Photovoltaics

Thin film equipment from **Oxford Instruments**

The Business of Science®

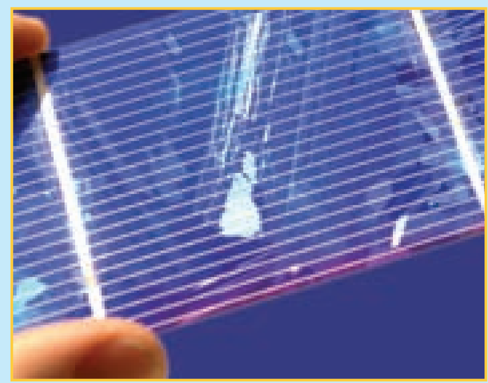
OXFORD INSTRUMENTS

Photovoltaics

Plasmalab®System100Pro **and Plasmalab**®System133Pro – Flexible systems for front end PV research

With over 20 years of experience in thin film materials processing, Oxford Instruments is ideally placed to work with customers in their development of materials and devices. Our company has the expertise to facilitate R&D, pre-production and production, through the full process as smoothly as possible.

Benefits offered by Oxford Instruments



Our tools handle substrates of various shapes and sizes. They can cluster and merge PVD, CVD, Etch and ALD technologies on the same platform, allowing multiple process steps to be carried out without a vacuum break. The cluster tool has the option of integrating a Kelvin Probe for in-situ measurement capability of material work functions and photo voltage, without vacuum break.

Other key benefits:

- High vacuum options available for handler and CVD, resulting in reduced background contamination levels
- Very high frequency and remote plasma CVD options for deposition onto damage sensitive surfaces
- Flexibility of power ramping within the software, minimising potential damage at the start of process
- High temperature substrate table options up to 950°C
- Refractive index tuning for single or multiple layer anti reflection coatings, enable improved cell efficiency
- Low pinhole density to avoid electrical shorts, particularly for larger area solar cells
- Substrate handling up to 210 mm[2] available

PlasmalabSystem133Pro

Example PV Applications

- Anti reflective coating
- Transparent conducting oxide
- Base material
- Surface texturing
- Edge isolation etch
- Passivation of interface defects

Process	Technology
SiN_x	PECVD
SiN_x	ICPCVD
Al_2O_3	ALD
Indium Tin Oxide (ITO)	PVD
ZnO / ZnO:Al	ALD
a-Si / poly Si	PECVD, VHF source
SiGe	PECVD
Etch	ICP

Flexible, powerful and reliable tools

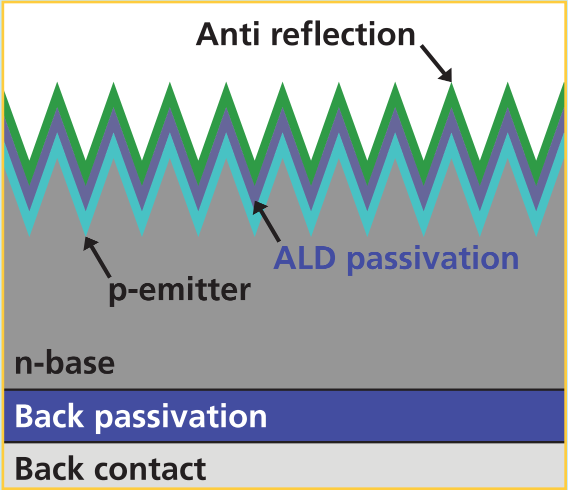
Process chambers are available as standalone modules with/without loadlocks or in a cluster configuration.

Atomic Layer Deposition (ALD)

Processes for Photovoltaic Applications

ALD Surface Passivation

Surface passivation is a major issue for crystalline silicon solar technology. The high level of built-in negative charges in an ultra-thin aluminium oxide layer deposited by plasma ALD can almost entirely eliminate electronic losses at the solar cell surfaces.



