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SHALLOW JUNCTION PHOTOVOLTAIC DEVICE PROGRAM

LAWRENCE LIVERMORE LABORATORY
LIVERMORE, CALIFORNIA

GRANT REQUESTED: ONE YEAR
$245,000

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Abstract

SHALLOW JUNCTION SILICON SOLAR CELLS

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The objective of this program is to develop techniques to produce low cost, high efficiency solar cells, with emphasis on those processes which are applicable to the automated production of both single crystal and defect-laden ribbon or thin film polycrystalline solar cell material. Shallow junction devices are under primary consideration with several types of silicon solar cells having been fabricated, namely, a) epitaxially-grown shallow junction cells, b) Schottky-barrier cells, c) Indium-Tin-Oxide on silicon cells and d) cells produced by a unique process utilizing a corona discharge. Our results with this latter process are described below.

Initial results in producing single crystal silicon solar cells were reported at the Eleventh Photovoltaics Specialist Conference, May, 1975, in Phoenix, Arizona. Cells with efficiencies of over 8% with fill factors of up to 0.76 were reported. These shallow junction cells had enhanced short wavelength response as compared to commercial, deeper junction cells.

Recent work has included the fabrication of polycrystalline silicon cells with AM1 efficiencies of over 3% without an antireflection coating. These cells were 5 mm x 5 mm x 20 microns of ~5 Ωcm silicon grown epitaxially on a 0.01 Ωcm 10 mil thick substrate. Open circuit voltages as high as 0.45 V were obtained.

Preliminary analysis of cells produced by the corona discharge technique indicates a profile of implanted ions which results in a low sheet resistance for the shallow ρ-layer. Additionally, the presence of heavily-defected regions within a given cell does not seem to grossly

affect the overall performance of the device.

Future activities are geared to optimizing the various process parameters by both experimental and theoretical means, in order to increase the efficiency of cells produced by this new technique.

We have therefore, shown the technical feasibility of the corona discharge technique as a means for producing efficient silicon solar cells and expect that with continued effort, further improvements can be made.

OVERALL PROGRAM OBJECTIVE

DEVELOP TECHNIQUES TO PRODUCE LOW COST, HIGH EFFICIENCY SOLAR CELLS, WITH EMPHASIS ON LOW TEMPERATURE PROCESSES WHICH RESULT IN SHALLOW JUNCTION DEVICES.

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THE CORONA DISCHARGE PROCESS FOR PRODUCING SHALLOW JUNCTION Si SOLAR CELLS

TECHNIQUE:

A Corona Discharge (up to 9 kV) of BF_3 produces Boron Ions which are implanted into the Silicon Cathode to form a shallow p^+ - n junction.

ATTRIBUTES:

- Low Processing Temperatures (<500°C) - Suitable for Ribbon and Thin Film Polycrystalline Si
- Simple Equipment and Processing Steps
- Cells with High Fill Factors
- Improved Short Wavelength Response

