	PURCHASE SPECIFICATION Department: ASSCP Unit : Corporate R & D	Spec. No	ASP/DST1/E1-02
		Rev. No	07
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ITEM: *Multi Chamber Process Equipment for the deposition of amorphous silicon and Indium tin oxide layers for heterojunction solar cells*

S. No.	TECHNICAL SPECIFICATION	VENDOR'S CONFIRMATION
1.	**SCOPE AND FUNCTIONAL REQUIREMENTS**	
	A customized system is required to deposit doped and undoped amorphous silicon (a-Si:H) and indium tin oxide (ITO) films on either 9 pseudo-square silicon wafers of size 125 mm x 125 mm or 4 pseudo-square silicon wafers of size 156 mm x156 mm in a single run, to produce a stacked structure as shown in Figure 1. The wafer thickness will be around 200 micrometer. The system will integrate plasma enhanced chemical vapor deposition (PECVD) and sputtering chambers in an in-line configuration to deposit all the layers in the sequence given in Figure 2 without breaking the vacuum. The typical thickness value for an individual a-Si:H layer will be 5 -20 nanometer and that for ITO layer will be 50 - 200 nanometer. The system will have one load lock, one isolation chamber, three PECVD chambers for intrinsic, p-type and n-type amorphous silicon and one chamber for ITO deposition by sputtering in the sequence as shown in Figure 2. The wafer carrier will enter the system from load lock and exit from the same load lock after the deposition of desired layers from the corresponding chambers. The transport and deposition should be computer controlled and recipe driven with the option of partial or complete manual operation. **Note: The schematics are just to guide design and should not be taken as a reason for compromising the functional requirements of the system.** It is intended to shut off the pumping after daily operations and start it afresh for next operation without venting in between. The base pressure and the substrate heating requirements mentioned should be attainable within 5 hours of start up.	

REVISION (07)	APPROVED BY S. Bhattacharya		
	CHECKED	PREPARED	DATE
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1	**SCOPE AND FUNCTIONAL REQUIREMENTS**				
	The system and chamber dimensions should be optimally chosen to meet the process requirements in the respective chambers in terms of the uniformity and quality of the films. Special care should be taken in designing showerhead electrode, heating arrangement, isolation gate valves to provide a contamination-free environment in the process chambers. The vendor will provide all the items and accessories to monitor and control the system as an independent unit. BHEL scope is limited to furnishing the facility requirements such as power, water, compressed air, abatement system etc. up to a common point on the support structure of system. Process gases will also be provided by BHEL.				
2	**DETAILS OF EQUIPMENT**				
2A	**Single run capability**	Processing of 9 pseudo-square silicon wafers of size 125 mm x 125 mm or 4 pseudo-square silicon wafers of size 156 mm x156 mm in a single run			
2B	**System configuration**	1 entrance conveyor and 6 rectangular vacuum chambers connected in In-line configuration. The vacuum chambers will be fabricated from SS 304 and will have fixtures and ports for mounting heaters, pumps, gauges, transport mechanism, power supply connections, viewing ports etc. The chambers will be electro polished from Inside and glass bead blasted from outside. Gate valves must be installed at the start of load lock, between all adjacent chambers and at the end of ITO chamber to perfectly isolate the chamber process environment from the environment of the adjacent chambers or atmosphere.			
2C	**Wafer Carrier Transport properties**	***a.***	***Speed***	Variable, up to 1000 mm/min.	
		b.	***Capabilities & operation***	Smooth transfer of wafer carrier in both directions and full integration with the system automation.	

