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APPENDICES

APPENDIX A.

PROCESS OF PREPARING SILICON WAFER

A.1 : INITIAL CLEANING SILICON WAFER

Purpose

To remove all foreign matters from the surface silicon wafer (dirt, scum, silicon dust, etc.) prior to processing.

Procedure

1. Boil in Trichloroethylene 5 minutes
2. Boil in Acetone 10 minutes
3. Boil in D.I. water 5 minutes
4. Boil in HNO_3 10 minutes
5. Boil in D.I. water 5 minutes
6. Etch wafer for 2 or 3 minutes in 50 % HF solution at room temperature.
7. Boil in D.I. water 10 minutes

A.2 : ETCHING SILICON DIOXIDE

Purpose

To remove the silicon dioxide from the surface silicon wafer prior to processing.

Solution I

- Ammonium fluoride 389 g
- Hydrofluoric acid 140 ml
- D.I. water 1,000 ml

Rate of etching 1,000 Å /min.

Solution II

- Ammonium fluoride	115	g
- HF	40	ml
- D.I. water	160	ml

Rate of etching 800 Å /min.

Solution III

- Ammonium fluoride	150	g
- HNO_3(70 %)	100	ml
- D.I. water	300	ml

Rate of etching 200 Å /min.

A.3 : POLISHING SICICON WAFER

Purpose

To polish the silicon wafer from lapped surface to polished surface.

Solution

- D.I. water	40	ml
- Acetic acid	140	ml
- Nitric acid (100 %)	210	ml
- HF solution (50 %)	30	ml

APPENDIX B.

PROCESS OF FABRICATING DEVICES

B.1 : STEPS OF FABRICATION SOLAR CELL AND CONCENTRATED SOLAR CELL

1. <111> crystal oreintation, p-type silicon wafers with resistivities of 4-5 Ω-cm and 1-2 Ω-cm

2. Initial cleaning of silicon wafers

   [Appendix A.1]

3. Grow initial silicon dioxide layer 5000-6000 Å thick

   [$T = 105^{\circ}C$ - Wet O_2(1 ℓ/min.), $T_{H_2O} = 80^{\circ}C$]

4. Open oxide window at the front surface of wafer with buffered HF solution

   [Wax coating on back and edge]

5. Clean the wafers

   [Trichoroethylene, Acetone, D.I. water]

6. Phosphorus diffusion at $1050^{\circ}C$, predeposition time for 7 minutes

   [$PClO_3$ liquid source, $C_s = 4 \times 10^{20}$ cm^{-3}, $x_j = 0.5$ μm]

7. Etch silicon dioxide layer at the front surface with buffered HF solution

8. Clean the wafer like step 5

9. Grow antireflection layer at the front surface with silicon dioxide 800-900 Å

   [$T = 1050^{\circ}C$ - Wet O_2(1 ℓ/min.), $T_{H_2O} = 56^{\circ}C$]

10. Etch silicon dioxide layer at the back surface with buffered HF solution

    [Wax coating on the front surface]

11. Clean the wafer like step 5

12. Aluminium evaporation at the back side with 7000 Å thick

    [5×10^{-7} Torr vacuum]

13. Annealing the back side contact for $500^{\circ}C$, 20 minutes

14. Photolitography at the front side with mask No 2 for solar cell or mask No 3 for concentrated solar cell

    [Using positive photoresis]

15. Etch silicon dioxide at the front side with buffered HF solution

    [Appendix A.2]

16. Clean the wafers like step 5

17. Nickel electroplating or nickel electroless plating

    [Appendix C]

18. Soldering

19. Clean the wafer like step 5

20. Testing

B.2 : STEPS OF FABRICATION ALPHA RADIATION DETECTOR

1. <111> crystal oreintation, p-type silicon wafer with resistivity of 7,500 Ω-cm, diameter 2-4 cm and 240 μm thick.