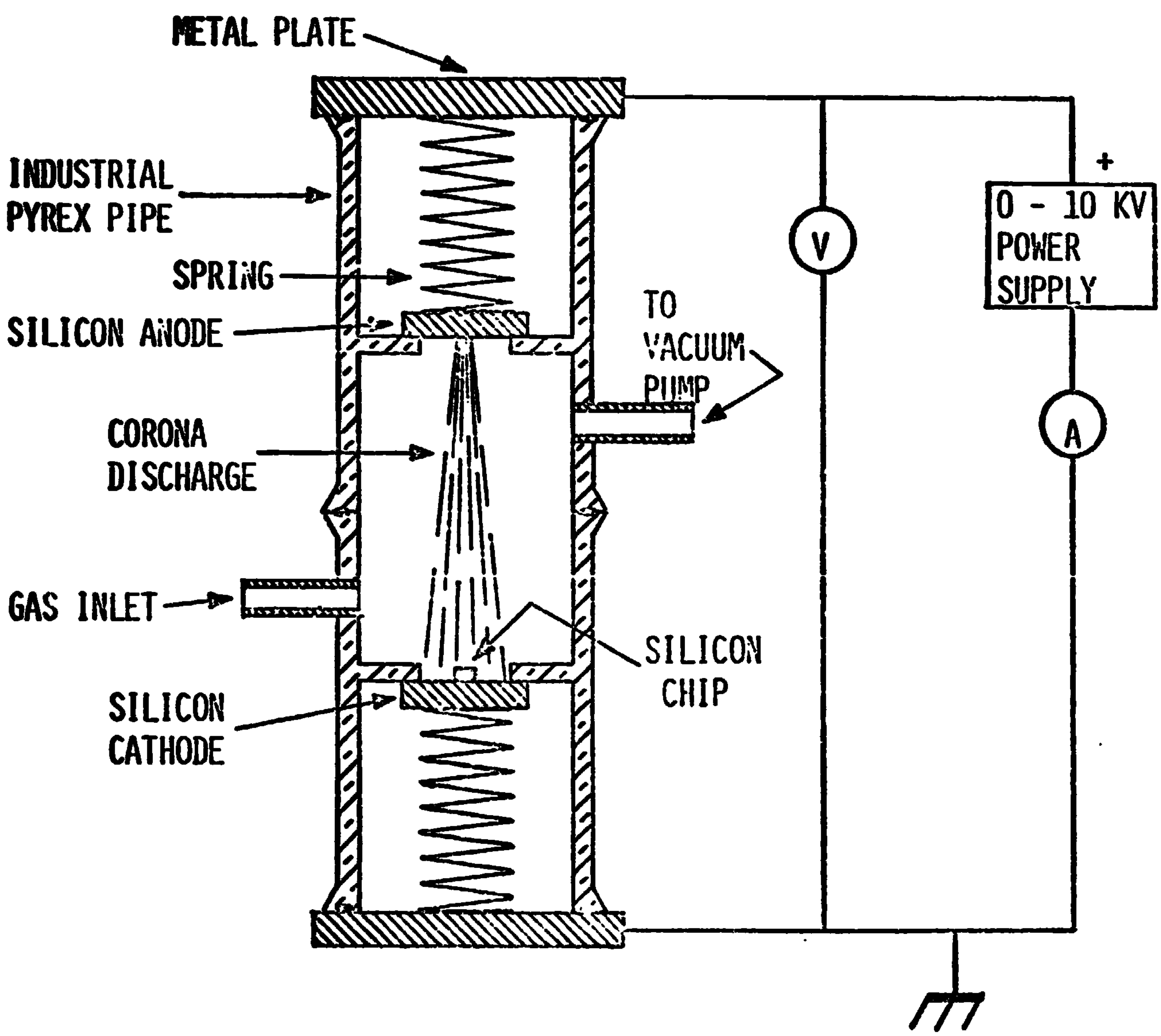

Figure 1. Schematic of Experimental Set-up.

A CORONA-MODE DISCHARGE HAS A
UNIQUE FEATURE WHICH CAN BE USED TO ADVANTAGE:

- POTENTIALS OF SEVERAL KILOVOLTS CAN BE SUSTAINED
    - MULTIPLY-IONIZED GASEOUS SPECIES ARE GENERATED

      E.G., $BF_3 \rightarrow BF_3^+ \ldots\ldots \rightarrow B^+ \ldots\ldots \rightarrow B^{+5}$

    - THE ENERGY OF B^{+5} FALLING THROUGH A POTENTIAL DROP OF 5 kV IS EQUAL TO 25 keV.

