

Supplementary Information

1 Equipment

Piece	Process	Model
UV ozone cleaner	Back contact	Ossila
DC sputterer	Back contact	Nordiko RFG-2500
Shaker	Solution	PSU-10i Orbital Shaker
Hotplate	Deposition	Harry Gestigkeit PZ 28-3TD
Hotplate controller	Deposition	Harry Gestigkeit TR 28-3T
Ultrasonic nozzle	Deposition	Sonotek 120kHz nozzle
Broadband generator	Deposition	Sonotek Precision Generator 06-05-00108
Solution delivery	Deposition	Sonotek Dual Syringe Pump 997
Gas flow meter	Deposition	Cole-Parmer Acrylic Bench Mount, $\leq 30\text{L/min}$
Linear stages	Deposition	Zaber X-LSQ150A
Furnace controller	Selenisation	Lenton Type 3508
Furnace	Selenisation	Lenton CSC 12/90/600 (H)
Quartz tube	Selenisation	Multi-lab, 80mm OD x 72.8mm ID x 1025mm L
Bath heater	Buffer	Haake DC 30
RF sputterer	Front contact	AJA Int. ATC Orion 8 UHV
Deposition sensor	Grid	Inficon Quartz Crystal Monitor
Deposition monitor	Grid	Inficon STM-2

Table 1: The equipment used throughout production

2 Precursors

Name	Abbrev	Process	Purity (%)	Supplier
Soda lime glass	SLG	back contact	Menzel Glaser	Fisher Scientific
Mo target	Mo	Back contact	99.95	Testbourne
Thiourea	TU	Solution/buffer	≥ 99.0	Sigma Aldrich
Cysteamine	CA	Solution	≥ 99.2	Chem-Impex Int.
Copper (II) oxide	CuO	Solution	99.98	Alfa Aesar
Zinc oxide	ZnO	Solution	99.99	Sigma Aldrich
Tin sulphate	SnSO ₄	Solution	≥ 95	Sigma Aldrich
Selenium shot	Se	Selenisation	99.999	Alfa Aesar
Cadmium sulphate	CdSO ₄	Buffer	≥ 99.0	Sigma Aldrich
Ammonium hydroxide	NH ₄ OH	Buffer	28-30 wt%	Acros Organics
ZnO target	ZnO	Front contact	99.99	Plasmaterials
Al ₂ O ₃ :ZnO (0.5% by wt.)	AZO	Front contact	99.99	Innovnano

Table 2: The materials used throughout production

3 Back contact

3.1 Preparation

50x50mm soda lime glass is cleaned at 50 °C by:

- 15min sonicating in acetone
- 15min sonicating in IPA
- 30min sonicating in DI water
- 5min UV-ozone cleaning

3.2 Deposition

Layer		Mo	Mo	MoN	Mo
Power setpoint	W	1180	1790	1790	1790
Target dimensions	cm	30x10	30x10	30x10	30x10
Power density	W cm ⁻²	3.933	5.967	5.967	5.967
Coat time	s	360	1800	600	120
Gas		Ar	Ar	Ar/N ₂	Ar
Gas flow	sccm	30	2	10/5	2
Approx. thickness	nm	600		~30	~50

