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POINT CONTACT SILICON SOLAR CELLS

Richard M. Swanson
Stanford University
Stanford, California

A new type of silicon concentrator solar cell has been developed. It is called the point-contact cell because the metal semiconductor contacts are restricted to an array of small points on the back of the cell. The point contact cell has recently demonstrated 22 percent conversion efficiency at one sun and 27.5 percent at 100 suns under an AM1.5 spectrum.

Text

The point-contact cell derives its high efficiency from a synergistic combination of:

- Light trapping between a texturized top surface and a reflective bottom,
- Thin, high resistivity, high lifetime base,
- Small point contact diffusions, alternating between n-type and p-type in a polka-dot pattern on the bottom, and
- Surface passivation on all surfaces between contact regions.

The operation and performance of experimental point contact cell is described in the following figures.

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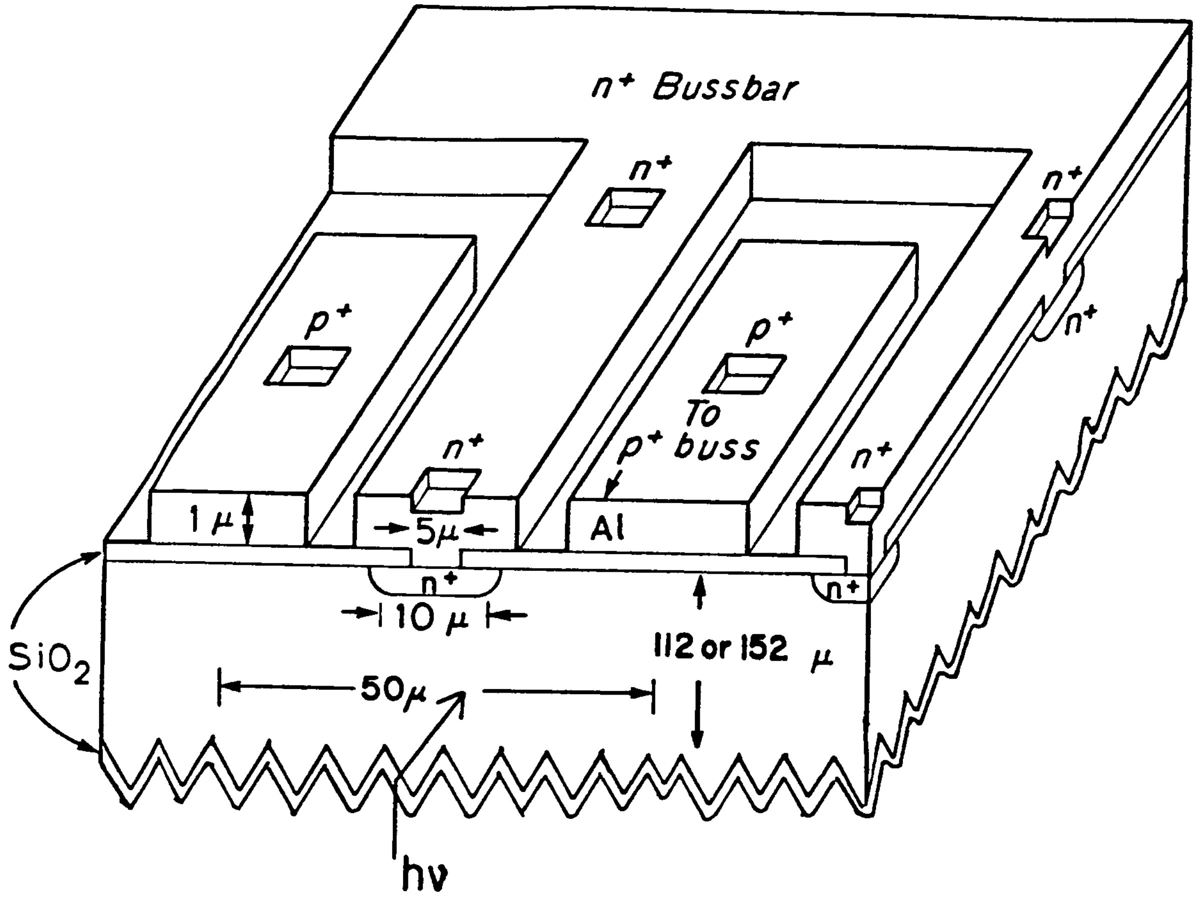

