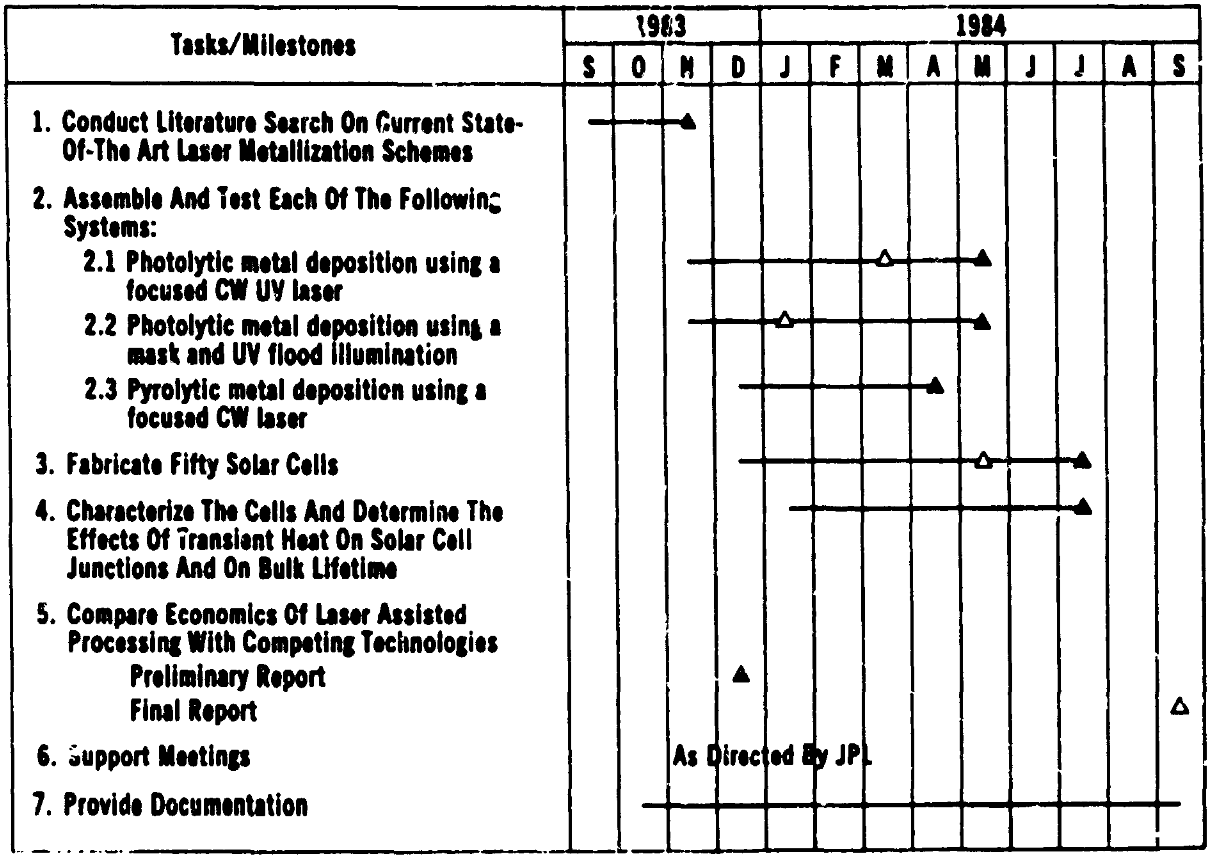
N85-32429

LASER-ASSISTED SOLAR-CELL METALLIZATION PROCESSING

WESTINGHOUSE ELECTRIC CORP.

