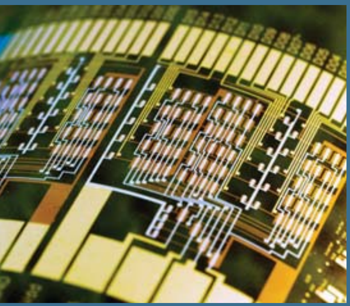
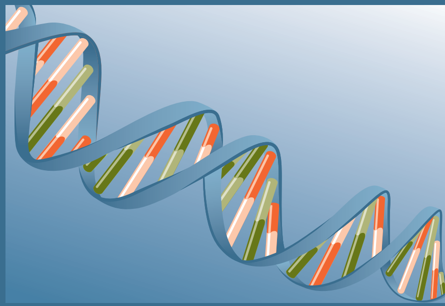
Atomic Layer Deposition

Applications & Products





CambridgeNanoTech
Simply ALD

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Atomic Layer Deposition (ALD) is capable of depositing ultra-thin films that are used in a wide variety of research and industrial applications such as semiconductor, optical, photovoltaic, and medical devices.

ALD films are sought after for their superior material properties, such as electrical, anti-bacterial, UV blocking, and anti-reflection.

Precursor cylinders

12 nm HfO_2 as a gate dielectric on a flexible substrate

Benefits of ALD

Perfect films

- Digital control of film thickness
- Excellent repeatability
- 100% film density
- Amorphous or crystalline films

Conformal Coating

- Perfect 3D conformality
- Ultra high aspect ratio (>2,000:1)
- Large area thickness uniformity
- Atomically flat and smooth coating

Challenging Substrates

- Gentle deposition process for sensitive substrates
- Low temperature and low stress
- Excellent adhesion
- Coats everything – even Teflon