2. Polishing wafer 5 minutes.

   [Appendix A.3]

3. Clean the wafer

   [Trichoroethylene, Acetone and D.I. water]

4. Put the wafer into the furnance and increases the temperature slowly at room temperature to 900°C for 1 hour.

5. Diffusion with H_3PO_4 for 15 minutes

6. Decrease temperature at 900°C to room temperature for 2 hours.

7. Lap the back side out by lapping machine

8. Nickel electroplating on the both sides with the mask pattern No 5 on the front surface

9. Wire soldering and encapsulation

10. Testing.

APPENDIX C

NICKEL ELECTROLESS PLATING [15]

Purpose : To deposite nickel on silicon wafer by thermal energy.

Procedure : The composition of the plating bath used in the experiment, that is

Nickel chloride [$NiCl_2.6H_2O$] .... 30 g/l

Ammonium citate [$(NH_4)_2HC_6H_2O_7$] .... 65 g/l

Ammonium chloride [NH_4Cl] .... 50 g/l

Sodium hypophosphite [$Na_2H_2PO_2.H_2O$] .... 10 g/l

The bath is heated to a temperature of $90^{\circ}C$, at which temperature about 200 cc of NH_4OH is added to 1000 cc of plating solution; the bath temperature is then elevated to $95^{\circ}C$, at which temperature the Si sample is immersed in the bath for 30 sec. nickel flims plated in this way were 1000-2000 Å thick. The equipment of nickel electroless plating was shown in Fig. C.1. This solution can be used 8-10 times in perfect adhesion.

Advantages :

- Chemical process
- Low temperature ($90^{\circ}C$)
- pH control (8-10)
- Simple apparatus
- Easy operation
- Effective material utilization

- Easily soldering
- Better mechanical strength

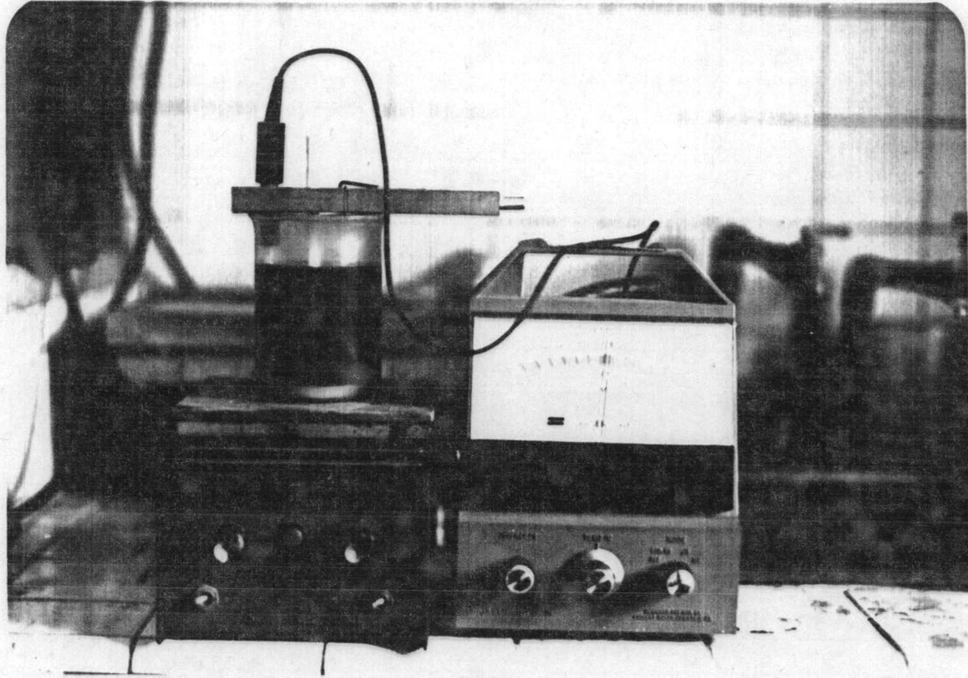

Fig. C.1 Nickel electroless plating

APPENDIX D

MACHINES USE TO FABRICATING DEVICES

D.1 : SCRIBING MACHINE

Purpose : Scribing is to make a fine cut of suitable depth into Si and make possible of wafer into die form. The scribing machine was shown in Fig.D.1.