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2.	DETAILS OF EQUIPMENT						
2 D	Chamber capabilities	*a.*	*Load Lock chamber*	i.	Base pressure (Torr)	< 1 x 10^{-3} at 150 °C substrate temperature	
				ii.	Pumping	Dry	
				iii.	Substrate Heating	~200 °C in 20 minutes using IR heaters inside the chamber or heaters mounted on the lid or bottom plate or on both on the atmospheric side of the chamber. The design of the mounting of heaters should be such that the viton gaskets mounted on the flanges do not get damaged due to heating.	
				iv.	View ports	≥ 2	
		b.	*Isolation chamber*	i.	Base pressure	≤ 8 x 10^{-7} Torr at 150 °C temperature after appropriate heating for 3-4 hours.	
				ii.	Substrate heating	350 °C in 5 minutes using Infrared heating	
				iii.	View ports	≥ 2	
				iv.	Ports with isolation valves	≥ 2, at the back side (port size : 40 KF)	
		c.	*Deposition chambers (Features common to intrinsic, p-type, n-type and ITO chambers)*	i.	Substrate heating	Up to 325 °C during process gas flow. The wafer temperature should be controlled between 100 to 325 °C within ± 5 °C. The heaters should be mounted on the atmosphere side of the chamber. The design of the mounting arrangement of heaters should be such that the viton O-rings mounted on the flanges do not get damaged due to heating. Also chamber should not develop any cold regions in the chamber due to heater design.	

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2.	DETAILS OF EQUIPMENT								
2 D	*Chamber capabilities*	*c.*	***Deposition chambers (Features common to intrinsic, p-type, n-type and ITO chambers)***		ii.	Base pressure	≤ 8 x 10^{-7} Torr at 150 °C substrate temperature		
					iii.	Process Pumping	PECVD	Automatic control of pressure in the range of 0.1 – 2 Torr	
							ITO	Automatic control of pressure in the range of 10^{-4} – 10^{-2} Torr	
					iv.	Process gas flow precision	± 1 sccm		
					v.	Process pressure precision	PECVD	± 1 mTorr	
							ITO	± 0.1 mTorr	
					vi.	Ports with isolation valves	≥ 2, at the back side (port size : 40 KF)		
				1. intrinsic a-Si:H	i.	Mode of deposition	Moving mode deposition with wafer carrier travelling under the electrode with gate valves closed on both sides of the chamber		
					ii.	Plasma sources	13.56 MHz (RF) and 40.68 MHz (VHF) generators with automatic matching network, both feeding power to the same electrode(s). Only one source to be used at a time. Power of the generator should be up to 600 W.		

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2	**DETAILS OF EQUIPMENT**							
2D	*Chamber capabilities*	*c. Deposition chambers*	1. Intrinsic a-Si:H	iii.	Electrode	Type	Shower head electrode with dark space shield, compatible with both RF and VHF plasma generators	
						Size (mm)	Length ~200, width – suitable for uniform deposition on all wafers	
						Spacing (mm)	10 – 40, adjustable after opening the system	
				iv.	MFCs on gas manifold	1 H2 & 1 SiH4 with required flow rates for typical intrinsic a-Si:H deposition		
						1 for NF3 (0-500 sccm)		
						1 additional for SiH4 (0-100 sccm)		
				v.	Process pumping	Dry		
				vi.	Resident zones	On both sides of the electrode for parking wafer carrier outside the plasma region		
				vii.	View port	3		
			2. p-type a-Si:H	i.	Mode of depositio n	Stationary mode deposition with wafer carrier under the electrode		
				ii.	Electrode	Showerhead with dark space shield		
				iii.	Plasma source	13.56 MHz with 600 W capability		

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2	DETAILS OF EQUIPMENT						
2D	*Chamber capabilities*	*c. Deposition chambers*	2. p-type a-Si:H	iv.	MFCs on gas manifold	1 H2, 1 SiH4, 1 TMB, 1 B2H6 with required flow rates for typical p-type a-Si:H deposition	
						1 for NF3 (0-100 sccm)	
						1 for SiH4 (0-100 sccm)	
				v.	View ports	2	
			3. n-type a-Si:H	i.	Mode of deposition	Stationary mode deposition with wafer carrier under the electrode	
				ii.	Electrode	Showerhead with dark space shield	
				iii.	Plasma source	13.56 MHz with 600 W capability	
				iv.	MFCs on gas manifold	1 H2, 2 SiH4 with required flow rates for typical n-type a-Si:H deposition	
						1 for NF3 (0-100 sccm)	
						1 for SiH4 (0-100 sccm)	
				v.	View ports	2	
			4. ITO	i.	Mode of deposition	Moving mode deposition from top and bottom at the same time with gate valves closed on both sides of the chamber	
				ii.	2 Sputtering cathodes	1 on top & 1 on bottom; installed with a minimum horizontal separation of 200 mm	
				iii.	Material	99.999% purity ITO	
					Size (mm)	length - 125 mm; width – suitable for uniform deposition on all wafers	