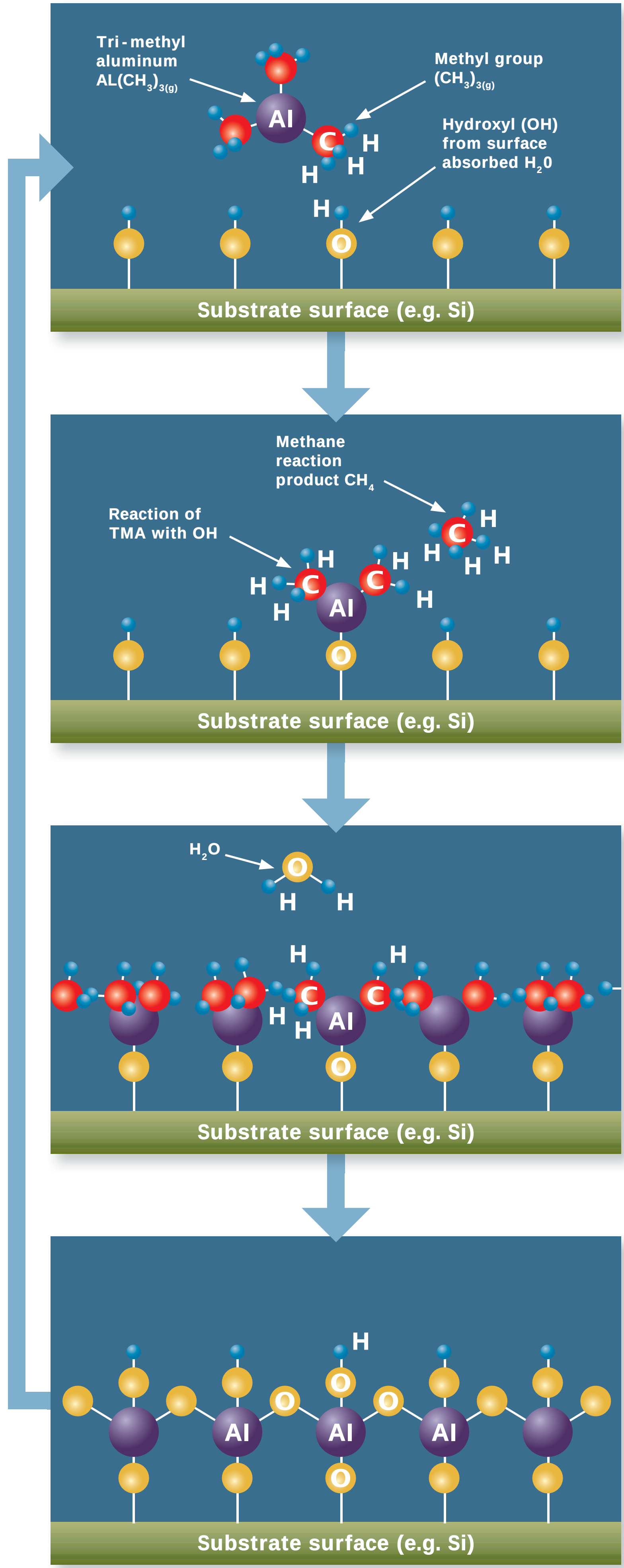
Atomic Layer Deposition (ALD) Overview

Atomic Layer Deposition (ALD) offers precise control of depositions down to the atomic scale. It is used to deposit nanometer thin films with special properties. The principle of ALD is based on sequential pulsing of chemical precursor vapors, forming one atomic layer during each pulse sequence. This generates pinhole free coatings that are extremely uniform in thickness, even deep inside pores, trenches, and cavities. A wide variety of thin films can be deposited using gas, liquid, or solid precursors.

Cambridge NanoTech ALD systems are engineered for a wide variety of applications from research to high-volume manufacturing. These systems deposit precise, conformal and ultra-thin films on multiple proven substrates. Their simplified system designs yield low startup and operating costs with excellent uniformity.

Science of ALD

- A single ALD cycle consists of the following steps:
    - **1** - Exposure of the first precursor
    - **2** - Purge or evacuation of the reaction chamber to remove the non-reacted precursors and the gaseous reaction by-products
    - **3** - Exposure of the second precursor – or another treatment to activate the surface again for the reaction of the first precursor
    - **4** - Purge or evacuation of the reaction chamber
- A perfectly conformal, ultra-thin film is formed
- In the example adjacent, precursors Trimethylaluminum (TMA) and H_2O are alternately pulsed to deposit an Aluminum Oxide (Al_2O_3) film



ALD for Research

Cambridge NanoTech's ALD research systems are designed by ALD scientists and are built for maximum experimental flexibility and value. With universal precursor delivery systems, researchers can use solid, liquid or gas chemistries in any precursor port. Many options to choose from including ozone generators, in-situ monitoring and various configurations. As always, our team of ALD experts are ready to answer your recipe development and film characterization questions. Over 170+ published academic papers feature research performed on Cambridge NanoTech's Savannah thermal ALD system and Fiji plasma ALD system.

Research Systems

Savannah™

- Compact, inexpensive system for research
- Available with three chamber sizes: 100mm, 200mm and 300mm
- Two deposition modes: Continuous Mode for high speed deposition and Exposure Mode™ for ultra high aspect ratio (>2,000:1)
- Substrate temperature: 400˚C-450˚C
- Uniformity (Al_2O_3): <1% (1σ)
- Up to 6 precursors
- Optional glovebox interface, ALD Booster™ for low vapor pressure precursors

Fiji™

- Plasma system for research
- 200mm substrate
- Three deposition modes: Plasma Mode, Continuous Mode for high speed deposition and Exposure Mode™ for ultra high aspect ratio (>2,000:1)
- Substrate temperature: 500˚C (optional to 1,000˚C)
- Up to 6 precursor lines and up to 6 plasma gas lines per chamber
- Uniformity (Al_2O_3): 1.5% (1σ)
- In-situ analysis: ellipsometry, optical emissions spectroscopy, mass spectrometry, etc.
- Optional packages to augment performance; Dual Chamber, High Temp, Cluster Tool, Wafer-Plus for larger samples, and No-Plasma
- Optional load lock

ALD for Manufacturing

Uniformity over large substrates, reproducibility and low temperature deposition make ALD an ideal candidate for the next generation of large-scale manufacturing thin film technology. Cambridge NanoTech has perfected ALD as a manufacturing-grade technology by simply scaling up the process and implementing it into automation lines and cluster tools around the world. Manufacturers that have integrated Cambridge NanoTech ALD systems have seen increased product quality and reliability as well as decreased operating costs and a greener footprint as compared to previous coating technologies.