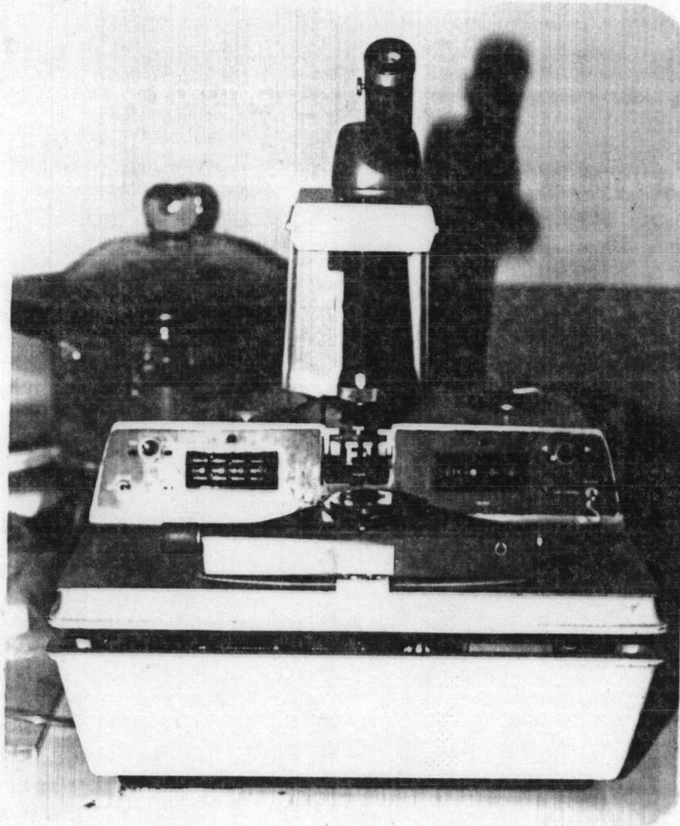

Fig.D.1 Scribing machine

D.2 : ULTRASONIC WIRE BONDING

Purpose : to connect the aluminium wire on the sample by ultrasonic energy (Fig.D.2)

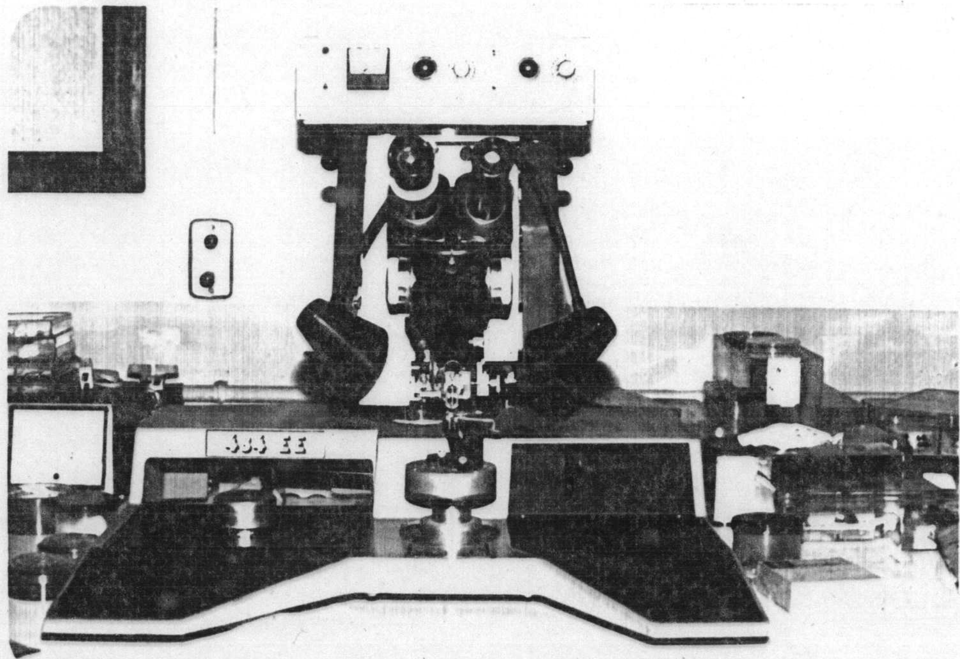

Fig. D.2 Ultrasonic wire bonding

APPENDIX E

EXPERIMENTAL RESULTS

Table E. 1 Summary of experimental results for Nickel, Copper-n-type, p-type silicon contacts with nonannealing and annealing 16 hours.