Table 3: Table of back contact deposition parameters

4 Absorber

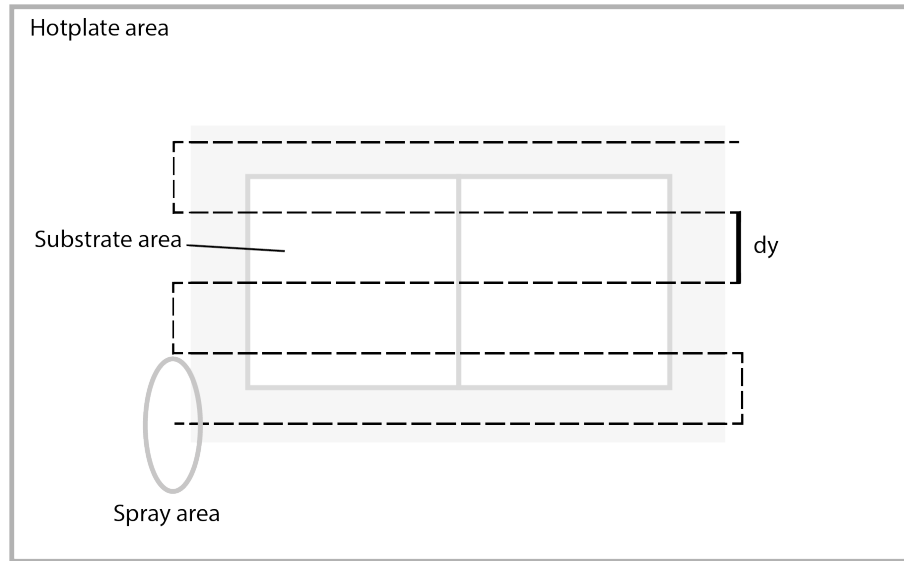


Figure 1: Image showing the motion of the deposition spot over the surface of the hotplate whilst pyrolysing

4.1 Deposition execution

We start the Labview program as the substrate touches the hotplate at temperature T ; a time t_1 elapses before the stages begin to move. They move with velocity v and displace a distance dy .

After spraying a full layer it pauses for a time t_2 before returning to the start and spraying again. It sprays n layers and pauses a time t_3 after the last layer.

The solution is delivered to the nozzle at rate r_1 where the nozzle atomises it at 120kHz with power p . The atomised solution is directed downwards using N_2 gas flowing at rate r_2 from a nozzle-to-hotplate distance of h .

4.2 Deposition parameters

Code	Parameter	Units	Value
T	Hotplate	°C	350
t_1	PreDwell	s	45
t_2	MidDwell	s	30
t_3	PostDwell	s	180
v	Stage speed	mm/s	40
dy	Sidestep	mm	10
r_1	Flow rate	ml/min	1.5
r_2	Gas flow	L/min	6
p	Power	W	4.5
n	Layers	-	12
h	Nozzle height	cm	5.5

Table 4: Table of spray deposition parameters

5 Selenisation

- Tube vented with N_2 gas; filled to starting pressure 80Torr
- Timer started as tube furnace lid closes
- Lid opened after 35 minutes
- Sample left to cool naturally

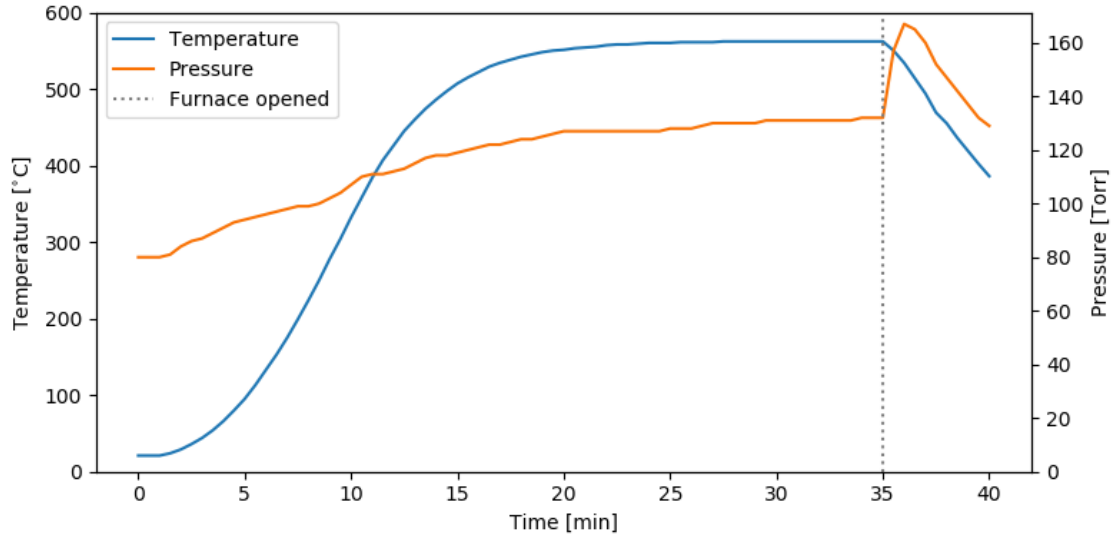


Figure 2: Temperature and pressure profile of selenisation

6 Buffer layer

1. Set circulating bath to 70°C
2. Add 183ml DI water to a beaker; leave to warm
3. When water temperature reaches 60°C:
 - Add 32.6ml NH_4OH
 - Add 25ml CdSO_4 (0.015M)
 - Start 15min timer
4. After 5mins add 12.5ml thiourea (1.5M) and submerge samples
5. When timer ends remove samples and rinse with DI water
6. Dry with compressed air