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2	**DETAILS OF EQUIPMENT**						
2D	***Chamber capabilities***	***c. Deposition chambers***	**4. ITO**	iv.	1 Plasma generator	5 kW asymmetric bipolar pulsed DC, frequency range: 25 kHz to 125 kHz	
				v.	MFCs on gas manifold	2 for Argon (0-200 sccm)	
						1 for H2 (0-10 sccm)	
				iv.	Resident zones	On both sides of the electrodes for parking wafer carrier outside the plasma region. The resident zones will also have heaters mounted on bottom plate on the air side of the chamber. The design of the mounting of heaters should be such that the viton gaskets mounted on the flanges and the sputter cathodes with ITO targets do not get damaged due to heating.	
				v.	View ports	4(1 for each resident zones, 1 for each cathode)	
2E	***Automation***			i.	Scope of automation	All operations after loading of wafer carrier in the conveyor to its exit after depositions in all the chambers	
				ii.	User friendly	Control and monitoring using a display screen (e.g. PC screen) and easy to use graphical interface.	
				iii.	Flexibility	Capability to combine individual controls and monitored parameters for recipe driven processing	
						Complete monitoring of process parameters in case of complete or partial manual operation	
				iv.	Data logging	Data logging and report generation capabilities for the monitored parameters	
2F	**Layout and support structure**			i.	Support Structure	The chambers will have to be mounted on a powder coated MS channel frames and integrated in In-line configuration	

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2	**DETAILS OF EQUIPMENT**					
2F	***Layout and support structure***	ii.	Entry conveyor	The entry conveyor should feed the wafer carrier into the load lock and should accept the carrier at up to 150 ^{o}C. It should be installed in a laminar flow bench.		
		iii.	Control panels	All the controls be racked at a convenient working height		
				All the control panels for equipments linked to automation be racked close to each other.		
		iv.	Hoist	An electrically operated hoist to run over the chambers to lift the chamber lid in case of maintenance.		
		v.	Pump exhaust, water and air lines	The chilled water lines for cooling of the pumps, compressed air and gas lines, and exhaust lines will run under the chambers as per proper international codes and safety procedures. All the lines should have a common connection where the facility lines can be conveniently connected.		
		vi.	Pumps and Enclosure	The pumps and the pumping arrangement should be placed under the chambers. The system should have opaque cover in front of the pumping arrangement.		
2G	**Diagnostics**	i.	1 Residual gas analyzer installed on intrinsic a-Si:H chamber			
2H	**Wafer carriers**	i.	Contamination free in vacuum and heated conditions as assessed by RGA on a system with base pressure of 1 x 10^{-6} Torr. Also the wafer carrier should maintain flatness after its multiple use for processing.			
		ii.	Quantity	2	For PECVD on 125 mm wafers	
				2	For PECVD on 156 mm wafers	
				2	For simultaneous top and bottom ITO deposition on 125 mm wafers	
				2	For simultaneous top and bottom ITO deposition on 156 mm wafers	
				1	For deposition on glass (thickness ≤ 0.5 mm) for establishing uniformity and the layer properties on 'acceptance criteria'.	