Subhadra Dutta

Milestone Chart



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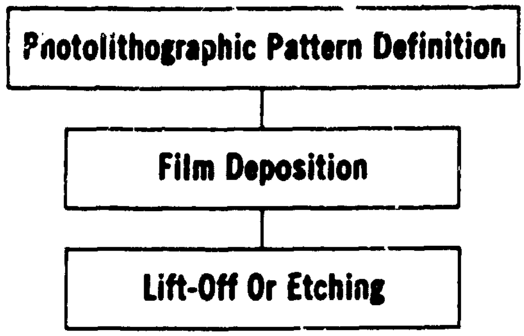
PROCESS DEVELOPMENT



Laser-Assisted Metallization Techniques Are Essentially One-Step Processes:

Potential Advantages of Laser Deposition Techniques for Photovoltaic Systems

- **High Resolution**
- **No Photolithography**
- **Clean And Contamination - Free**
- **In-Situ Sintering**
- **Low Contact Resistance**

Laser-Assisted Deposition Techniques

Pyrolytic Deposition (Thermal)

- Laser Chemical Vapor Deposition (LCVD)
- Laser Deposition From Solutions

Photolytic Deposition (Non-Thermal)

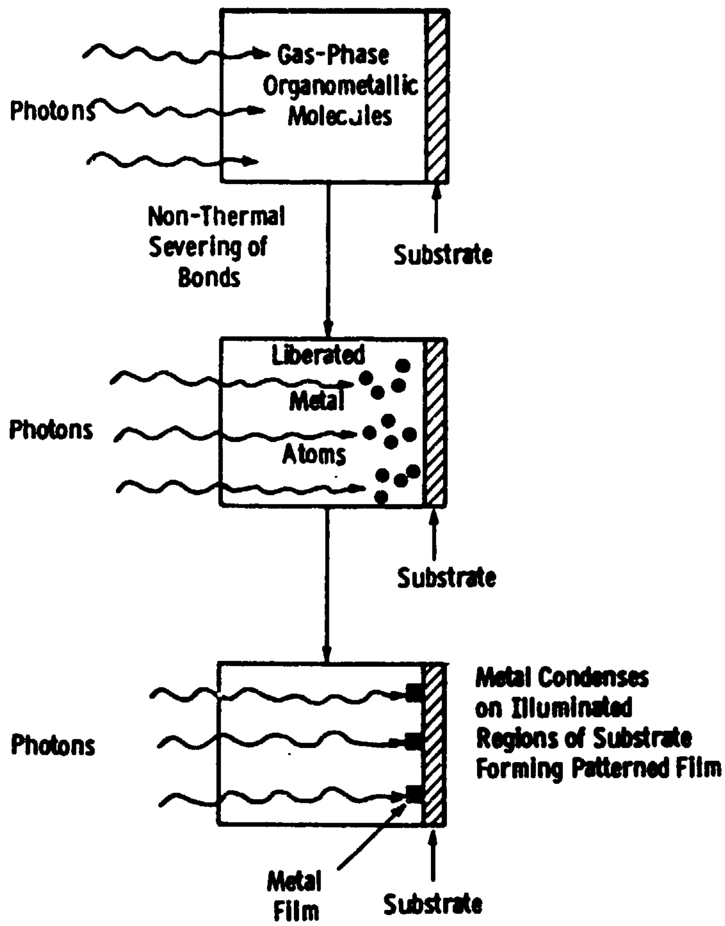
- Laser Photodissociation Of Vapors
- Laser Photodissociation Of Solutions