Manufacturing Systems

Phoenix™

- Batch manufacturing system
- Substrate size

  Up to 370 x 470 mm (GEN 2.5)

  - 100 wafers - 100 mm (cassette)
  - 100 wafers - 150 mm (cassette)
  - 100 wafers - 200 mm (cassette)
  - 17 wafers - 300 mm (cassette)
- Deposition temperature: 85-285˚C
- Uniformity (Al_2O_3): <2% (1σ)
- Ideal for pilot production or small batch manufacturing
- Low maintenance requirements

Tahiti™

- Large area manufacturing system
- GEN 4.5 substrate, may be scaled up
- Deposition temperature: 250˚C
- Uniformity (Al_2O_3): <2.5% (1σ) within plate
- Stacked chamber architecture
- Four-hour maintenance
- Automation-ready and easily integrated with existing manufacturing network
- Industrial-grade touch display

Applications

Cambridge NanoTech delivers turnkey ALD products to a large number of markets and applications. Researchers and technologists are taking advantage of the unique benefits that are only simultaneously available with ALD, such as low temperature processing, uniformity, reproducibility, strong adhesion, and low stress.

Cambridge NanoTech recognizes that the key to developing new applications and realizing ALD as a proven technology is a strong foundation of exceptional research and support. With a fully equipped R&D lab and a staff of PhD scientists that are completely dedicated to advancing the science of ALD, Cambridge NanoTech has carefully cultivated a robust base of

Optical

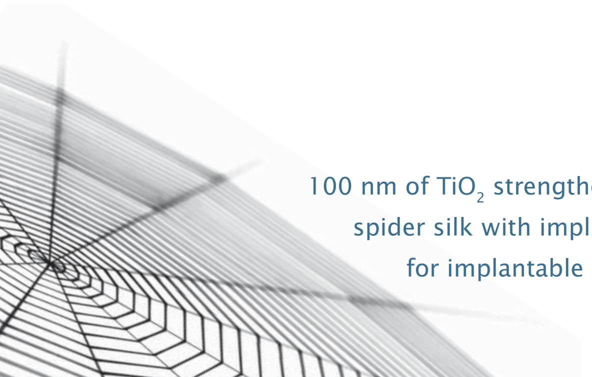
Antireflection
Electroluminescence
Encapsulation barriers
Integrated optics
OLED passivation
Optical filters
Photonic crystals
Transparent conductors

Nanostructures

AFM tips
Around particles
Inside pores
Nanotubes

Energy

Batteries
Catalysis
Fuel cells
Solar cells



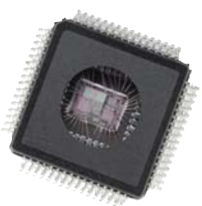
100 nm of TiO_2 strengthens spider silk with implications for implantable biomaterials

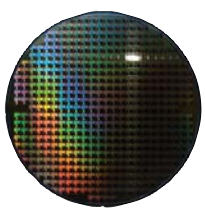
ALD knowledge. This expertise is applied to assist our customers and partners with the most demanding challenges in ALD.

Because of strong roots in ALD research, Cambridge NanoTech has exceptional access to novel ALD applications and has enjoyed nurturing many of these extraordinary applications to maturity. The transition from serving academic customers to manufacturing customers has been a completely organic process and is a product of the ALD experts at Cambridge NanoTech working closely with industry partners, leading universities, and key customers.

Electronics

Diffusion barriers
DRAM
Gate dielectrics
Gate electrodes
Magnetic heads
MEMs
Metal interconnects
Multilayer-capacitors
RFID





Biomedical

Antibacterial
Biocompatible
DNA sequencing
Drug delivery
Implantable devices

Other applications

Anti-corrosion
Anti-stiction
Chemical
Etch resistance
Internal tube liners
Magnetic
Roll to roll

Cambridge NanoTech

Cambridge NanoTech was founded in 2003 by Dr. Jill Becker after she completed a Ph.D in Chemistry at Harvard University under the supervision of Professor Roy Gordon. Cambridge NanoTech is credited with simplifying the ALD process, a feat that has allowed us to design compact, cost-effective systems, which have quickly become the standard in the ALD academic research community. Since 2004, Cambridge NanoTech has released cutting-edge ALD research systems and has scaled up the ALD process with the release of ALD manufacturing systems that have been successfully integrated with multiple automated production lines around the world.