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3	**Training and pre-dispatch inspection**	One week training will be imparted to BHEL personnel on operation, maintenance and process control at supplier's works. Pre-dispatch inspection will also be carried out by BHEL personnel.		
4	**Installation**	The system will be required to be installed at BHEL, ASSCP, Gurgaon (Near New Delhi), India. The system will be demonstrated meeting the acceptance criteria in at least 5 runs.		
5	**Documentation**	Proper operation manuals for the system including manuals for all the standard equipment installed on the system.		
6	**BHEL scope**	i. ii. iii. iv. v. vi. vii. vii	Three phase (440V) and single phase (220V) AC supply through UPS. Chilled water at 5kg/cm2 at 15 °C Compressed air at 6 kg/cm2 Air conditioned clean room of class 100,000 House exhaust NaOH Scrubber with exhaust Process gases with gas pipe lines up to the system gas manifolds Toxic gas monitoring * Vendor should indicate if any other utility is required	
7	**Warranty**	12 months from the date of Installation		
8	**Spares**	Required for 2 years trouble free operation		
9	**Safety**	Necessary interlocks for safe operation with specialty process gases. **The system should conform to international safety regulations.**		
10	**Acceptance criteria**	1.	The deposition process chambers and Isolation Chamber should be demonstrated to reach a pressure ≤ 8 x 10^{-7} Torr at 150 °C substrate temperature after 3-4 hours of appropriate heating.	
		2.	The Load Lock Chamber (LLC) should be demonstrated to reach a pressure < 1x10^{-3} Torr at room temperature with own pumping arrangement and 1 x 10^{-5} Torr with pumping through isolation chamber	
		3.	The temperature of the wafers in process chambers should be demonstrated to exceed 325 °C with the accuracy of ± 5°C. The uniformity of the temperature over the wafers should be ±5°C.	
		4.	The deposition of amorphous silicon layers should be demonstrated at both maximum and minimum electrode spacing in all PECVD chambers.	

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10	Acceptance criteria	5.	Intrinsic hydrogenated amorphous silicon layers deposited by PECVD in intrinsic chamber on Corning Eagle 2000 or equivalent glass should have state of the art properties: optical band gap (Tauc) 1.65-1.75 eV, dark conductivity $\sigma_D < 10^{-10}$ (ohm cm)$^{-1}$; photoconductivity under global AM1.5 illumination $\sigma_L > 10^{-5}$ (ohm cm)$^{-1}$. The film thickness should have uniformity ±5% over the area of 400 mm x 400 mm. The uniformity may be demonstrated on an ordinary glass.	
		6.	p^+-doped hydrogenated amorphous silicon layers deposited by PECVD in P chamber on Corning Eagle2000 or equivalent glass using diborane/TMB mixtures should have dark conductivity $\sigma_D >1x10^{-5}$ (ohm cm)$^{-1}$, bandgap > 1.6 eV –1.75 eV. The film thickness should have uniformity ±5% over the area of 400 mm x 400 mm. The uniformity may be demonstrated on an ordinary glass.	
		7.	n^+-doped hydrogenated amorphous silicon layers deposited by PECVD in n chamber on Corning Eagle 2000 or equivalent glass using SiH_4-PH_3 gas mixtures should have the dark conductivity $\sigma_D >10^{-3}$ (ohm cm)$^{-1}$. The film thickness should have uniformity ±5% over the area of 400 mm x 400 mm. The uniformity may be demonstrated on an ordinary glass.	
		8.	80 nm ITO layers deposited by sputtering in ITO Chamber should have the sheet resistance of 45 ohm/sq. and transmission > 88%. The film thickness should have uniformity ±5% over the area of 400 mm x 400 mm. The uniformity may be demonstrated on an ordinary glass.	
		9.	The transport arrangement should be smooth, snag-free and fully integrated in the automation scheme of the system. Smooth movement including transfer of the wafer carrier in the chambers.	
		10.	Automation capabilities should be demonstrated by executing the recipe driven depositions and the start up process.	
		11.	The supplier should provide list of clients and record of at least 2 successfully working custom built PECVD and sputtering equipment with the similar pressure and temperature range.	