ALD Transparent Conductive Oxide (TCO)

ZnO is a transparent conducting oxide that can be deposited in a highly controlled and conformal manner by ALD.

ZnO:Al – ALD is ideally suited for controlled doping of small amounts of aluminium to reduce the conductivity.

Oxford Instruments ALD Capabilities

- Proven process capability in solar cell technology
- **FlexAL**® (load lock) and **OpAL**™ (open load) tools customised for PV applications
- Proven low damage remote plasma source whilst still producing high plasma densities for excellent film quality
- Scale up route with cassette to cassette handling

The use of alumina deposited by ALD as front passivation over n-type crystalline silicon solar cells has shown significant improvements in conversion efficiency.[1] An Al_2O_3 and SiN_x or SiO_x stack deposited by PECVD has shown to be an effective combination for passivation.[2,3]

Atomic Layer Deposition

Processes for Photovoltaic Applications

High solar cell efficiencies using a FlexAL tool

A record efficiency has been demonstrated for PERL solar cells based on n-type silicon by the application of an ultra-thin Al_2O_3 layer at the front of the solar cell.

Research carried out between the Eindhoven University of Technology (TUe) and a leading solar cell institute in Germany is shown below. All data is courtesy of TUe[1,2,3,4].

Good lifetime uniformity

Lifetime mapping of a 100 mm diameter p-type c-Si wafer, passivated with 30 nm Al_2O_3 deposited by plasma ALD (Figure 1).

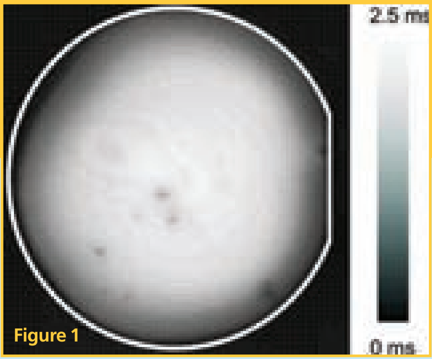


Figure 1

Low effective surface recombination velocities

Figure 2 shows injection level dependent effective lifetime of a p-type c-Si wafer passivated with Al_2O_3 deposited by plasma ALD.

Effective lifetimes of 1.2 and 2.5 ms were obtained for 10 and 30 nm thick Al_2O_3 films, respectively.

The 30 nm thick value corresponds to a S_{eff}, max of 6 cm/s.

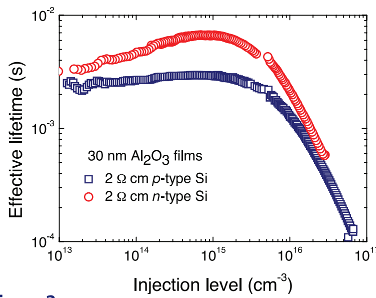


Figure 2

Excellent passivation of p-type emitters

The low recombination velocity in figure 3 shows Al_2O_3 provides a state-of-the-art level of surface passivation of p-type c-Si, for use in n-type solar cells, with an arbitrary doping level. Heavily B-doped c-Si surfaces are even more effectively passivated by Al_2O_3.

The high negative fixed charge density effectively shields the bulk minority carriers, i.e. the electrons from the p-type c-Si surfaces.

