Extending product lifetime with ALD moisture barrier

Whitepaper

EXTENDING PRODUCT LIFETIME WITH ALD MOISTURE BARRIER
Atomic Layer Deposition (ALD) is a thin film technology that enables new and highly competitive products. Typical applications of ALD require nanometer-thick, pinhole-free, and totally conformal thin films on different shapes and geometries. With ALD, it is possible to create moisture barriers that are thinner and keep humidity and vapors out better than other hermetic packaging options, which makes it a winning moisture barrier for many industries, especially the semiconductor industry. ALD moisture protection can be applied in different phases of the production process: wafer-level, chip-level, package or module level, and/or assembled PCB level.
ALD is a chemical vapor deposition (CVD) method, which was initially developed for manufacturing nanolaminate insulators (Al₂O₃/TiO₂) and zinc sulfide (ZnS) phosphor layers for thin film electroluminescent (TFEL) displays. Large-scale production of these displays started in the mid-1980s, mainly thanks to ALD. The unique properties of ALD coating, together with the high repeatability, were the main factors leading to successful industrial production.

ALD is based on surface controlled thin film deposition. During coating, two or more chemical vapors or gaseous precursors react sequentially on the substrate surface, producing a solid thin film. Most ALD coating systems utilize a flow-through traveling wave setup, where an inert carrier gas flows through the system and precursors are injected as very short pulses into this carrier flow. The carrier gas flow takes the precursor pulses as sequential “waves” through the reaction chamber, followed by a pumping line, filtering systems and eventually a vacuum pump.
KEY BENEFITS

• True nanometer scale film thickness
• Superior, pinhole-free moisture barrier
• Perfect for large-area substrates and complex 3D objects due to high conformality
• A highly repeatable and scalable process
• Suitable for new materials and structures
ALD MOISTURE BARRIER

THE ULTIMATE PROTECTION AGAINST MOISTURE

ALD is truly the ultimate moisture barrier. With ALD, it is possible to create moisture barriers that are thinner and keep humidity and vapors out better than other hermetic packaging options. ALD offers the only way to create conformal ultra-thin protective coatings on surfaces with high aspect ratios and complex 3D shapes. ALD is also a great solution for encapsulating sensitive devices enabling longer product lifetimes and wiser use of raw materials. The ultra-thin ALD moisture protection can be applied in different phases of the production process: wafer-level, chip-level, module or package level, and/or PCBA-level.

Beneq has been researching and producing ALD-based moisture barrier solutions for years providing solutions to leading manufacturing companies in MEMS, power semiconductors, RF, LED, and III-V semiconductors. We meet the varying needs and requirements of these customers by offering ALD equipment solutions for all production stages from wafer-level to PCBs.
FAST AND COST-EFFICIENT

Wafer-level ALD solutions offer an easy and fast way of creating an ALD barrier, which can be applied automatically with cluster tools. The latest wafer ALD equipment provide high throughput, low operating cost and competitive up-time. Wafer-level ALD moisture barrier solutions can be used for example in LED industry to extend the lifetime of LED chips. Wafer-level is cost-effective and often provides sufficient protection against moisture.

FOR ULTRA-SENSITIVE SOLUTIONS

With critical components and ultra-sensitive electronics, it makes sense to apply multiple ALD coatings in several phases of the production process to ensure impeccable protection against moisture. For example, unlike wafer-level moisture protection, chip-level also protects the side-walls of the chip against moisture.

REDUCED MAINTENANCE COSTS

It’s also important to take into consideration that with some applications maintenance costs can be extremely high and repair difficult to perform. With applications like these, ALD coating applied in several phases, or in the later phases of the production, pays itself back during the lifetime of the application – even if the initial costs are higher than only using the wafer-level protection.
DIFFERENT APPLICATIONS, DIFFERENT NEEDS

The requirements for moisture barrier always depend on the application. Food packaging requires much less protection than electronics and semiconductor components. However, even within those applications there are big differences: a circuit board, for example, requires less protection than an OLED display.

To answer the question when to apply ALD moisture protection, we need to look at the application and the requirements of the application in question. Depending on the product and the production process, ALD moisture protection can be applied in one or several stages of the production. Each product is unique, and the customer is always the expert of their own product, which is why the decision of when to use ALD moisture barrier is always made together with the customer based on their needs and requirements.
**WAFER-LEVEL MOISTURE BARRIER**

One the world’s leading LED manufacturers needed help with improving the moisture barrier of their high brightness LED chips. The chips were not meeting the lifetime specification of the product due to oxidation caused by moisture. Traditional coating technologies were not sufficient to prevent the oxidation.