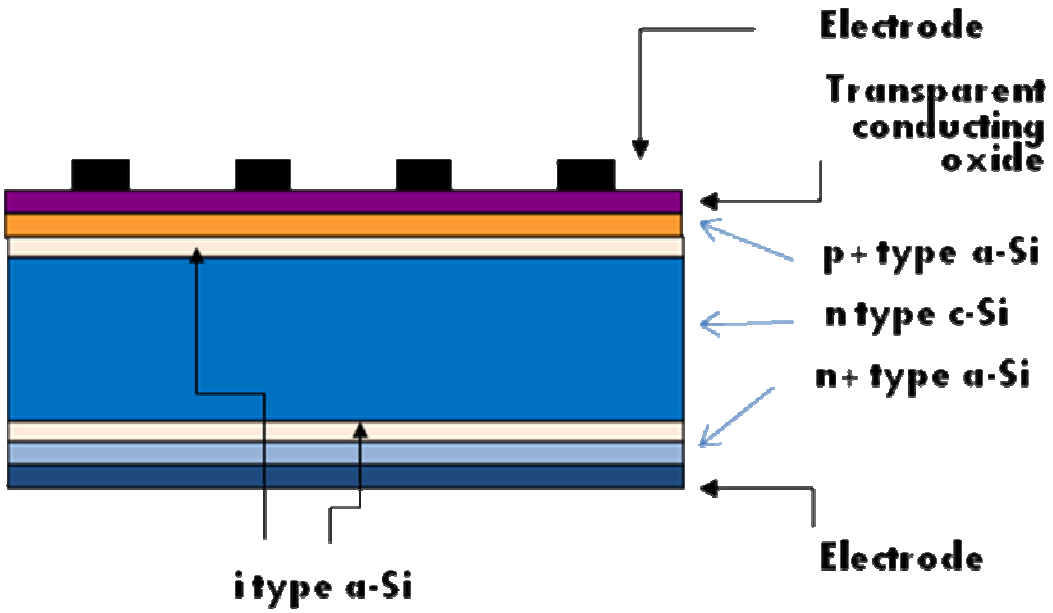

Fig. 1 Schematic of a silicon heterojunction solar cell

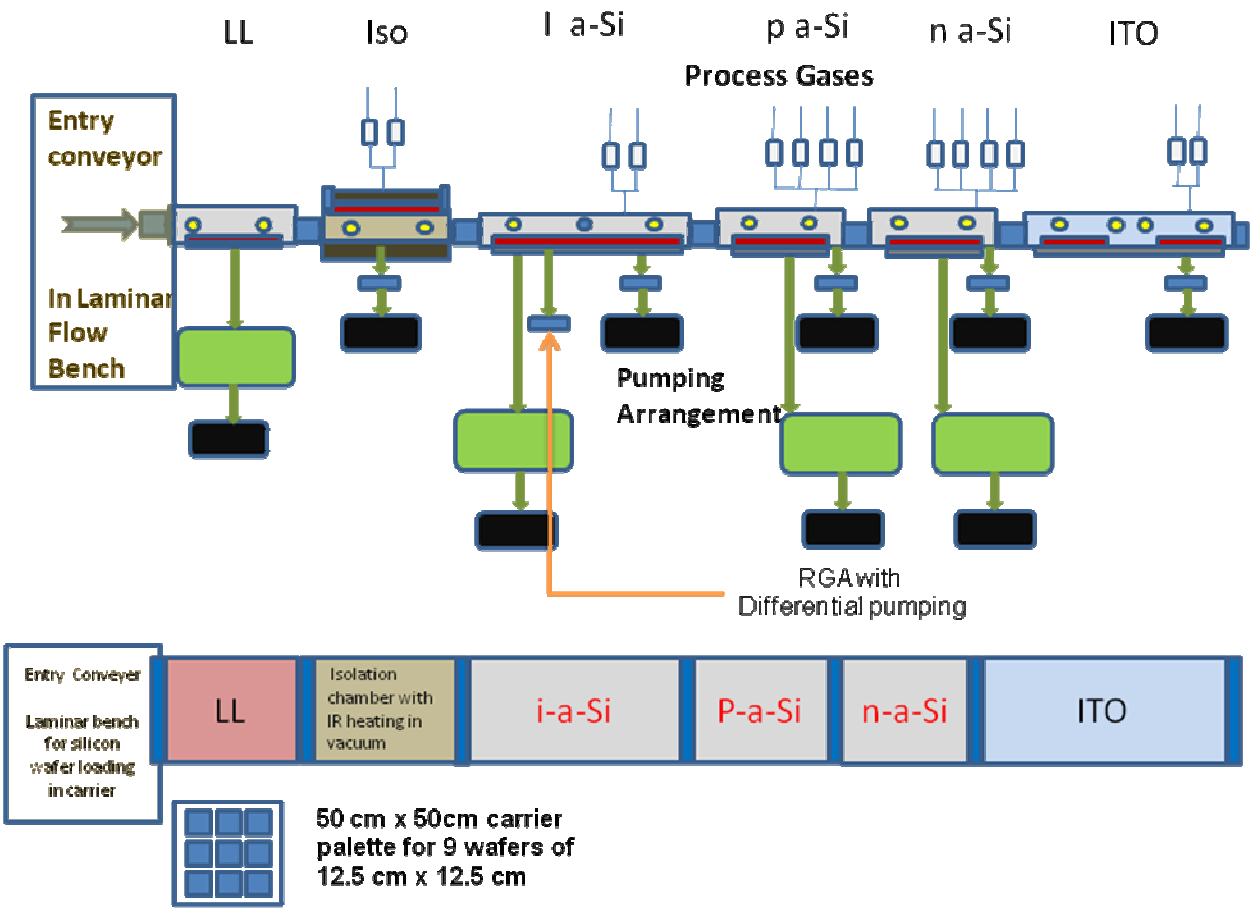