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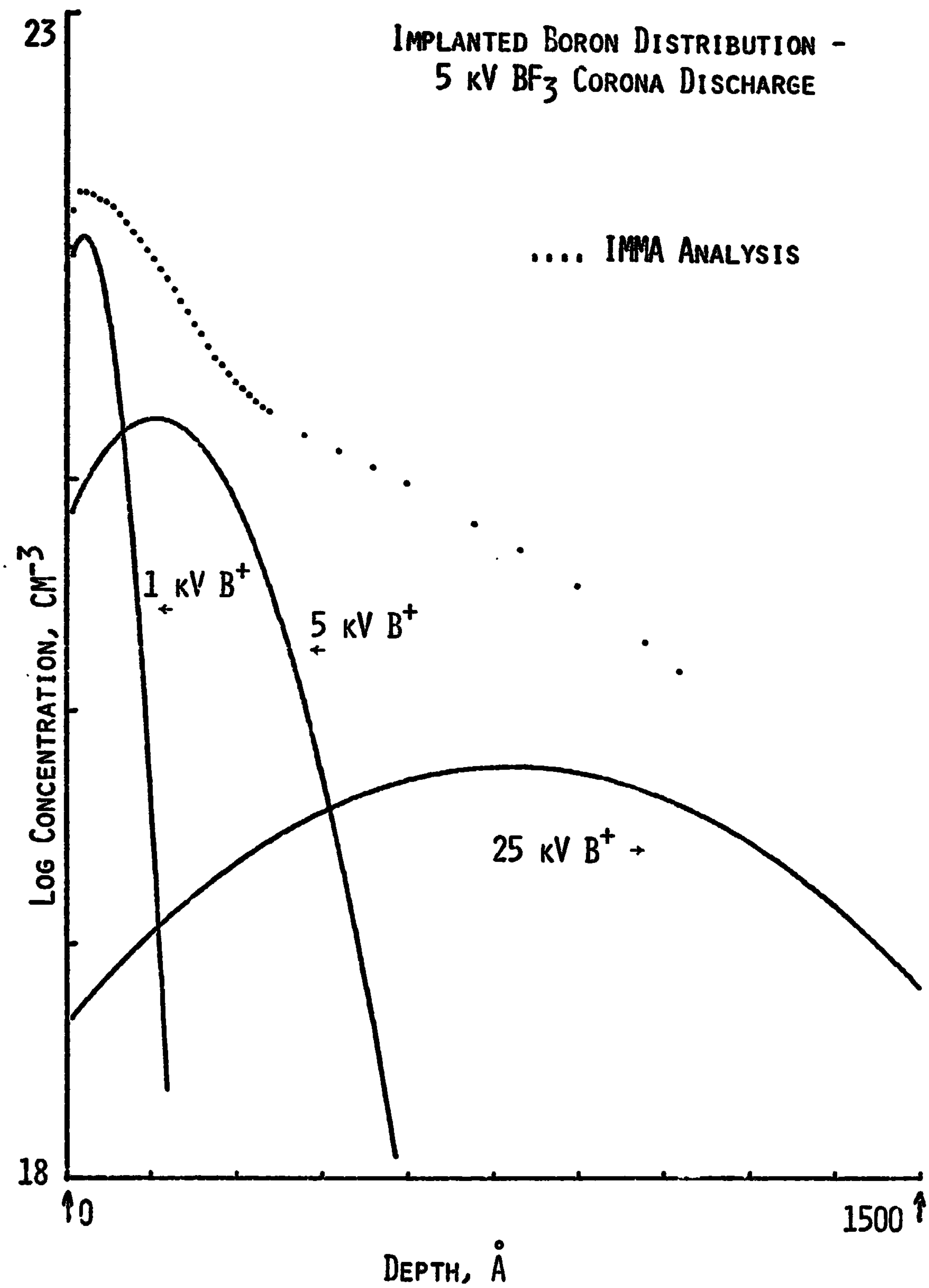

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IMPLANTED BORON DISTRIBUTION -
5 KV BF_3 CORONA DISCHARGE
.... IMMA ANALYSIS
1 KV B^+
5 KV B^+
25 KV B^+
LOG CONCENTRATION, CM^{-3}
18
0
1500
DEPTH, Å