Figure 1: Structure of the test cells currently being made. Both electrical leads are on the back surface in an inter-digitated pattern. The metal touches the silicon only in an array of points, alternating between n and p-type in a checkerboard pattern. The cell is thin, around 100 μm, and fabricated of high lifetime, high resistivity float-zone silicon. The regions between contacts are passivated with SiO_2 and the front surface is texturized.

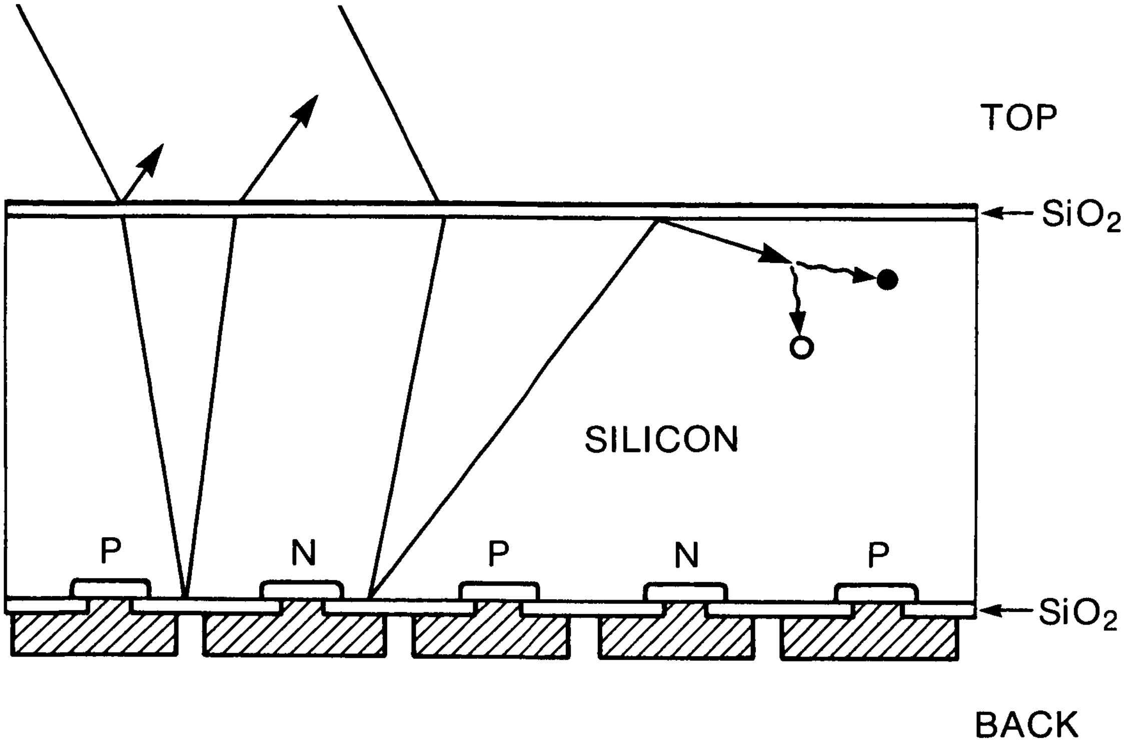

Figure 2: Light trapping is caused by the diffuse nature of scattering from a texturized surface. If a photon is not absorbed upon reaching the back surface it is reflected off the back surface reflector. If it is still not absorbed by time it reaches the top there is a very high probability (about 88 percent) that it will be beyond the angle for total internal reflection and hence will be reflected back into the cell. Much of the weakly absorbed near bandgap light is thus trapped within the cell.