Laser Assisted Electroplating

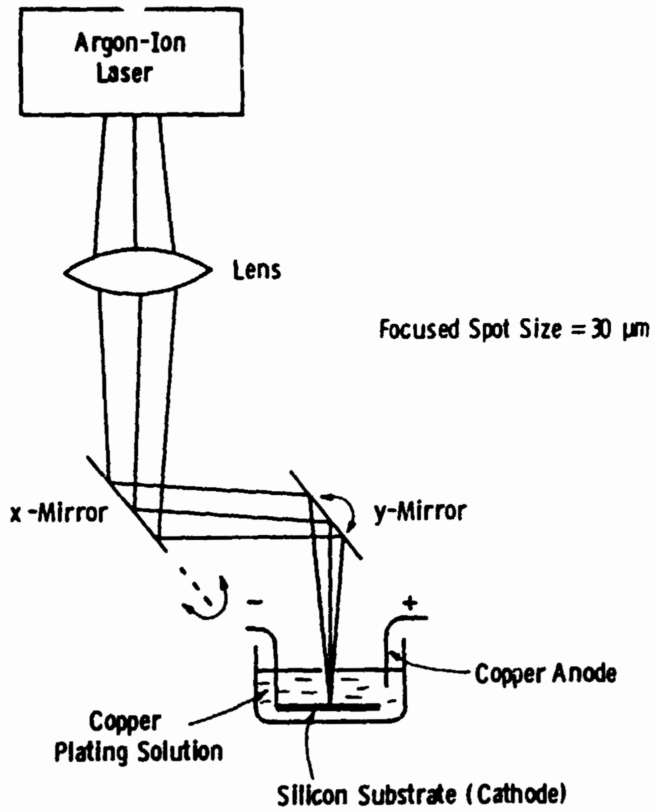
Photolytic Deposition

Laser-Induced Photodecomposition of Gas-Phase Organometallic Compounds:

This Technique is Fundamentally Different from Thermally Based Laser Processes



Experimental Setup for Laser-Assisted Electroplating



S. Dutta
l.t.-m.z. 3-9-84

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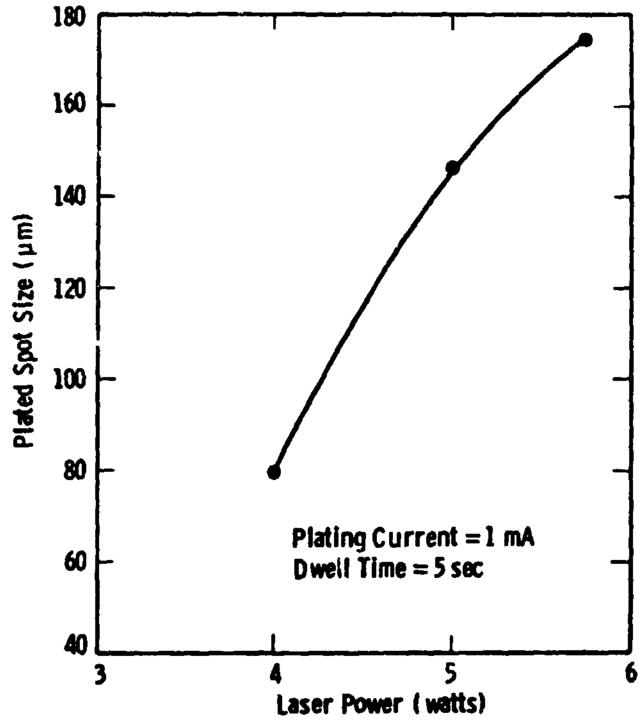
Laser Power Dependence of Electroplated Spot Size



Nomarski Micrograph (200X) of Copper Line Deposited by Laser-Assisted Electroplating Results

25 µm

Linewidth = 25 µm

Laser Power = 4 W

Laser Dwell Time = 50 µsec

Line Thickness = 6000 Å

Plating Current = 2 mA

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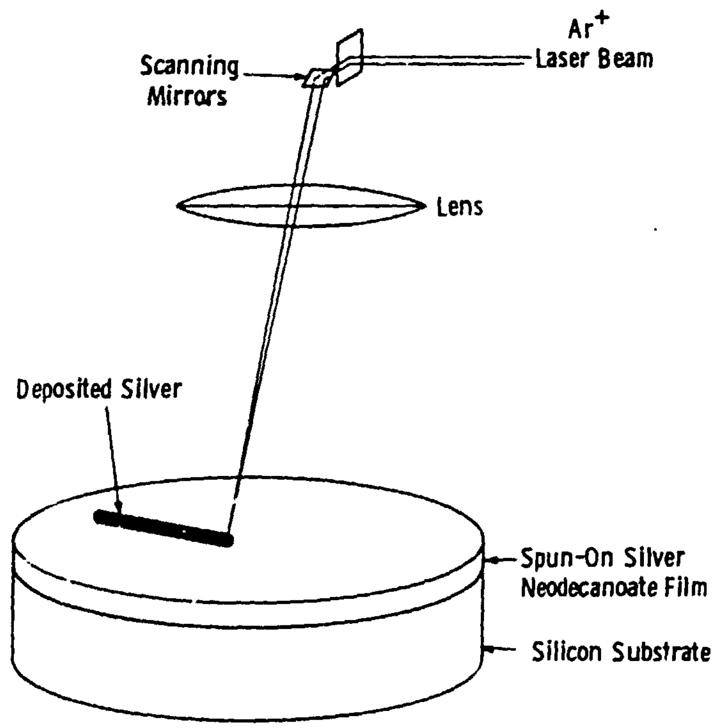
Summary of Laser-Assisted Electroplating Results