7 Top contact

Layer		iZnO	AZO
Power setpoint	W	180	180
Target diameter	inches	3	3
Power density	W cm^{-2}	3.947	3.947
Coat time	s	900	5400
Gas		1% O_2/Ar	Ar
Gas flow	sccm	6/5	7

Table 5: Deposition details for RF sputtered front contact

8 Grids

Ag pellets are evaporated by passing 85A through a tungsten boat, until 500nm of Ag is deposited (~30minutes)

9 Images

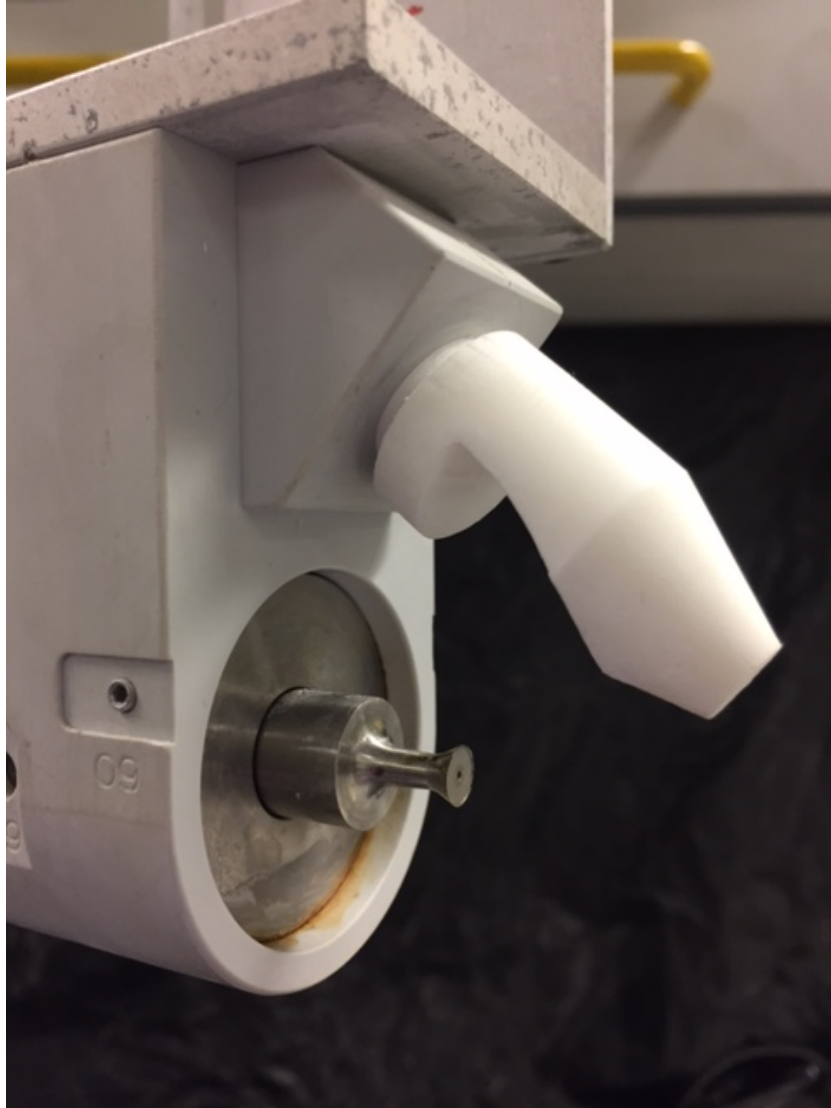


Figure 3: Photo of nozzle

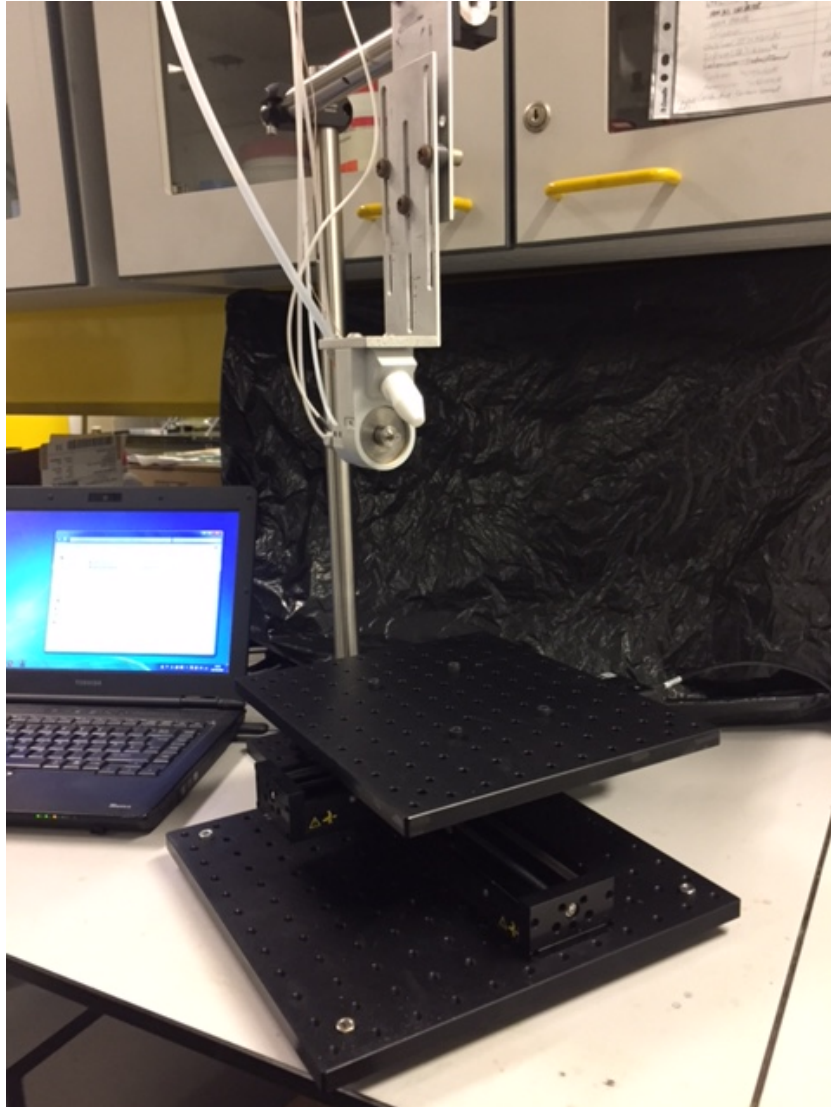