Coating DNA with 50nm of Al_2O_3 may provide cost effective diagnostic sequencing

1962

ALD is invented by V.B. Aleskovskii

1974

ALD is patented by T. Suntola

2003

Dr. Jill Becker completes Harvard Ph.D. in Chemistry and founds Cambridge NanoTech

2004

First product, Savannah ALD research system is released

2005

Cambridge NanoTech sets sights on applying ALD principles to manufacturing tools

2005

Within first 24 months of release 50 Savannahs are sold

2006

Cambridge NanoTech starts building staff of in-house Ph.D. research scientists

Cambridge NanoTech is completely dedicated to ALD by advancing the science, making the technology more accessible, and pursuing our own in-house research. We provide a complete ALD solution including the industry's best support, established access to chemical suppliers and products that are turnkey and operational within hours of delivery.

Cambridge NanoTech has continued to contribute to the ALD community by publishing ALD research, developing new recipes and collaborating with customers on breakthrough research. In addition, on our website we host an in-depth Knowledge Center; a comprehensive database of ALD theses, abstracts and papers by our customers that are housed, cataloged and easily searched to help determine the direction of your research or if an application is production-ready.

2009

Fiji plasma ALD system is released

2010

Cambridge NanoTech develops large area ALD system for solar cell manufacturing

2008

Phoenix batch production tool is released

2009

Tahiti released for large area manufacturing

2011

Cambridge NanoTech now has over 250 research and production ALD systems in the field

Going Green with Cambridge NanoTech

ALD is projected to have a positive impact on the global greening initiative because it is a precise process that uses much less raw material than other coating technologies. In addition, ALD is expected to produce sustainable energy products, such as solar cells.

Less is more

In general, gas phase processing is more environmentally benign than other processing methodologies. ALD also uses less raw material than other thin film technologies and the ultra-thin ALD films perform just as well as thicker films. For example, films as thin as 25 nm have shown excellent electrical properties on organic substrates. In addition to using less precursor materials, Cambridge NanoTech's ALD systems require much less pressure and energy to deliver the precursors from their cylinders to the chamber and substrate.

Precision eliminates waste

The excellent large-area uniformity, repeatability and high purity offered by ALD is much more precise than other coating technologies, yielding less scrapped material because of manufacturing impurities. The products manufactured with ALD-coated substrates are also projected to have a better reliability and a longer lifetime because of the precision and conformal coatings provided by ALD. ALD is also predicted by experts to have a "maximizing" effect on everyday products such as displays that derive energy from sunlight.

Organic Electronics

Recent advances in organic electronics include varied device architectures, increasingly complex circuitry, reliable fabrication methods, and new semiconductors. Unlike their inorganic, metal counterparts, organic electronics are carbon-based and are used to fabricate products that are lighter, more flexible, and less expensive. ALD enables the incorporation of organic electronic components in products including OLED displays, flexible electronic paper, thin film transistors, photovoltaics, photodetectors and RFID tags. Organic electronics are also much cheaper to manufacture and are estimated to cost 1 cent/cm2 compared to 1 dollar/cm2 for traditional silicon substrates.

Cradle to Grave

Not only will organic products made with ALD use less materials and energy during their fabrication but these products also require less energy to run during their useful life compared to those made with inorganic electronics. In addition, they don't require the materials of concern that have typically been used in traditional electronics such as harsh solvents, arsenic, phosphine, lead and mercury, providing for easier disposal and less of an environmental impact.

ALD Film Dielectric Constants

ALD Film	Min. Practical Deposition Temperature °C	Dielectric Constant (k)
Al_2O_3	>25	6-9
SiO_2	>100	3.9
HfO_2	>80	>15
TiO_2*	>80	>20
Ta_2O_5	>100	>22
ZrO_2	>80	>14

