picosun
AGILE ALD

APPLICATION NOTE

Conformal ALD coatings for LED phosphors protection

INTRODUCTION

- **Picosun's Atomic Layer Deposition (ALD) technology offers a revolutionary way for surface functionalization and modification of powders and particles.**
- **For moisture-sensitive LED phosphors, ALD coating forms hermetic encapsulation around each particle to protect against ambient air and moisture.**

ADVANTAGES OF PICOSUN'S ATOMIC LAYER DEPOSITION SOLUTIONS FOR LED PHOSPHORS MANUFACTURING

- ALD forms uniform, conformal and pinhole-free coating on each phosphor particle individually, without agglomeration or sintering.
- Ultra-thin, only nanometer-scale ALD films are practically massless and dimensionless so they keep the particle size, weight and surface area close to original.
- ALD films are so thin they do not decrease the amount of light emitted by the phosphors, or their quantum efficiency.
- ALD films can be deposited on both hydrophilic and hydrophobic surfaces, ceramic, metallic, and organic particles with sizes down to sub-micron range.
- ALD is a gentle, gas-phased coating method and process temperatures are moderate, which eliminates the risks for microscopic surface damage to the coated substances and makes the method suitable also for sensitive materials.
- Endless surface protection and modification possibilities can be achieved just by changing the ALD film material and/or thickness. This can give particles completely new physical, chemical, electrical, and optical properties. Also nanolaminates for further enhanced surface protection, and mixed or doped films can be manufactured.
- If needed, ALD can be combined with several other surface treatment and film deposition methods.
- Picosun's turn-key powder coating solutions are mature and production-proven in various manufacturing environments such as optoelectronics and pharmaceuticals industries.
- Optional vibrational module in Picosun's ALD coating equipment guarantees fully conformal coating on large batches up to 100 g range (depending on coated surface area) without agglomeration or sintering. Unlike with competing methods such as fluidized bed technique, Picosun's technology ensures no damage to the ALD film or the particle surface.

RESULTS

Examples of Picosun's ALD moisture barriers

- **Example 1**
  - Reference: 330 nm PECVD SiO_2: water vapor transmission rate (WVTR) ~10^{-3} g/m^2/d.
  - Picosun's 40 nm ALD barrier layer: WVTR 2 x 10^{-5} g/m^2/d (customer data, limited by measurement time).

➔ **ALD film exhibits 100 x higher performance at 1/8 film thickness.**

- **Example 2**
  - Reference: PEN/PET: WVTR ~10^{-1} g/m^2/d.
  - Picosun's ALD nanolaminate: WVTR 4-5 x 10^{-5} g/m^2/d (customer data, limited by time and device glue life, not ALD film barrier properties).

  ➔ **ALD film exhibits 2000 x higher performance compared to reference material.**

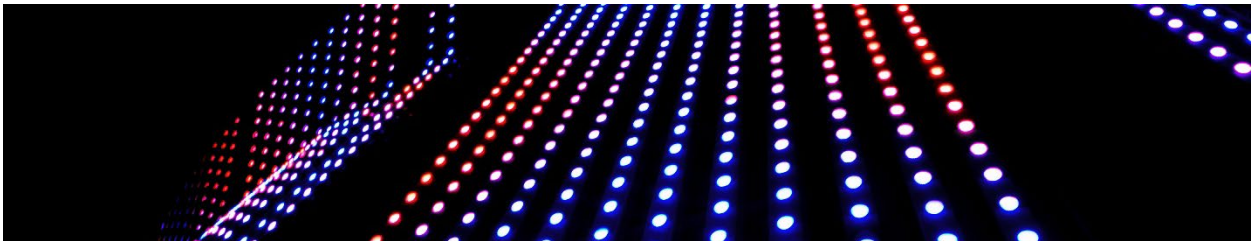
- **Example 3**
  - Coated surface: LED phosphor powder, immediately unstable in air.
  - Coating each grain of phosphor with a perfectly conformal ALD film of less than 40 nm thickness hermetically seals the grains' surface.

  ➔ **ALD-coated phosphor has lifetime over 1400 hrs at 100 % RH / 100 °C.**

CUSTOMER REFERENCE

Picosun is referred to in a European patent application(*), where Picosun's powder coating ALD technology is utilized to coat LED phosphors with protective barrier films.

(*)Patent app. no. EP3194528



ABOUT PICOSUN AND ALD

Picosun is the leading provider of AGILE ALD® thin film coating solutions for global industries and prominent research organizations. PICOSUN® ALD equipment are used in wafer-based semiconductor industries such as IC components, LEDs and sensor manufacturing, powder materials processing, and coating of macroscopic 3D items such as machinery parts, medical implants and devices, watch parts and coins.

Picosun's history reaches back over four decades, to the invention of the ALD technology itself. Our exclusive dedication to ALD and the unmatched, Ph.D level expertise of our team make us your ideal partner in all your thin film coating needs!

ALD is the most sophisticated thin film coating method of today, and a key enabling technology in modern microelectronics industries. Ultra-thin ALD films have the highest conformality and uniformity down to nanometer-scale surface details and, thanks to the surface-controlled, self-limiting film growth mechanism, they are dense, crack- and pinhole-free. Several ALD materials are also intrinsically biocompatible and thus optimal for medical applications.

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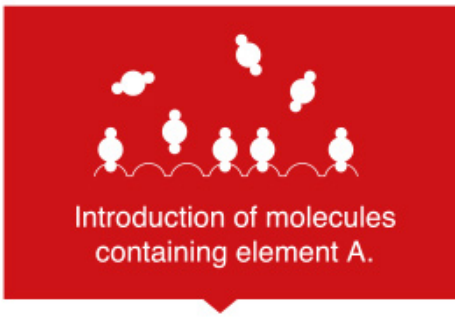
THE PRINCIPLE OF ALD



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