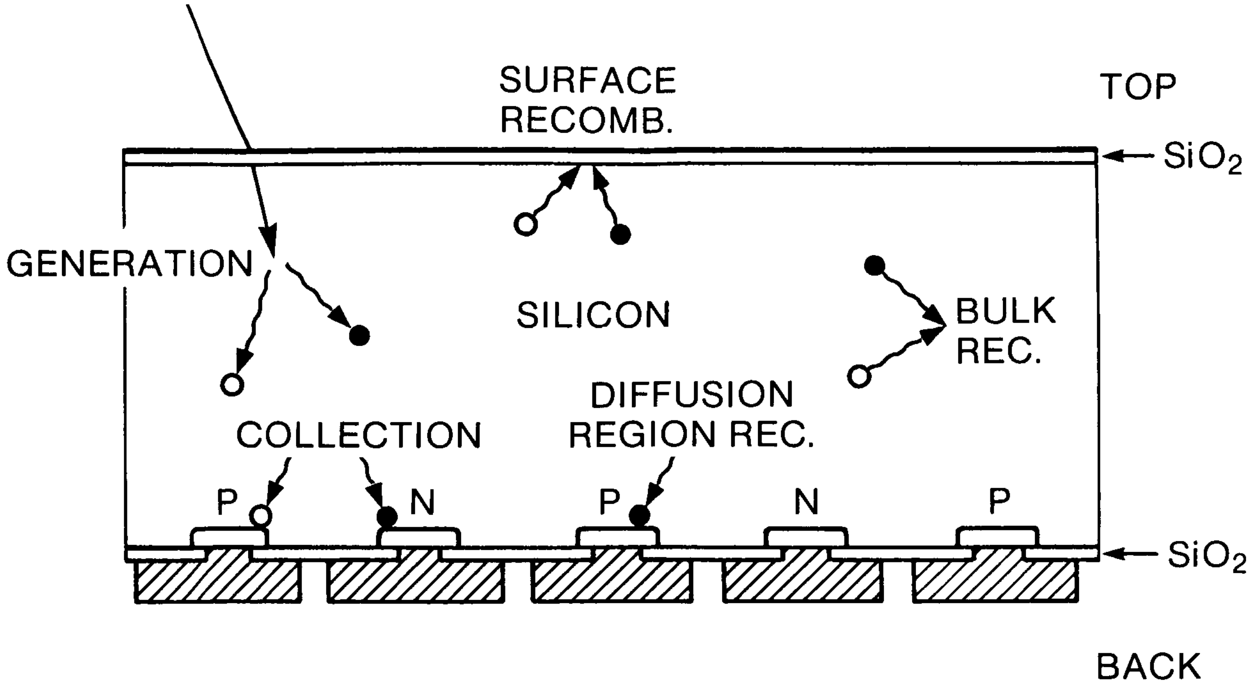

Figure 3: For high efficiency it is necessary to reduce carrier recombination as much as possible. This is to provide for:

- Collecting as large a fraction of the photo-generated carriers as possible,
- Generating as large a voltage (which goes exponentially in the p-n product) as possible, and
- Producing as much conductivity modulation in the base, and hence reducing base voltage drop, as much as possible.

The point contact cell reduces recombination by passivating the surfaces with SiO_2, using high lifetime float-zone silicon, and reducing the metal-semiconductor contact fraction through the point contact scheme.