- **Novel Technique For Greatly Enhancing Local Plating Rates – Yield Fine-Line, Directly-Written Patterns With Excellent Adhesion**
- **Multiple Rapid Laser Scans Yield Finer, More Even Line And Higher Local Plating Rate Than Single Slow Scan (Same Total Exposure Time)**
- **Plated Linewidth Depends On Laser Power, Plating Current, And Electrolyte Level**

Laser Pyrolysis of Spun-on Metallo-Organic Film

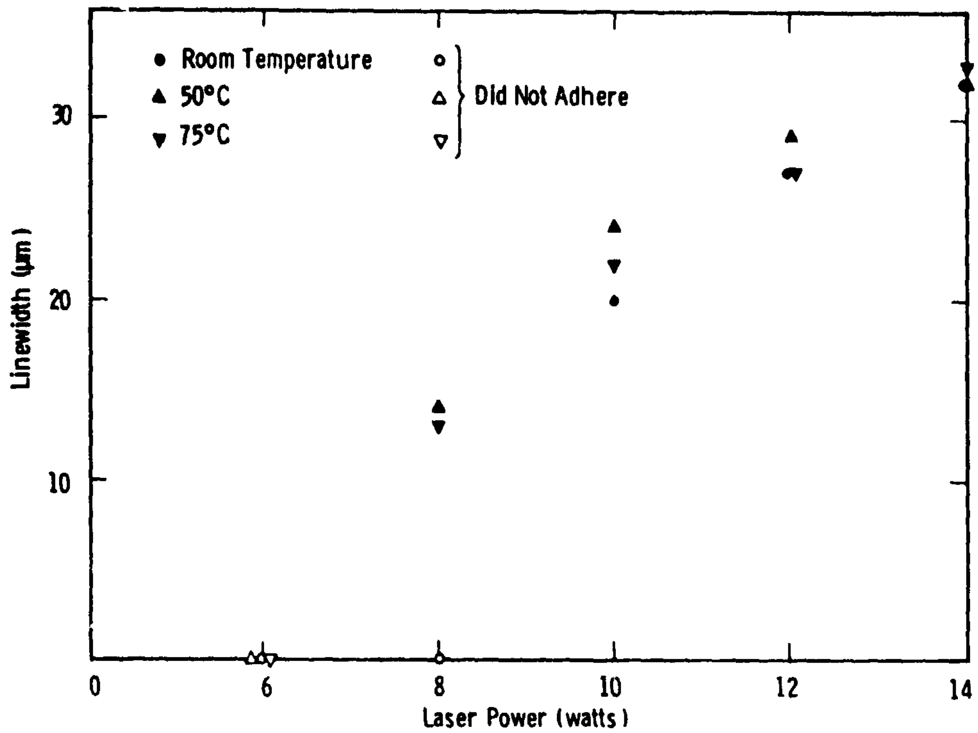


Sample Base Temperature 75°C

Focussed Laser Spot Decomposes Spun-On Film

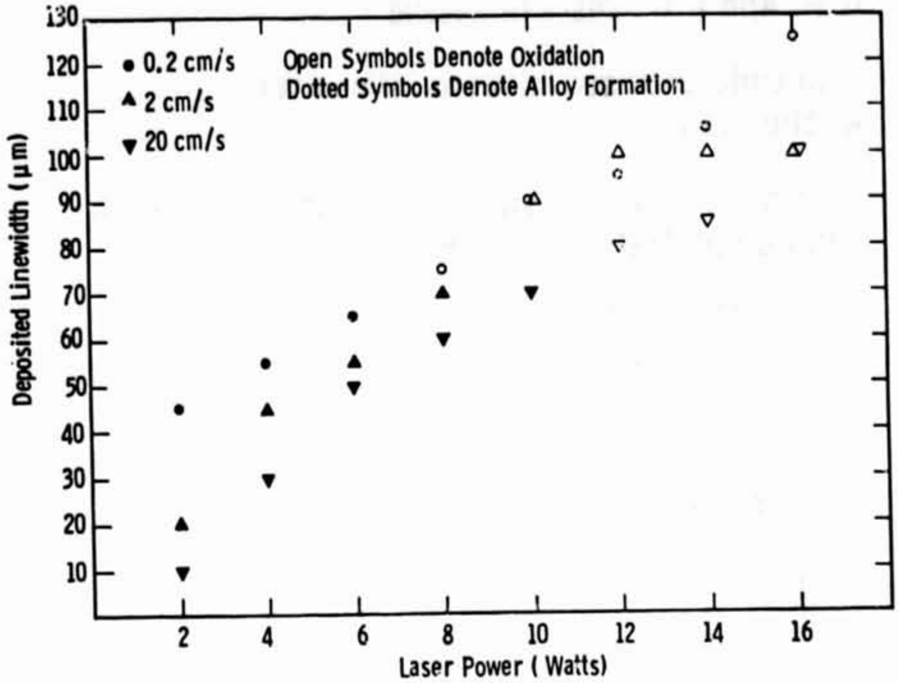
Silver Metallization Patterns are Formed by Direct-Writing

Line Width vs Laser Power and Substrate Temperature

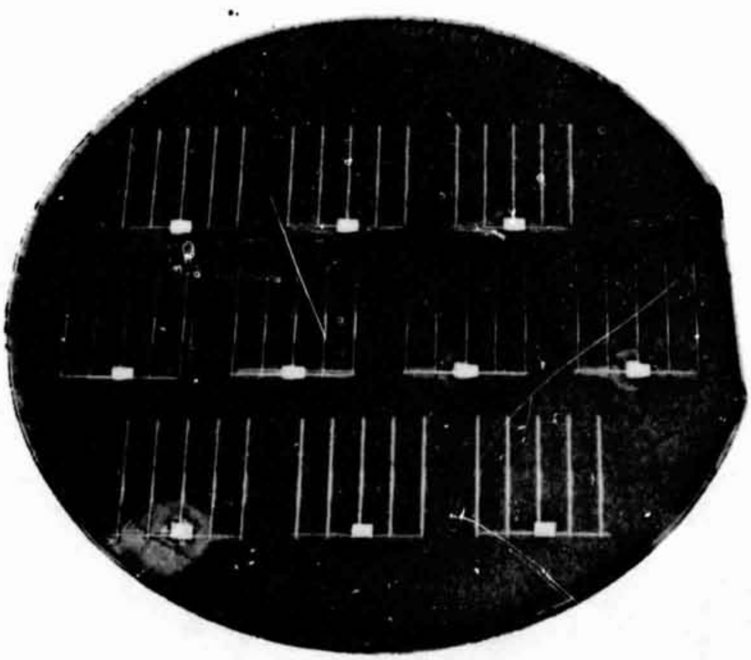


Nomarski Micrographs (200X) of Silver Lines Decomposed at (a) 4 W, (b) 8 W, (c) 14 W Before & After Tape Test

Deposited Line Widths as a Function of Scan Speed and Laser Power



Laser-Written Solar-Cell Metallization Patterns Using Spun-on Silver Neodecanoate



Laser Metallization Process

1. Make Solution Of Silver Neodecanoate (Obtained From G.M. And R.W. Vest) In Xylene
2. Spin Onto Diffused, Coated Silicon Wafers At 1000 rpm
3. Decompose Film Locally With Argon-ion Laser To Form Comb Metallization Patterns
   - Laser Power = 8W
   - Spot Size = 50 μm
   - Scan Speed = 20 cm/s
   - Scan Overlap (Contact Pads) = 60%
   - Deposited Silver Thickness = 400 Å
4. Electroplate Selectvely Onto Patterns
   - Plated Silver Thickness = 8 μm
5. Define Mesas To Isolate Cells And Characterize Cells