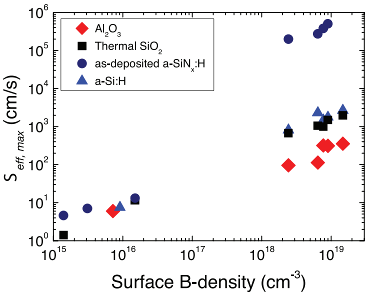


Figure 3

References

1. High efficiency n-type Si solar cells on Al_2O_3-passivated boron emitters, Jan Benick, Bram Hoex, M. C. M. van de Sanden, W. M. M. Kessels, Oliver Schultz, Stefan W. Glunz, *Applied Physics Letters 92*, 253504 **(2008)**
2. Silicon surface passivation by atomic layer deposited Al_2O_3, B. Hoex, J. Schmidt, P. Pohl, M. C. M. van de Sanden, W. M. M. Kessels, *Journal of Applied Physics 104*, 044903 **(2008)**
3. Surface Passivation of High-efficiency Silicon Solar Cells by Atomic-layer-deposited Al_2O_3, J. Schmidt, A. Merkle, R. Brendel, B. Hoex, M. C. M. van de Sanden, W. M. M. Kessels, *Prog. Photovolt: Res. Appl.* **(2008)**
4. On the c-Si surface passivation mechanism by the negative-charge dielectric Al_2O_3, B. Hoex, J. J. H. Gielis, M. C. M. van de Sanden, and W. M. M. Kessels, *Journal of Applied Physics* 104, 113703 **(2008)**

PVD of Transparent Conductive Oxide (TCO)

Processes for Photovoltaic Applications

Transparent Conductive Oxide (TCO)

Indium Tin Oxide deposition by PVD

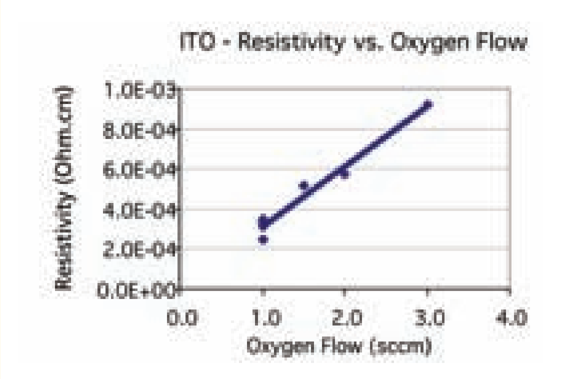
Sputter deposited ITO with resistivity down to $3x10^{-4}$ Ohm cm and optical transmission of up to 92%.

Sputter deposition is the favoured method for depositing thin layers of indium tin oxide used in many photovoltaic devices.

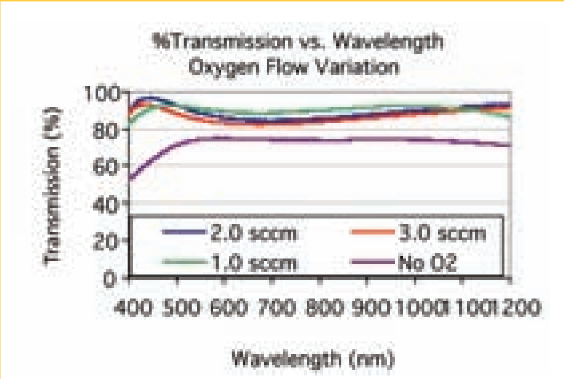
Oxford Instruments Plasma Technology has specifically developed a pulsed DC magnetron process to deposit ITO films using a typical commercially available ceramic oxide target.

Key parameters and trends such as pressure and oxygen/argon gas flow ratios have been identified. The process can be adjusted to provide films with optimum film properties.

Low resistivity down to $3.0x10^{-4}$ Ω cm is achieved while maintaining high optical transmission in the visible and near infra red spectrum at up to >90%.



Resistivity of 100 nm ITO films deposited onto thermal SiO_2



Optical transmission of ITO deposited into glass

Surface texturing by ICP etch

Black silicon surface texturing produced in the **Plasmalab**System100 ICP380 may be used to reduce light reflection losses below 2%.

Surface analysis (AES/AFM/EDX/TEM) has confirmed that the Si is still crystalline and of device quality – the needles are essentially structured crystalline Substrate.