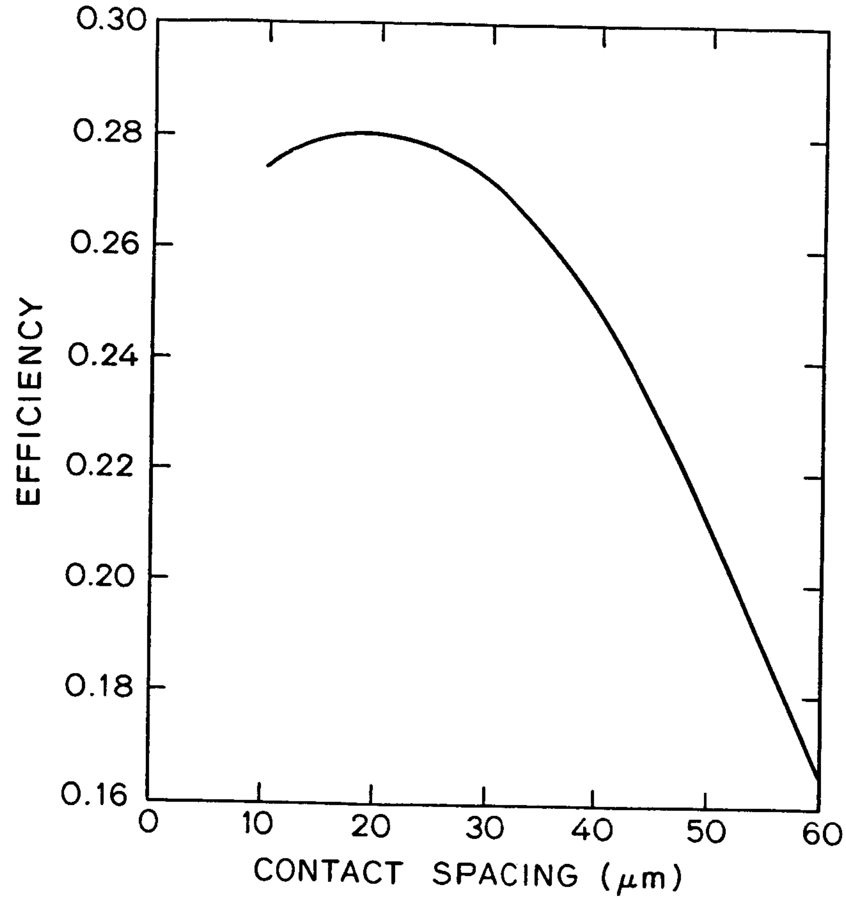

Figure 4: A three dimensional model has been developed to explore the potential of the cell and optimize the design. Important findings are:

- The contact spacing must be rather small to prevent excessive losses through base spreading resistance at the contact diffusions.
- The cell must be thin, in the 60 to 100 μm range, in order to keep the front surface carrier density low enough that Auger recombination (which goes as the third power of carrier density) does not excessively limit collection efficiency.
- The base lifetime must be over 500 μsec.
- The surface recombination velocity must be less than 10 cm/sec.
- The cell is capable of efficiencies of around 29 percent at 27 °C if the above conditions are met.

This figure shows the calculated efficiency versus contact spacing at a cell temperature of 330 K.

One Sun Results AM1.5 100 mW/cm^2								
Cell	Thickness	Texturized	Efficiency	V_{oc}	J_{sc}	V_{mp}	Fill Factor	Temp
11-3B	112 μm	Yes	22.2%	.681 V	41.5 mA/cm^2	.582 V	.786	24 °C
11-1A	152	No	18.5%	.678	35.0	.570	.778	26

Figure 5: Important one sun parameters of the test cells are shown. This table illustrates the importance of texturizing for improving the short circuit current.