Lighted I-V Data for Unsintered Laser-Metallized Cells

Cell I.D.	Short-Circuit Current J_{sc} (mA)	Open-Circuit Voltage V_{oc} (V)	Fill Factor	Efficiency (%)
Laser 1-2	23.1	0.557	0.761	9.8
Laser 1-3	22.8	0.558	0.755	9.6
Laser 1-6	23.7	0.557	0.776	10.3
Laser 1-7	23.7	0.556	0.770	10.1
Laser 1-8	23.7	0.559	0.764	10.1
Laser 1-9	24.2	0.560	0.764	10.3
Laser 1-10	24.2	0.558	0.772	10.4
Laser 1-11	23.8	0.553	0.774	10.2
Laser 1-12	24.2	0.558	0.773	10.4
Laser 1-14	24.6	0.558	0.769	10.5
Laser 1-15	24.5	0.562	0.755	10.4
Laser 5-7	24.3	0.562	0.734	10.0
Laser 5-10	24.7	0.562	0.650	9.0
Laser 5-11	24.7	0.566	0.751	10.5
Laser 5-14	24.6	0.567	0.762	10.6
Laser 5-15	25.1	0.570	0.776	11.1

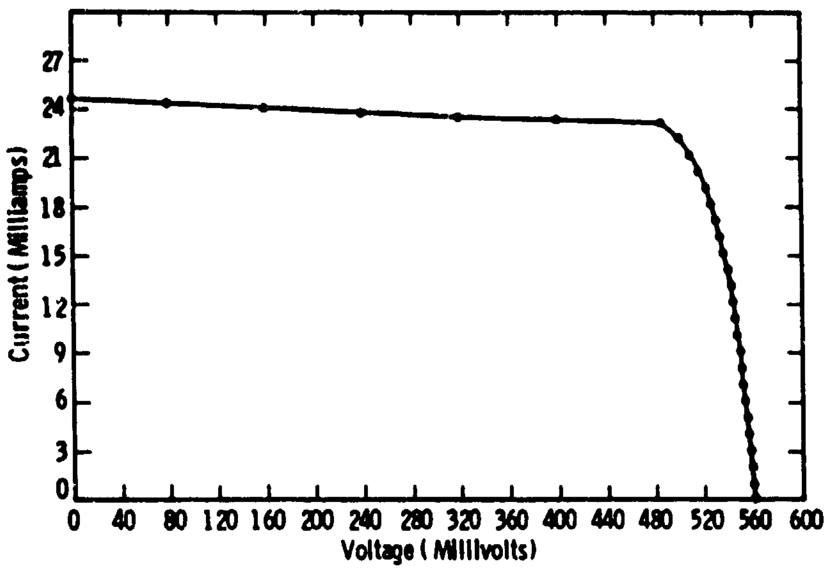
Lighted I-V Data for Unsintered Baseline Cells

Cell I.D.	Short-Circuit Current J_{sc} (mA)	Open-Circuit Voltage V_{oc} (V)	Fill Factor	Efficiency (%)
RSC 1-2	23.4	0.573	0.772	10.4
RSC 1-3	23.2	0.562	0.681	8.9
RSC 1-5	23.4	0.571	0.762	11.0
RSC 1-6	25.0	0.569	0.746	10.6
RSC 1-7	25.0	0.567	0.718	10.2
RSC 1-8	24.6	0.571	0.734	10.3
RSC 1-9	23.5	0.568	0.751	10.0
RSC 1-10	25.4	0.569	0.768	11.1
RSC 1-11	25.6	0.568	0.734	10.7
RSC 1-12	25.9	0.567	0.710	10.5
RSC 1-14	26.1	0.571	0.716	10.6
RSC 1-15	25.9	0.567	0.608	8.9
RSC 2-2	25.8	0.569	0.764	11.2
RSC 2-3	26.1	0.567	0.746	11.1
RSC 2-5	26.3	0.569	0.719	10.8
RSC 2-6	25.9	0.566	0.759	11.1
RSC 2-7	25.8	0.566	0.753	11.0
RSC 2-8	25.6	0.567	0.735	10.7
RSC 2-9	25.6	0.566	0.722	10.5
RSC 2-10	25.9	0.566	0.749	11.0
RSC 2-14	26.1	0.567	0.702	10.4
RSC 2-15	26.0	0.567	0.636	9.4