Fig. 2 Schematic of the proposed In-line System

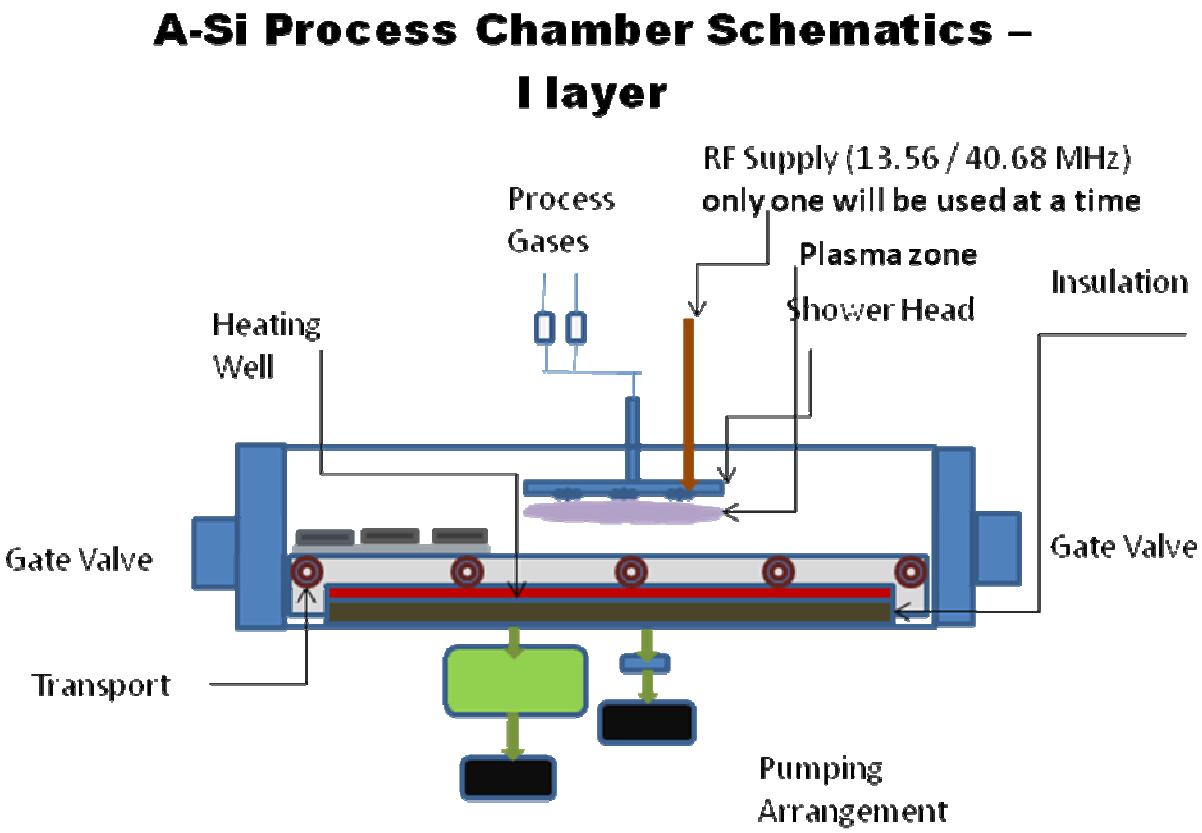

Fig. 3 Schematic of