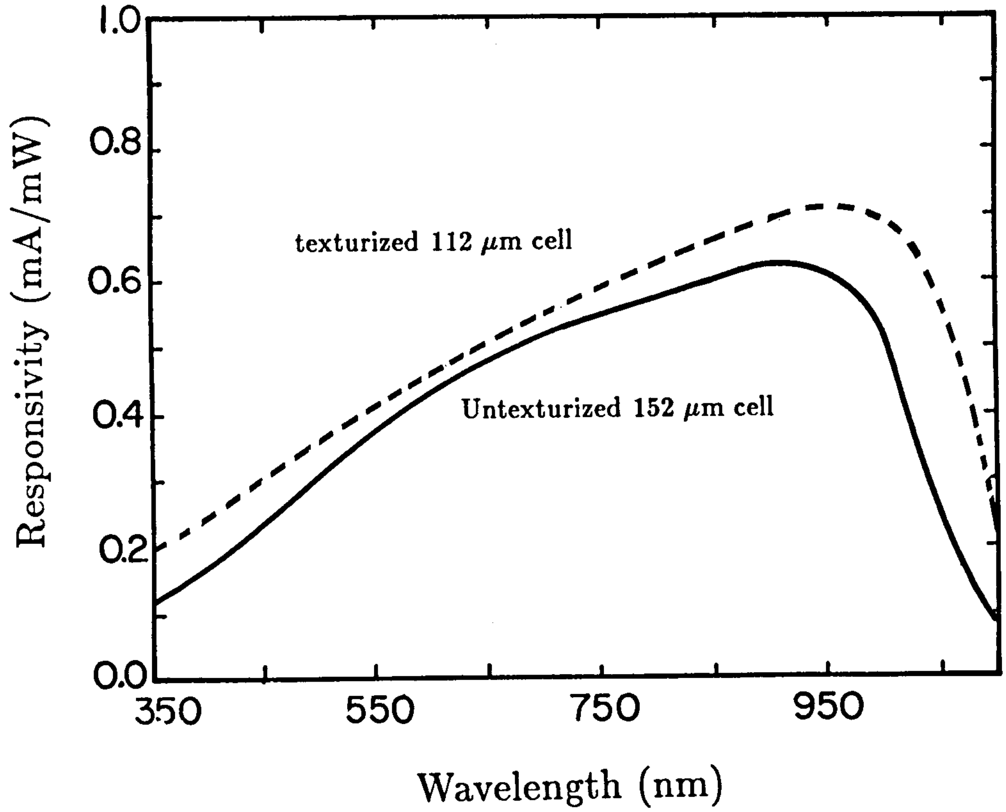

Figure 6: The spectral responsivity of a texturized and untexturized cell is shown. At shorter wavelengths the texturizing has reduced the reflectivity, resulting in improved response. Near the bandgap, however, the response has been dramatically increased due to light trapping.

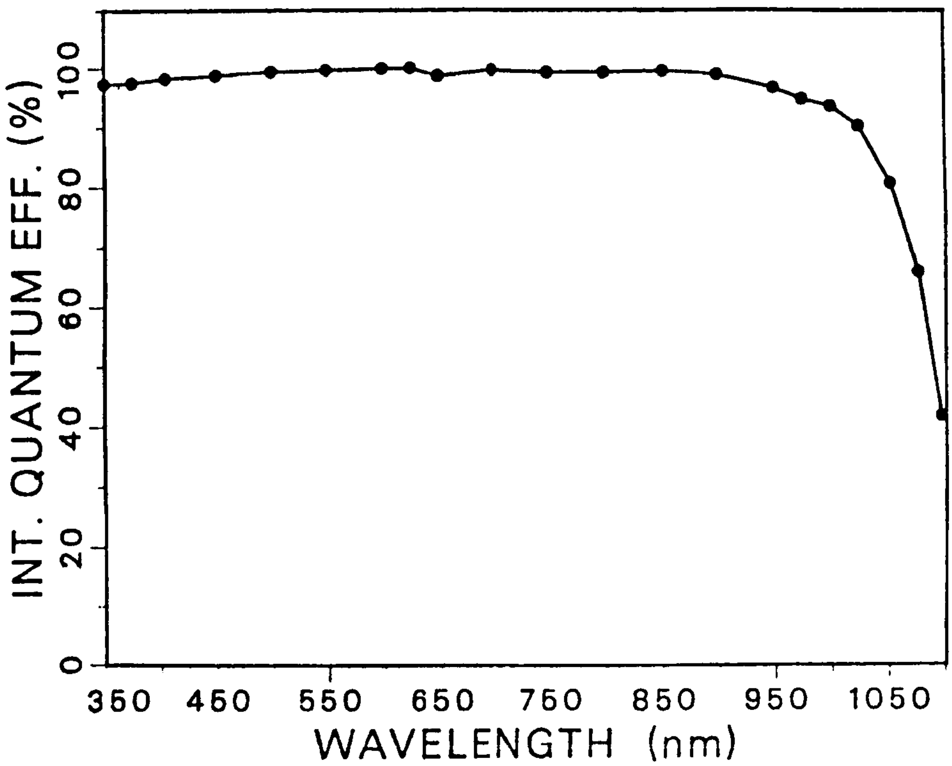

Figure 7: The internal quantum efficiency is essentially unity until near the bandgap, where competing absorption mechanisms, such as absorption in the back surface mirror, become comparable to photo-absorption.