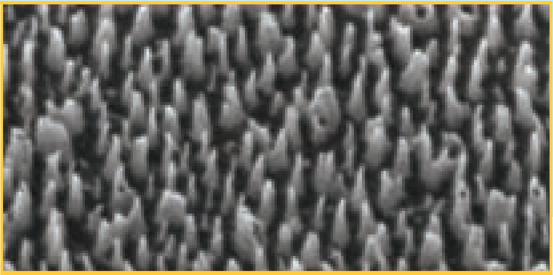


Image courtesy of Adam Williamson at X-FAB Semiconductor Foundries

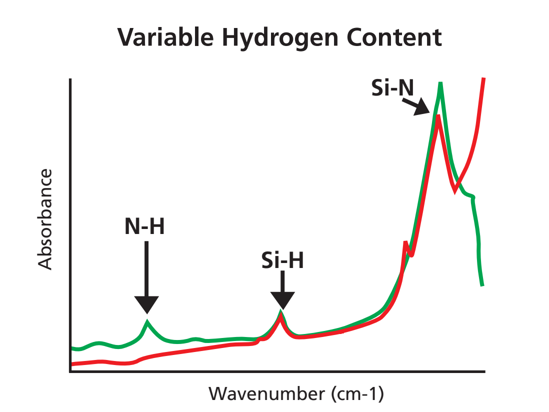
Plasma Enhanced Chemical Vapo

Processes for Photovoltaic Applications

Silicon Nitride Anti-Reflection Layer and Passivation Layers by PECVD

Up to 30% sunlight can be reflected without the use of an anti-reflection coating. Processes can be tuned to give a range of refractive indices and hydrogen content.

Refractive index tuning for single or multiple layer anti reflection coatings result in improved cell efficiency.

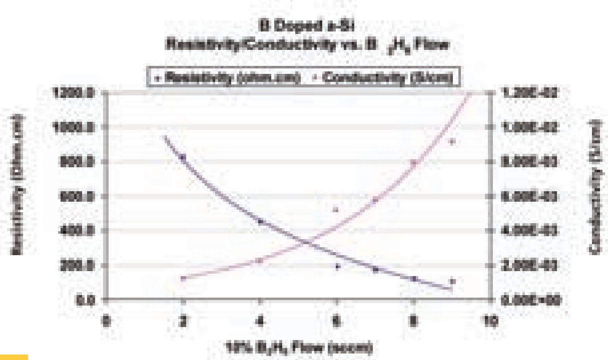


FTIR spectra of PECVD silicon nitride films deposited at 300°C

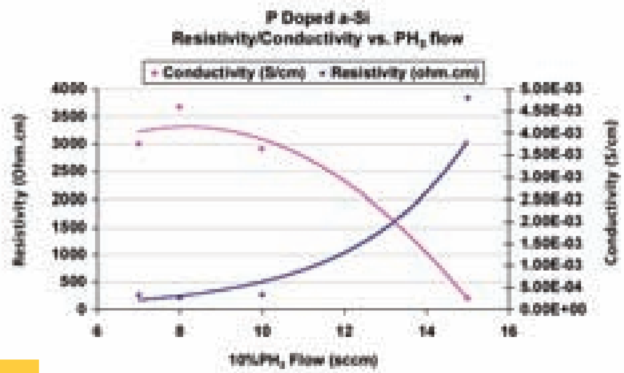
Amorphous Silicon Deposition by High Frequency PECVD

Gas chemistry or kinetics are important factors in photovoltaic applications of amorphous silicon. Oxford Instruments Plasma Technology offers a wide variation in possible process schemes that can influence not only bulk film properties but also impingement of plasma species at the surface or interface.

Various gas chemistries can be supplied and source options include RF, very high frequency RF and remote or downstream plasma.



a)



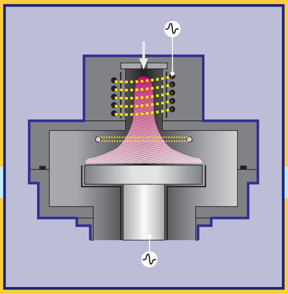
b)

Electrical properties of doped amorphous silicon a) p-doped b) n-doped

ur Deposition (PECVD)