Figure 4: Photo of nozzle over stages

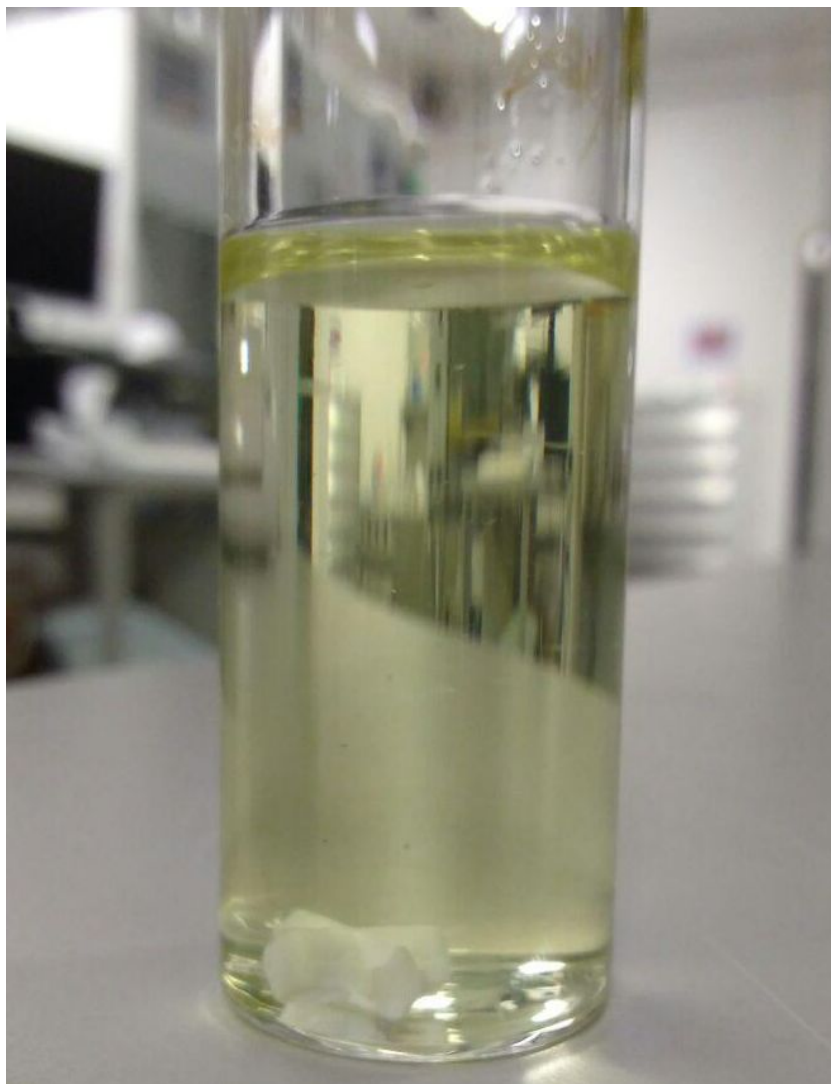


Figure 5: Photo of dissolved solution, pre-dilution



Figure 6: Photo of graphite box

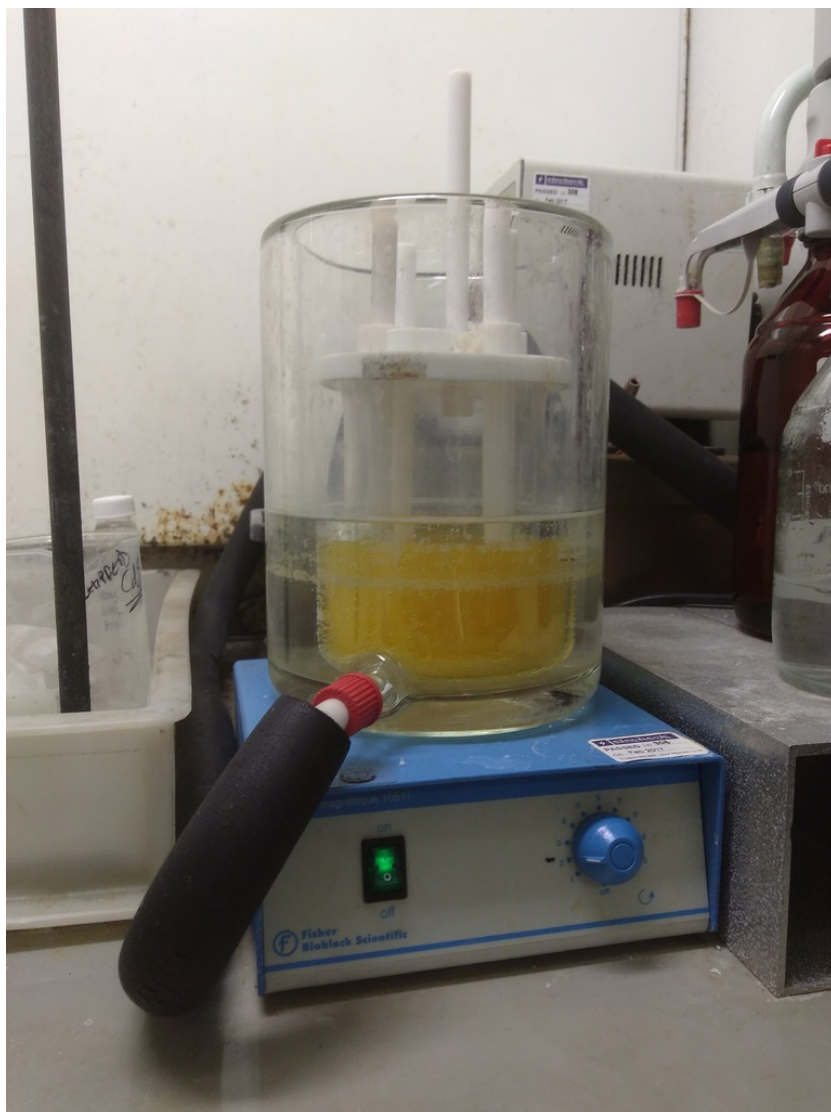


Figure 7: Photo taken during CdS deposition