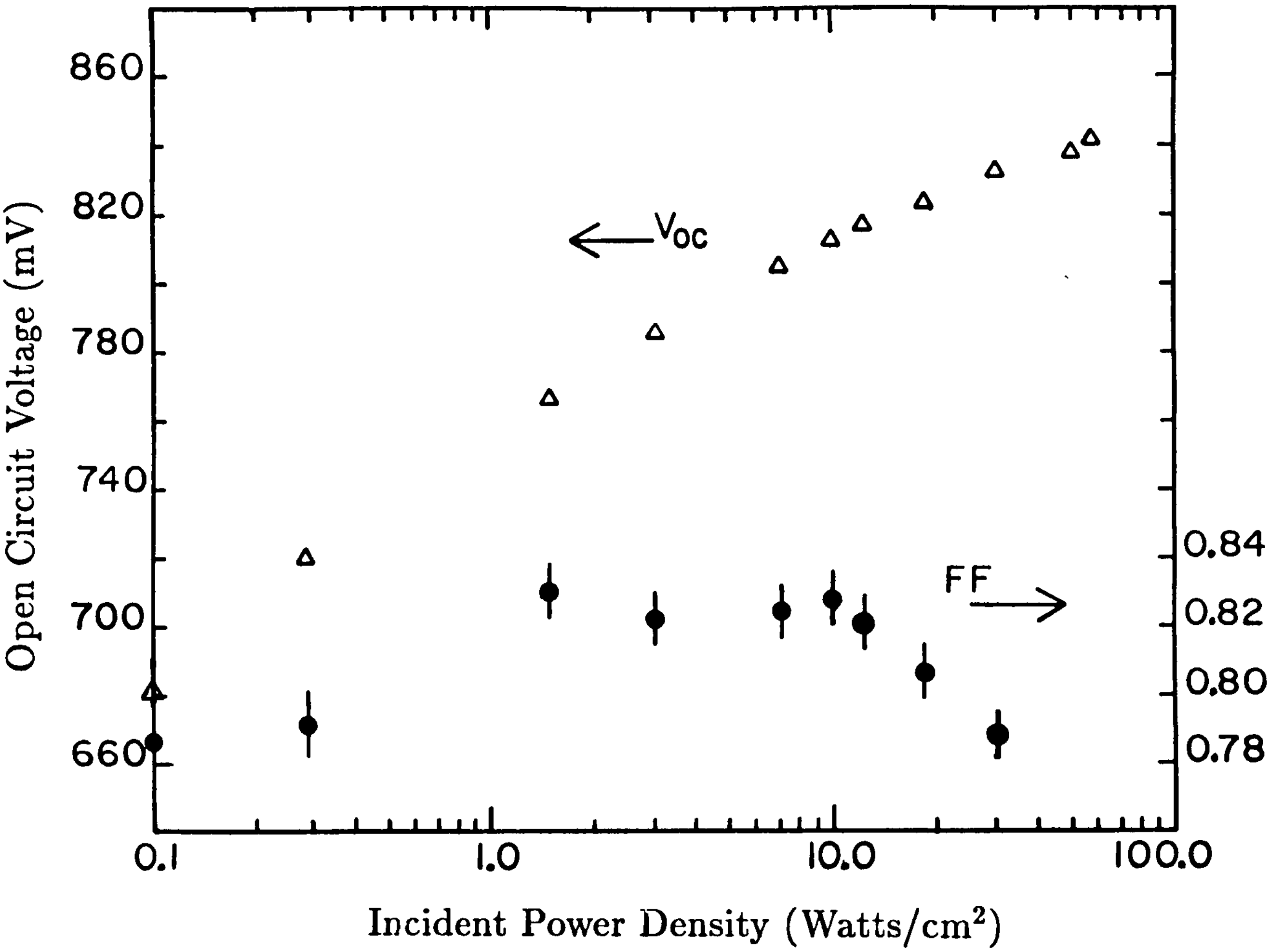

Figure 8: The measured open circuit voltage and fill factor of a 113 μm texturized cell is illustrated.