Metals deposited	Type of doping	Substrate resistivity (Ω-cm)	Impurities concentration (cm^{-3})	Contact resistance (Ω)		Contact resistivity (Ω-cm^2)	
				Before annealing	After annealing	Before annealing	After annealing
Ni	p(B)	0.015	5.5×10^{18}	0.10	0.06	3.36×10^{-4}	2.28×10^{-4}
Ni	p(B)	0.100	3.0×10^{17}	0.24	0.07	8.06×10^{-4}	2.35×10^{-4}
Ni	p(B)	0.226	1.0×10^{17}	1.54	1.45	5.17×10^{-3}	4.87×10^{-3}
Ni	p(B)	4.50	3.0×10^{15}	4800	3400	1.61×10	1.06×10
Ni	p(B)	11.10	1.0×10^{15}	5030	4380	1.69×10	1.47×10
Ni	n(P)	0.012	2.5×10^{18}	0.83	0.17	2.75×10^{-3}	5.71×10^{-4}
Ni	n(P)	0.029	7.0×10^{17}	1.28	1.22	4.30×10^{-3}	4.09×10^{-3}
Ni	n(P)	1.23	3.5×10^{15}	6.17	5.61	2.07×10^{-2}	1.88×10^{-2}
Ni	n(P)	10.70	3.5×10^{14}	1580	2140	5.30	7.19
Ni	n(P)	11.10	3.0×10^{14}	2140	2550	7.19	8.56
Cu	p(B)	0.013	5.0×10^{18}	0.21	0.14	7.05×10^{-4}	4.70×10^{-4}
Cu	p(B)	0.226	2.0×10^{17}	0.48	0.16	1.61×10^{-3}	5.37×10^{-4}
Cu	p(B)	0.546	4.0×10^{16}	0.43	0.29	1.44×10^{-3}	9.74×10^{-4}
Cu	p(B)	4.50	3.0×10^{15}	210	170	7.05×10^{-1}	5.71×10^{-1}
Cu	p(B)	9.84	1.0×10^{15}	260	250	8.73×10^{-1}	8.40×10^{-1}
Cu	n(P)	0.0116	2.5×10^{18}	0.14	0.09	4.70×10^{-4}	3.02×10^{-4}
Cu	n(P)	0.092	7.0×10^{18}	50	37	1.68×10^{-1}	1.24×10^{-1}
Cu	n(P)	1.23	3.5×10^{15}	390	790	1.31	2.65
Cu	n(P)	4.32	9.0×10^{14}	1320	2120	4.43	7.12

Table E.2 Photovoltaic parameters of the solar cells

Electroplating contacts				Electroless plating contacts			
No 1 Pa=810 Wm^{-2} 1:55 P.M,T=41°C		No 2 Pa=761 Wm^{-2} 2:06 P.M,T=42°C		No 3 Pa=817 Wm^{-2} 2:10 P.M,T=44°C		No 4 Pa=745 Wm^{-2} 2:15 P.M,T=42°C	
I (mA)	V (V)	I (mA)	V (V)	I (mA)	V (V)	I (mA)	V (V)
77	-	75.5	-	76.8	-	78	-
76	.083	74	.084	75.8	.081	76	.090
75	.233	73.5	.158	74	.156	75	.160
73	.298	73	.229	72	.225	71	.221
69.5	.350	68	.346	68	.281	66	.275
64	.383	62.5	.379	63	.319	62	.315
52.5	.418	57	.400	57	.347	57	.345
38	.445	47	.424	52	.366	52	.366
30	.456	40	.436	40	.399	40	.406
20	.469	35	.444	29	.425	29	.433
10	.480	26	.457	20	.443	19	.453
6	.487	20	.464	11	.459	10	.473
2	.491	10	.479	6	.469	4	.482
-	.500	-	.490	-	.480	-	.490
I_{sc}=77	V_{oc}=.500	I_{sc}=75.5	V_{oc}=.490	I_{sc}=76.8	V_{oc}=.480	I_{sc}=78	V_{oc}=.490

APPENDIX F

APPLICATION OF PLATING TECHNIQUE.