Comparison of Laser-Metallized and Baseline Cells Lighted I-V Data

Cell I.D.	Short-Circuit Current J_{sc} (mA/cm^2)	Open-Circuit Voltage V_{oc} (V)	Fill Factor	Non-AR-Coated Cell Efficiency (%)
Laser 1–14	24.6	0.558	0.769	10.5
Baseline 2–9	25.6	0.566	0.722	10.5
Laser 5–11	24.7	0.566	0.751	10.5
Baseline 1–12	25.9	0.567	0.710	10.5
Laser 5–14	24.6	0.567	0.762	10.6
Baseline 1–6	25.0	0.569	0.746	10.6
Laser 5–15	25.1	0.570	0.776	11.1
Baseline 2–3	26.1	0.567	0.746	11.1

Lighted I-V Characteristics of Laser-Metallized Solar Cell



Dark I-V Data for Baseline Cells

Cell I.D.		Normalized Series Resistance (Ω-cm^2)	Normalized Shunt Resistance (KΩ cm^2)	J_{01} (A/cm^2)	J_{02} (A/cm^2)	Efficiency (%)
RSC 1-3	Before Sintering	1.3	0.8	5.1×10^{-12}	2.4×10^{-5}	8.3
	After Sintering	0.9	6.9	4.3×10^{-12}	3.8×10^{-6}	10.1
RSC 1-9	Before Sintering	1.0	4.9	4.2×10^{-12}	8.8×10^{-5}	10.0
	After Sintering	0.8	113.7	4.4×10^{-12}	1.3×10^{-6}	10.9
RSC 1-10	Before Sintering	1.0	$>10^3$	4.5×10^{-12}	1.7×10^{-7}	11.1
	After Sintering	0.8	769.9	4.9×10^{-12}	1.1×10^{-6}	10.9
RSC 1-15	Before Sintering	2.2	2.4	4.0×10^{-12}	4.7×10^{-6}	8.9
	After Sintering	0.8	5.8	4.3×10^{-12}	3.5×10^{-6}	8.9
RSC 2-2	Before Sintering	1.0	$>10^3$	4.2×10^{-12}	8.7×10^{-9}	11.2
	After Sintering	0.7	$>10^3$	4.2×10^{-12}	3.1×10^{-8}	11.3
RSC 2-3	Before Sintering	1.1	0.4	5.0×10^{-12}	3.9×10^{-5}	11.1
	After Sintering	0.8	1.3	4.3×10^{-12}	1.1×10^{-5}	11.1
RSC 2-12	Before Sintering	1.5	$>10^3$	4.3×10^{-12}	1.8×10^{-8}	7.4
	After Sintering	1.0	77.6	3.4×10^{-12}	2.4×10^{-5}	7.0
RSC 2-15	Before Sintering	1.8	$>10^3$	4.1×10^{-12}	9.1×10^{-9}	9.4
	After Sintering	1.3	$>10^3$	3.3×10^{-12}	4.9×10^{-8}	9.3

Conclusions

- High Quality Solar Cells Obtained By Laser Metallization Technique
  - Non-AR-Coated Cell Efficiency = 11.1%
- In-Situ Sintering Occurs During Laser Writing Process
  - Series Resistance Of Laser-Metallized Cells Lower
- Finer Lines Should Yield Higher Efficiencies
  - Laser-Written Linewidths = 50 μm
  - Baseline Linewidths = 25 μm
  - Comparable Efficiencies Despite Greater Cell Shadowing In Laser-Metallized Cells