the Intrinsic a-Si Deposition Chamber

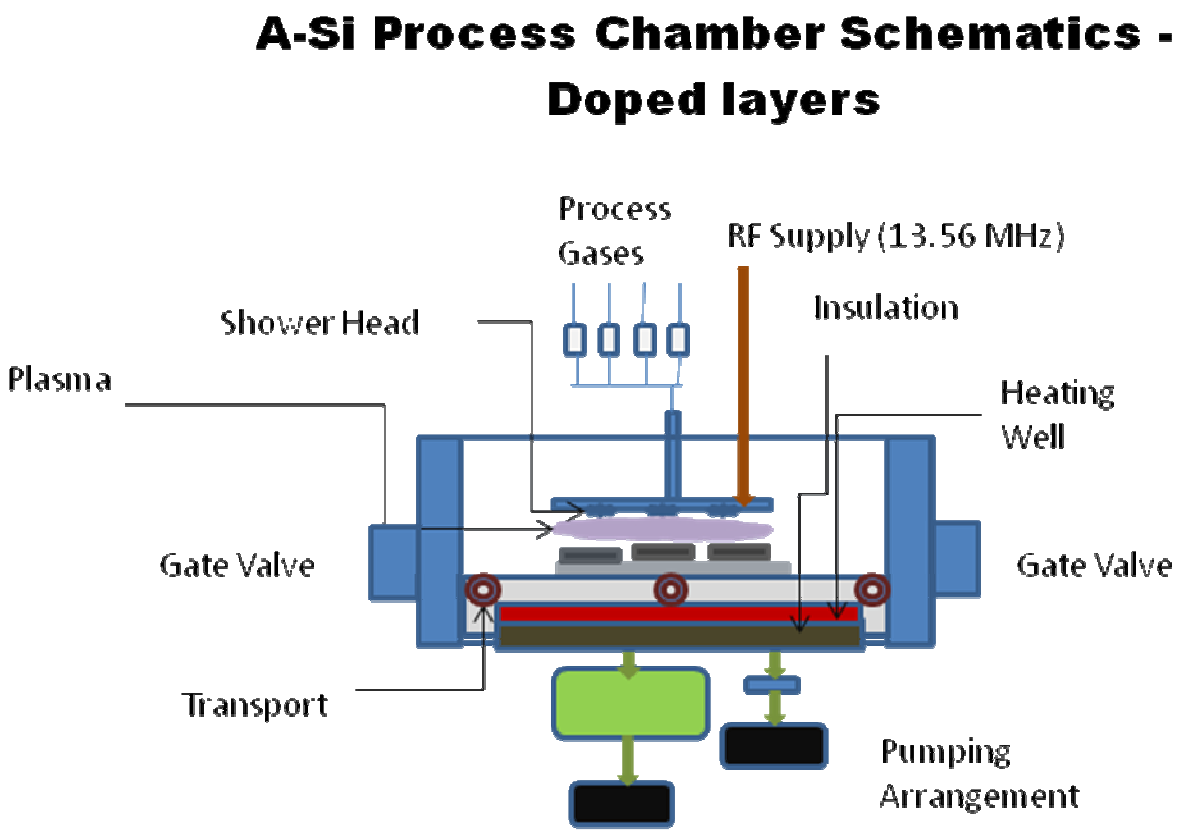

Fig. 4 Schematic of the Doped a-Si Deposition Chamber