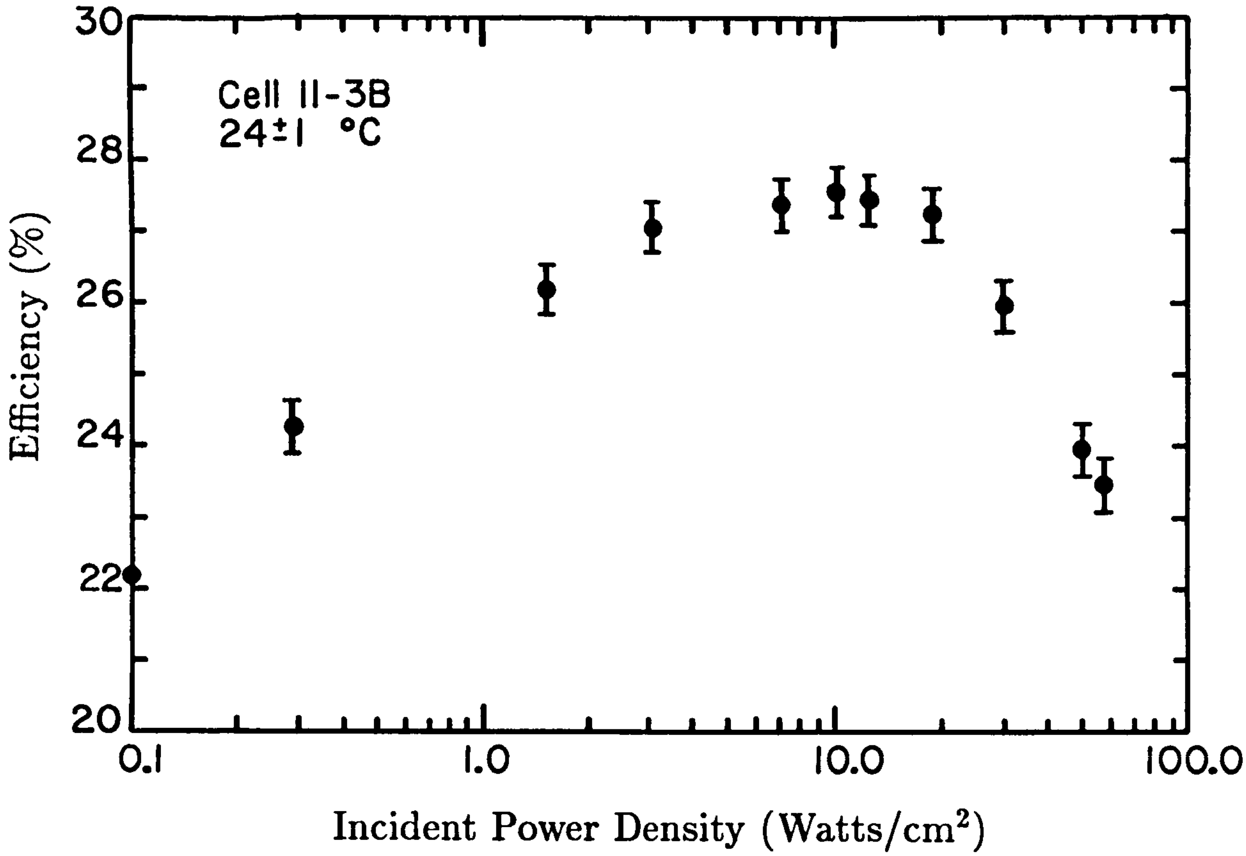

Figure 9: The measured efficiency of the cell from the previous figure is presented. The one sun efficiency is 22%, increasing to 27.5% at 100 suns. The major portion of the drop-off above 100 suns is due to metal series resistance; however, a significant portion results from a decrease in internal quantum efficiency at high intensity due to Auger recombination in the dense electron-hole plasma generated by the light. A thinner cell will reduce this effect. By decreasing the metal series