Beneq applied wafer-level moisture barrier to the chips and the problem was solved. The lifetime specification of the LED chips was met with Beneq’s solution.

**CHIP-LEVEL MOISTURE BARRIER**

A big player in the power semiconductor device industry needed help with a device that did not pass the Highly Accelerated Stress Test (HAST), which tests the device performance after long-term, high-humidity, high-temperature exposure. The side walls of the device needed to be protected against moisture.

A conformal ALD Al₂O₃/TiO₂ multilayer moisture barrier was deposited on the chip-level with the Beneq P400A high-capacity batch ALD system. To enable coating with the chips on dicing frames, low-temperature was used.
PACKAGE-LEVEL MOISTURE BARRIER

High-brightness LEDs by one of the world’s leading LED manufacturers were experiencing silver reflector corrosion, which was leading to decreased light output, increased heat build-up and reduced product lifetime. The traditional methods for LED packaging were not sufficient to prevent the corrosion.

Beneq solved the issue by using ALD to coat the semi-finished wire-bonded LED assemblies before sealing the package to protect the silver surface with an nSILVER-type ALD coating.

PCB-LEVEL MOISTURE BARRIER

A supplier of personal safety monitoring electronics needed to improve the protection of their PCBAs against moisture. Traditional parylene coating was not sufficient for the PCBs with moisture sensitive components. The component function was compromised by penetrating moisture, which had led to reduced device lifetime.

Beneq developed a production scale low-temperature ALD moisture barrier solution to provide the PCBAs a high-quality solution against moisture.
MOISTURE BARRIER FOR ELECTRONICS AND SEMICONDUCTOR COMPONENTS

The unmatched quality of ALD coatings makes it the winning moisture barrier for the steadily growing electronics and semiconductor industry. The growth of semiconductor industry has been driven by e.g. IoT, 5G, automotive applications and the increasing amount of semiconductor technology in devices used for working, communicating, manufacturing, health care, and wellbeing.

These new applications and products require ultra-thin, high-quality coating solutions to answer the need for high-conformality and impeccable moisture protection. ALD answers this need by improving the performance and durability of the leading semiconductor applications with an extremely thin, pinhole-free moisture barrier. ALD has shown great promise in the emerging semiconductor technologies and is expected to play a crucial role in advancing the industry.
IDEAL SOLUTIONS FOR ALD IN EMERGING MORE THAN MOORE MARKETS

Beneq has been working on increasing the capacity of ALD equipment and moving ALD from research laboratories to industrial production for years now. Beneq’s products provide an optimal solution for high performance ALD on wafers in industrial applications, such as optical coatings, insulators and barriers, and high-volume manufacturing of wafer coatings in the semiconductor and MEMS industry. They have been designed with special focus on emerging More than Moore semiconductor markets, such as Power and RF devices, RF and Piezoelectric MEMS, MEMS sensors and actuators, image sensors, LED, and OLED. Beneq’s solutions have enabled completely new innovative products and coatings that have not been possible in industrial scale before.
EXAMPLE: ENCAPSULATION OF OLED MICRODISPLAYS

Organic Light-Emitting Diode (OLED) devices, such as VR glasses, are extremely sensitive to oxygen and moisture. Thin film encapsulation is considered to be the best method for protecting these devices. Protection of OLED displays against moisture is one of the most promising but also one of the most challenging applications of moisture barrier technology. And this is exactly where the electronics industry is moving: towards flexible solutions with flexible displays. Beneq developed an ALD-based OLED encapsulation already in 2009 and has since found more and more applications for it.
CUSTOMER CASE:

One of the leading Asian OLED microdisplay manufacturers needed thin-film encapsulation of the highest quality for their devices to guarantee long device lifetime. A typical encapsulation requirement is a Water Vapor Transmission Rate (WVTR) smaller than $1 \times 10^{-6} \text{ g/(m}^2 \text{ day)}$, which is challenging to achieve with conventional thin-film deposition methods, due to low process temperature requirements.

Beneq’s solution for the OLED microdisplay manufacturer enabled a 50 nm thick $\text{Al}_2\text{O}_3/\text{TiO}_2$ nanolaminate coating, which was deposited at a low temperature of 90°C using a fully automated Beneq TFS 200 ALD system integrated to the customer’s manufacturing cluster.
THE HOME OF ALD

Beneq® is the Home of ALD. The Beneq factory is where atomic layer deposition was applied in industrial production for the first time. Our Atomic Layer Deposition solutions improve the performance and durability of electronics and optics. They are the invisible advantage in leading semiconductor, IoT, 5G and automotive applications. No matter what the shape of your product or the kind of ALD coating you need to improve its performance, Beneq ALD equipment and coating services make it thinner, faster and pixel perfect every time.