ITO Process Chamber Schematics

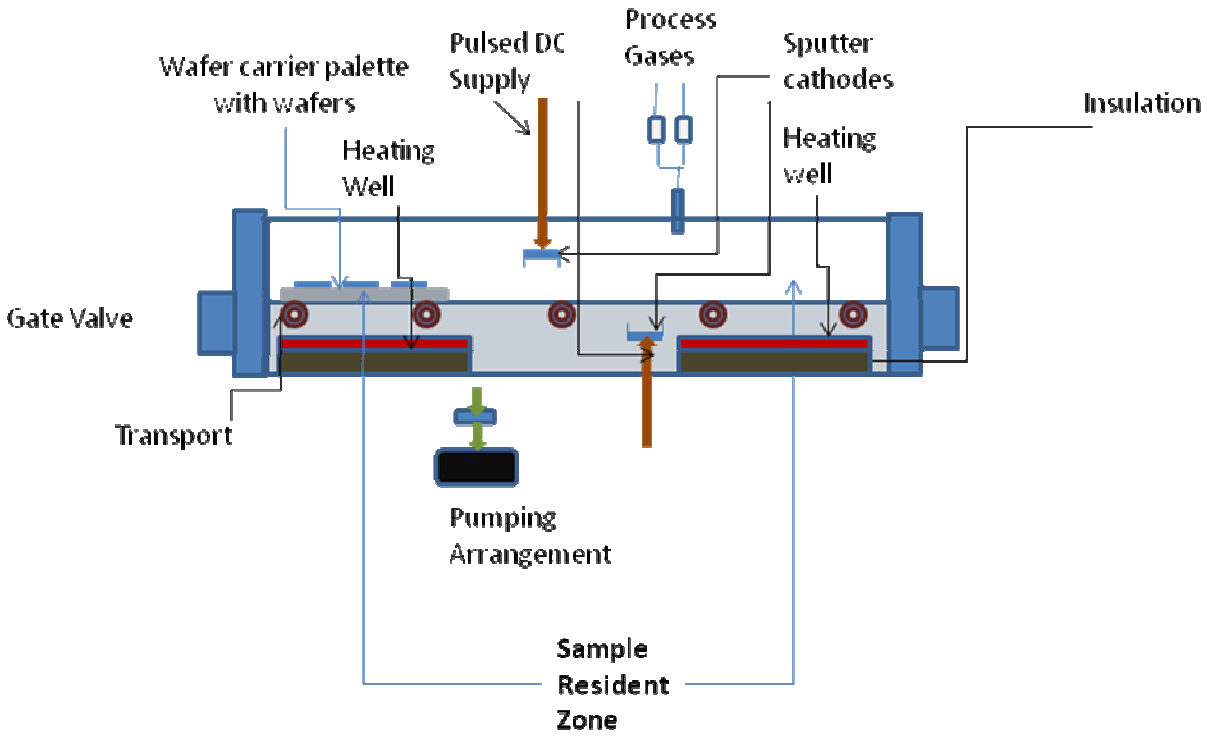

Fig. 5 Schematic of ITO Deposition Chamber