F.1 : SOLAR CELL

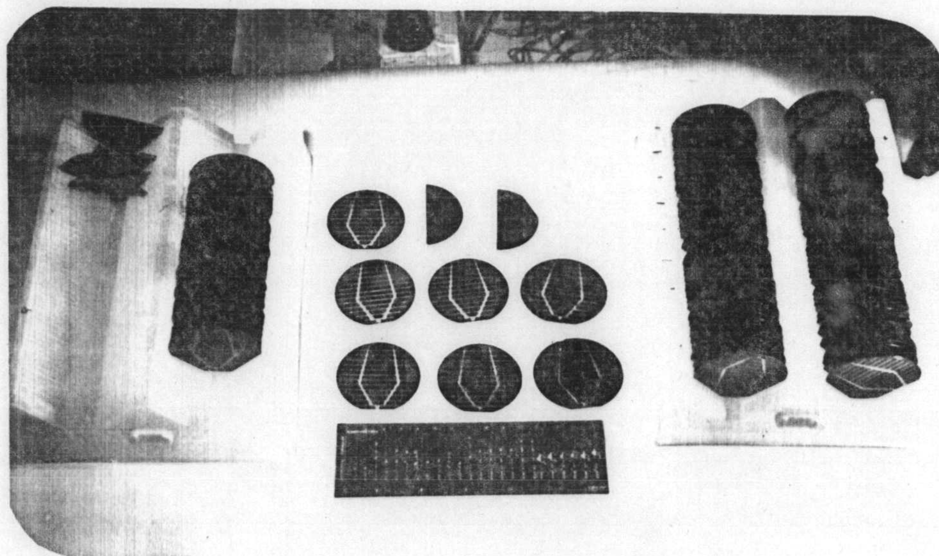

Fig. F.1 Solar cells by plating technique

F.2 : CONCENTRATED SOLAR CELL

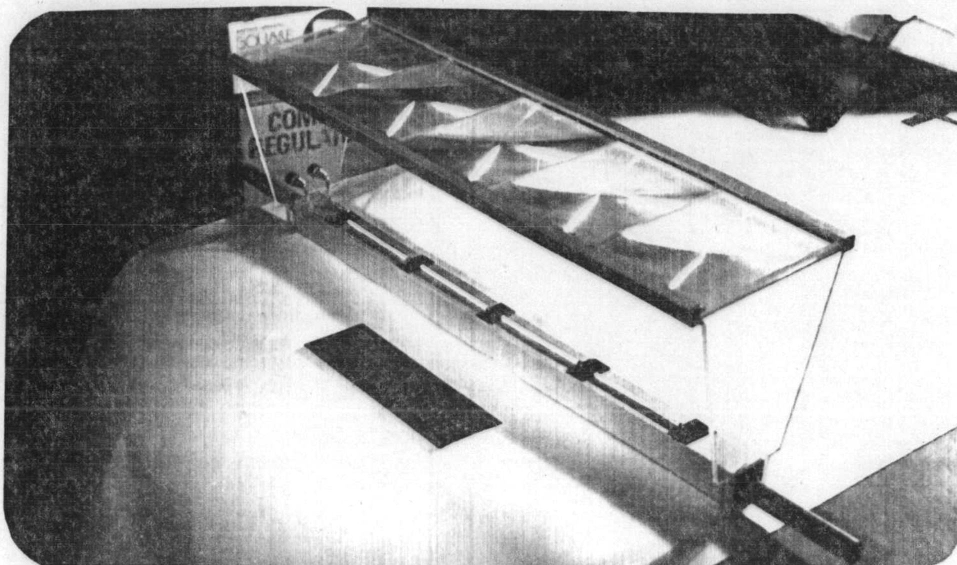

Fig. F.2 Concentrated solar cells by plating technique

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