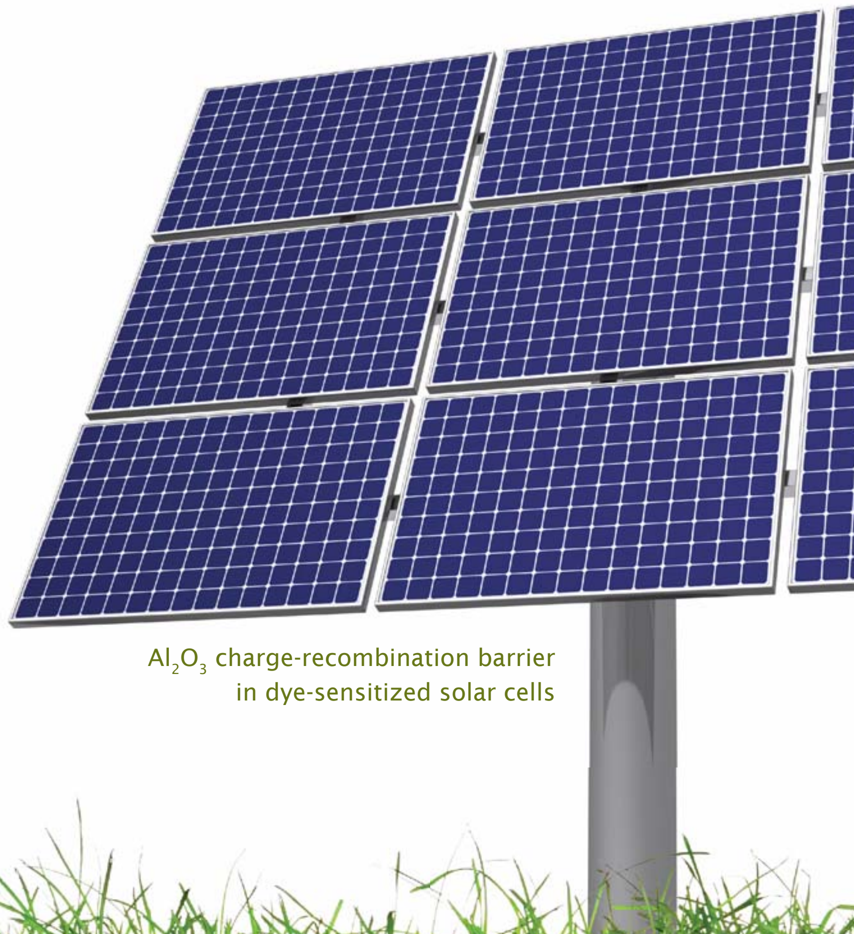
* Deposition using titanium tetrisopropoxide and water.

Environmental & Human Health

Recent research at North Carolina State University explored applying ALD to a variety of environmental and human health issues. Scientists used ALD to coat complex nanoscale structures with thin films, providing implications for a host of health applications. The work was done by depositing ALD films on nanoporous alumina membrane, which was chosen as a platform for this research because of its biomimicry and similarity to filters found naturally in the human body.

For example, the researchers deposited a five-nanometer film of Zinc Oxide on a nanoporous aluminum filter and observed that the treated filter was shown to neutralize two common pathogens: E. coli and Staphylococcus aureus. This research may be used to develop effective, low-cost, point-of-use water purification devices, which would be vital to developing countries or in emergency situations to give people access to safe drinking water.

Additionally, the researchers coated a nanoporous aluminum membrane with eight nanometers of Platinum and observed decreased cell viability and imperviousness to contamination after being exposed to platelet-rich blood. These properties are appealing for applications in implantable devices and biosensors, since protein contamination and cell adhesion can impede transport of biological molecules between the device and the surrounding tissues.



Al_2O_3 charge-recombination barrier in dye-sensitized solar cells

Customer Testimonial

We decided to purchase the Fiji system for a number of reasons. Overall, we believe Cambridge NanoTech offers the best value for the money. In terms of performance, the dual chamber system provides excellent process versatility, more functionality, and fits in a very small footprint as compared to competitive products. Plus, Cambridge NanoTech has an excellent reputation in the ALD community. The team at Cambridge NanoTech provided us with tremendous support during the start-up phase as well as superb training. They are very accommodating and continue to provide follow-up support as needed.

—Alan Blake, Process Engineer
Tyndall National Institute, Ireland

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www.cambridgenanotech.com

Worldwide Support

Cambridge NanoTech has a full staff of Ph.D. support scientists that are dedicated to providing our customers with a complete ALD solution including applications support, recipe development, research collaboration, and system integration. With established sales and support locations worldwide, we're proud to provide the best support in the industry.

Headquarter Locations:

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Cambridge NanoTech Sales and Support Locations

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