FIGURE 2

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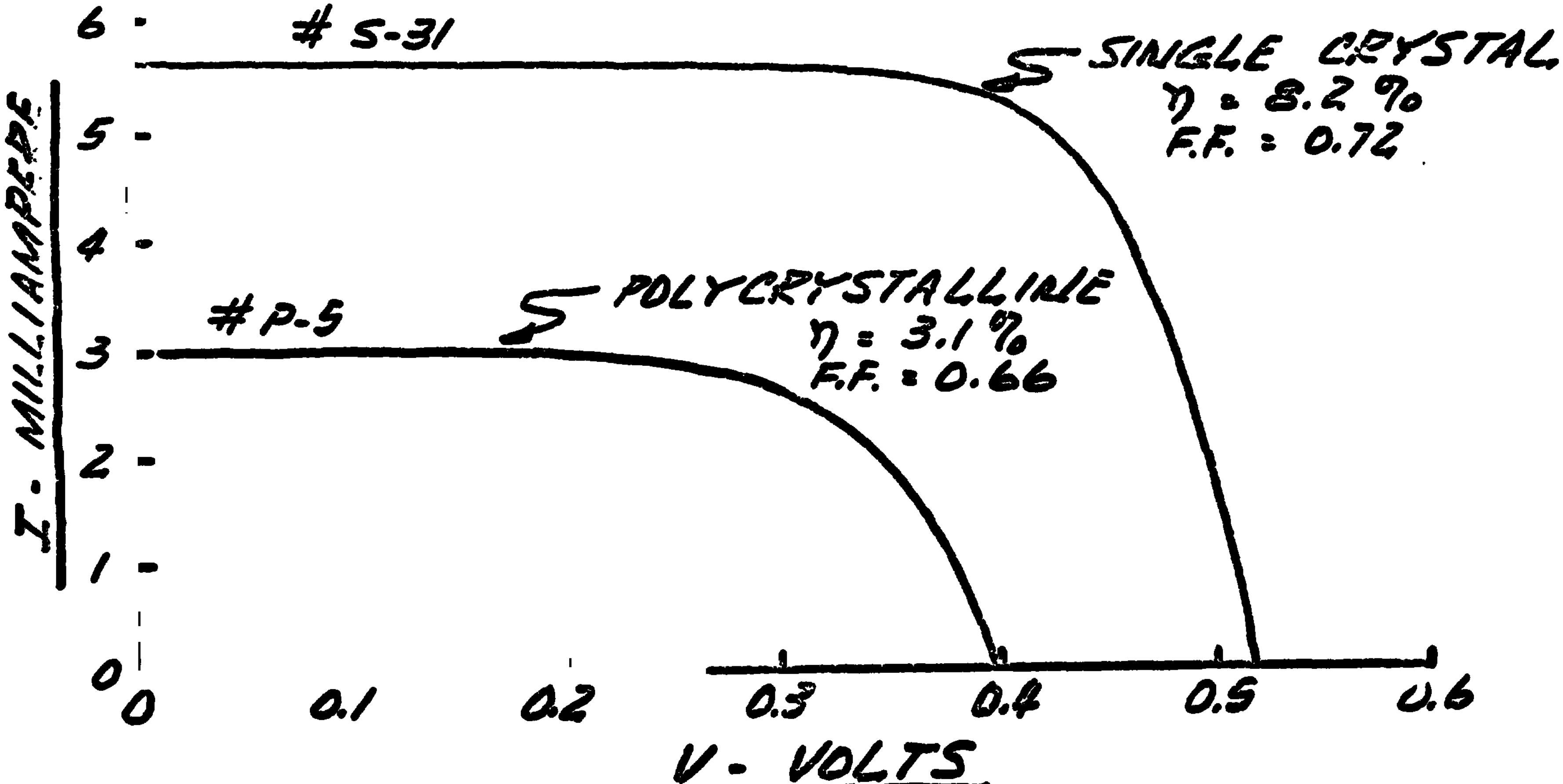
FIGURE 3