resistance, thinning the cell to 80 μm, and providing a double layer anti-reflection coating it is expected that efficiencies over 29% can be reached.

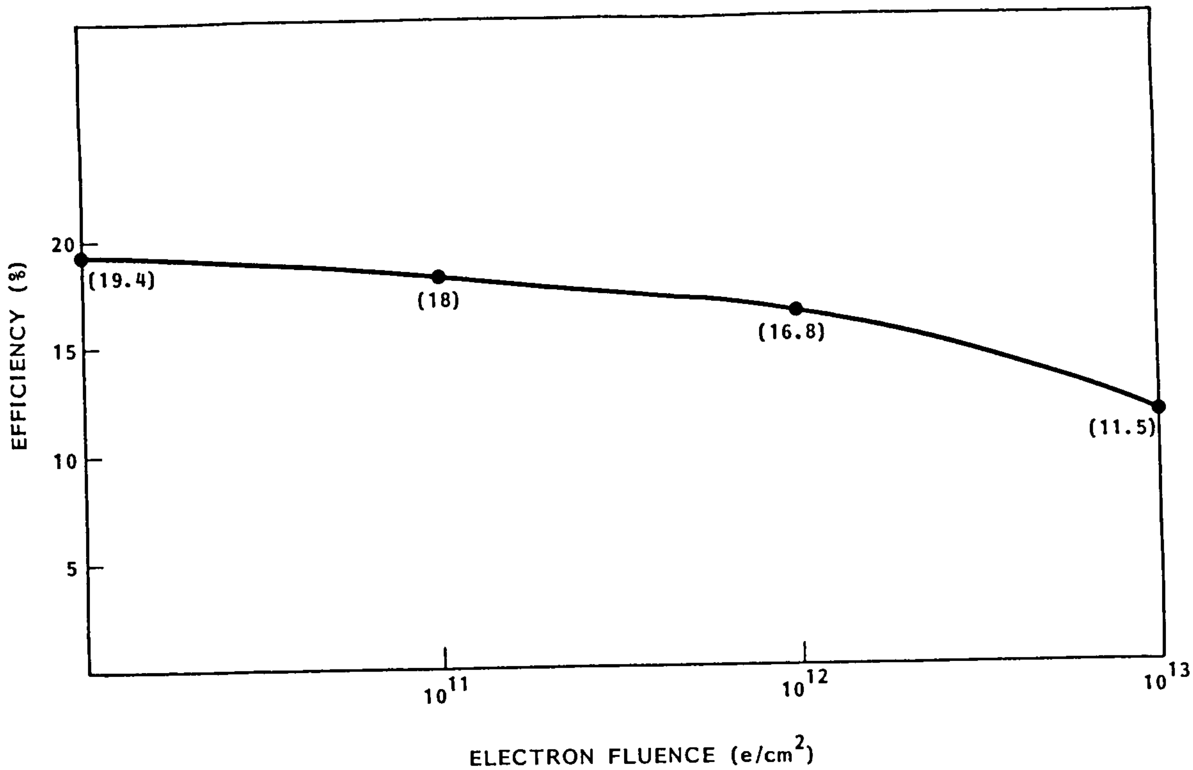

Figure 10: This figure shows the measured AM0 efficiency versus 1 MeV electron fluence. The radiation was done at Boeing under the direction of Lockheed and the measurements were performed at Lockheed. It is expected that much improved radiation sensitivity can be achieved through the use of doped substrates and front surface fields.