Remote Plasma PECVD

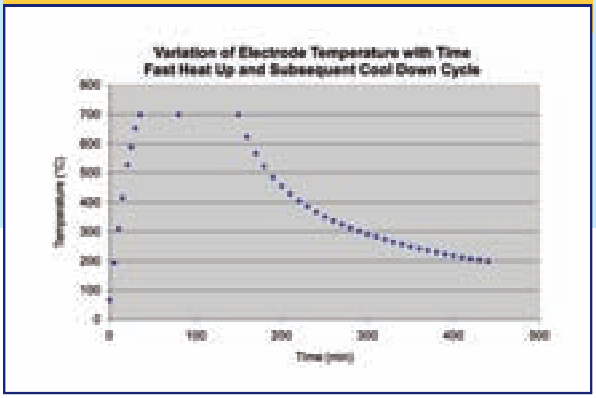
- Various plasma source options available
- High density plasma at 5 x 10^{11}/ cm^2
- Reduced surface ion damage
- Ion flux control through transmission plates (patent filed)
- High quality films deposited at reduced temperature



Hot table option

High temperature table option is available, with radiation shielding

- Incorporates a dual heater assembly to optimise temperature uniformity
- Fast ramping from ambient to 700°C in less than 40 minutes

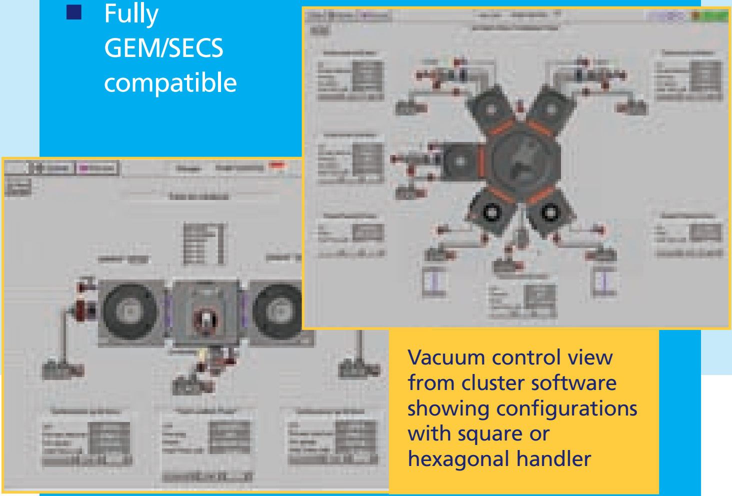


Process tool software

Oxford Instruments **PC**2000™ Software is renowned for its clarity and ease of use, making it quick to train process operators while retaining full functionality for fab managers and service staff. The front end visual interface which controls and monitors the process tool is configured exactly for the customer's system.

Process tool software benefits:

- Ability to control a tool cluster from a single interface
- Process recipes are written, stored and recalled through the same software, building a library
- Password controlled user login allows different levels of user access and tasks, from 'one button' run operation to full system functions
- Continuous system data logging ensures traceability of each wafer and process run
- Fully GEM/SECS compatible



Vacuum control view from cluster software showing configurations with square or hexagonal handler

Development and support

Process capabilities

Oxford Instruments boasts an extensive process library and new processes are continually being developed.

Process development

- The list of developed processes is continually expanding; please contact your sales representative for the latest information
- Alternative chemistries may also be available for certain materials
- Oxford Instruments provides on-going process support to its customers offering advice on developing new materials and continued access to our latest ALD process developments

Oxford Instruments Applications Laboratories

Worldwide Service and Support

Oxford Instruments is committed to supporting our customers' success. We recognise that this requires world class products complemented by world class support. Our global service force is backed by regional offices, offering rapid support wherever you are in the world.

We can provide:

- Tailored service agreements to meet your needs
- Comprehensive range of structured training courses
- Immediate access to genuine spare parts and accessories
- System upgrades and refurbishments

click onto **www.oxford-instruments.com** for more information

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- **Atomic Layer Deposition**
- **Ion Beam Etch & Deposition**
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