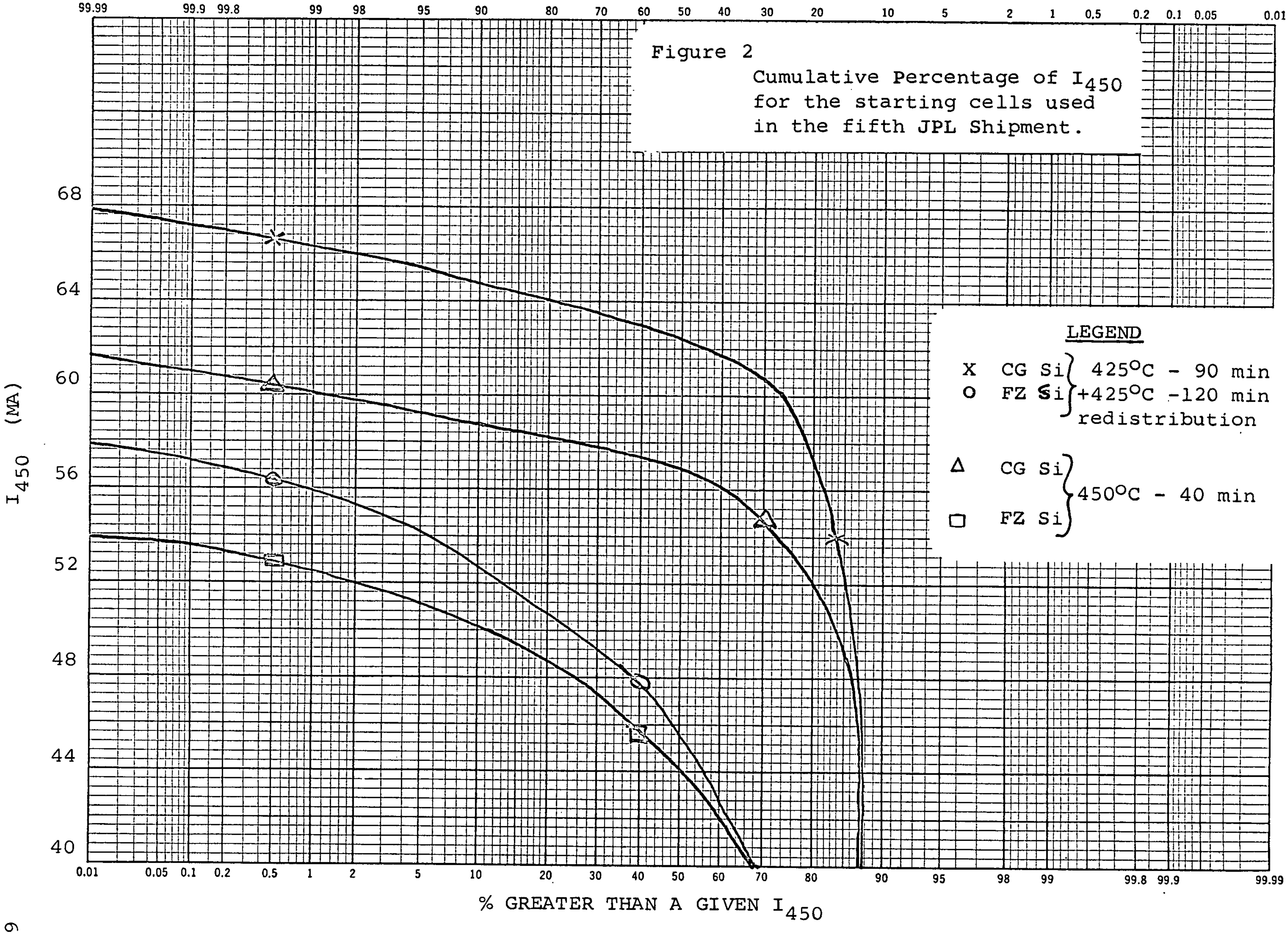


Figure 2
Cumulative Percentage of $I_{450}$ for the starting cells used in the fifth JPL Shipment.