I-V CHARACTERISTICS
SILICON CORONA CELLS



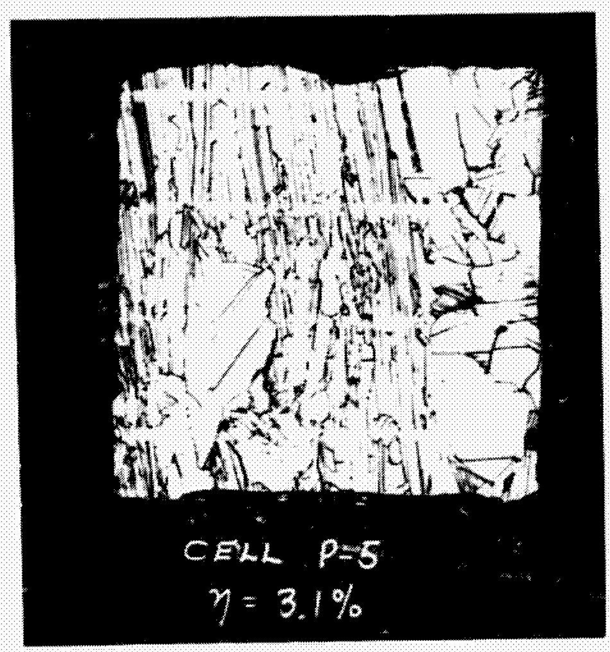


Figure 4. Photograph of Cell P-5. (Dimensions - 5 x 5 mm; Al fingers 0.125 mm wide on 1.25 mm centers.)

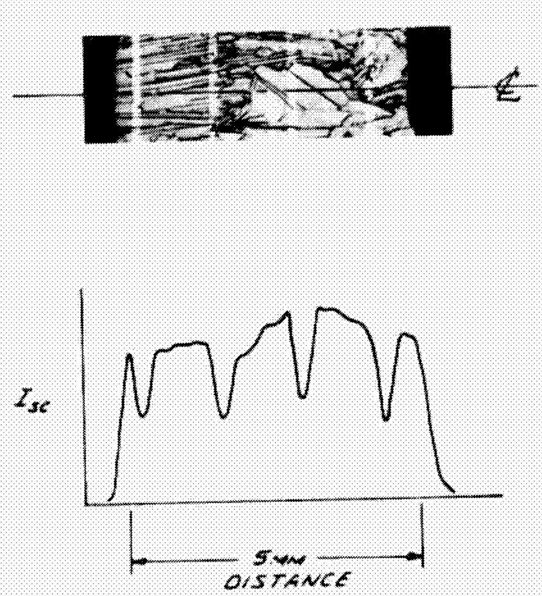


Figure 5. I_{sc} Line Scan of Cell P-5. Light Beam Diameter ~ 0.3 mm.

SUMMARY OF KEY RESULTS

- CONCEPT OF SOLAR CELL FABRICATION BY CORONA DISCHARGE TECHNIQUE HAS BEEN PROVEN
    - SINGLE CRYSTAL CELLS WITH >8% EFFICIENCY (AM1) W/O A-R COATING
    - POLYCRYSTALLINE SILICON CELLS WITH >3% EFFICIENCY (AM1) W/O A-R COATING
- SHALLOW-JUNCTION CELLS ARE NOT GROSSLY AFFECTED BY HIGHLY DEFECTED REGIONS

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PLANNED ACTIVITY FOR NEXT 6 MONTHS

- ESTABLISH FABRICATION TECHNOLOGY
- GENERATE THEORETICAL MODEL OF IMPLANTED DOPANT DISTRIBUTION
- DETERMINE EFFECT OF GASEOUS ADDITIVES ON ION POPULATION IN CORONA DISCHARGE
- GENERATE THEORETICAL MODEL FOR SHALLOW JUNCTION CELLS
- SCALE UP CELL DIMENSION
- FABRICATE CELLS WITH INCREASED EFFICIENCY

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