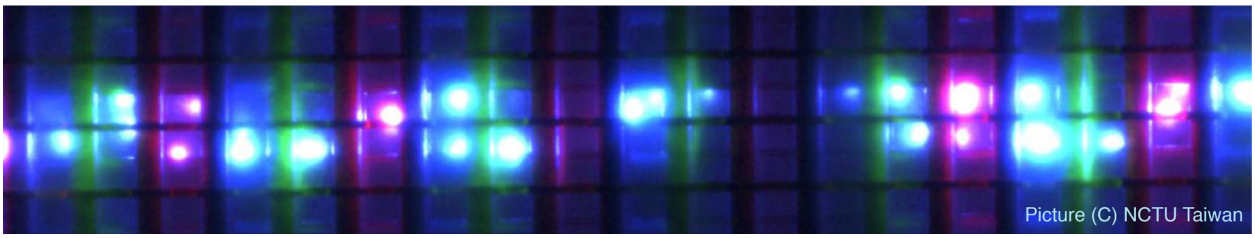
picosun
AGILE ALD

APPLICATION NOTE

Conformal ALD coatings for mini- and micro-LED passivation and barrier films



INTRODUCTION

- **Picosun's Atomic Layer Deposition (ALD) technology offers a revolutionary way to improve mini- and micro-LED brightness, reliability and lifetime.**

- **ALD films' superior conformality enables excellent passivation, barrier and optical layers on challenging 3D nanostructures, high aspect ratios and micropatterned geometrical shapes typical for mini- and micro-LEDs.**

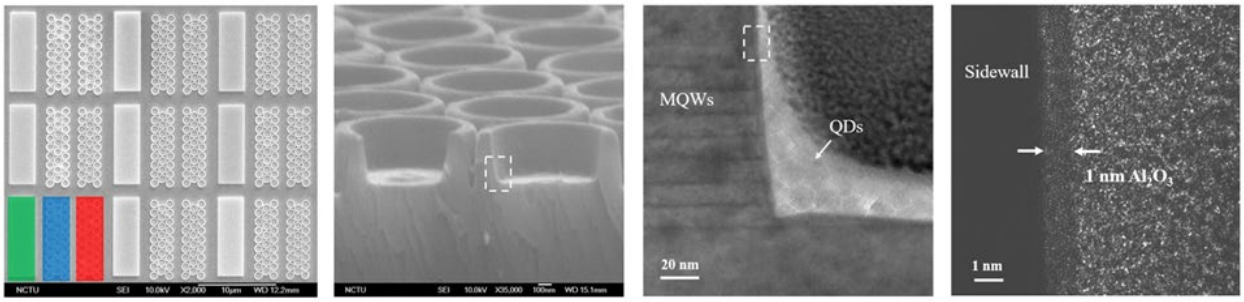
ADVANTAGES OF PICOSUN'S ATOMIC LAYER DEPOSITION SOLUTIONS FOR MINI- AND MICRO-LED MANUFACTURING

- ALD forms ultra-thin, pinhole-free coating that covers uniformly and conformally even the smallest nanoscale 3D details of the mini- / micro-LED structure.
- To improve LED lifetime and reliability, hermetic encapsulation / barrier layer against moisture and gases can be manufactured with ALD.
- Passivation layer deposited with ALD improves LED efficiency by reducing leakage current. Optically transparent, ultra-thin ALD films with superior conformality outperform conventional methods such as PECVD in LED passivation (*). This aspect gets crucial when LED size diminishes from conventional LEDs to micro-LEDs with dimensions as small as only a few microns.
- Due to the microscopic dimensions and 3D micropatterning of the device, sidewall phenomena are important in micro-LEDs. Thanks to its superior conformality, ALD is the best thin film method available for depositing sidewall passivation layers for micro-LEDs (**). Impressive light intensity enhancement by Picosun ALD technology has been obtained by ALD sidewall passivation to eliminate manufacturing damages (traps and defects) caused by reactive ion etching (***).
- Light escape through sidewalls may significantly lower micro-LED brightness. ALD-deposited optical reflectors such as DBR (Distributed Bragg Reflector) stacks direct all light "out" from the LED top surface and maximize the illumination intensity.
- In LEDs equipped with silver mirrors, ALD film acts as an anti-tarnish protective barrier on the silver layer and prevents silver migration under high electric fields.
- ALD is a gentle, gas-phased coating method with moderate process temperatures. This eliminates the risks for microscopic surface damage to the coated substrates 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. Also nanolaminates for further enhanced barrier performance and surface protection, and mixed, graded or doped films can be manufactured.

CUSTOMER RESULTS AND REFERENCES

Picosun's ALD technology for micro-LED performance enhancement

- **National Chiao-Tung University (NCTU) Taiwan**
  - ALD passivation to fix the light intensity loss caused by manufacturing process damage to quantum dot nanoring micro-LED structure.
  - **Impressive gain of 143.7 % in light-emitting intensity has been measured (***).**



Quantum dot nanoring micro-LEDs with 1 nm ALD Al_2O_3 sidewall passivation (image credit Picosun customer, Prof. Hao-Chung Kuo, NCTU Taiwan) (***).

Picosun's ALD films as 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 (Picosun 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 (Picosun 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.**

(*) Guo et. al., Optics Express, Vol. 21, No. 18, p. 21456 (2013)
(**) Wong et. al., Optics Express, Vol. 26, No. 16, p. 21324 (2018)
(***) Chen et. al., Photonics Research, Vol. 7 No. 4, p. 416 (2019)

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.

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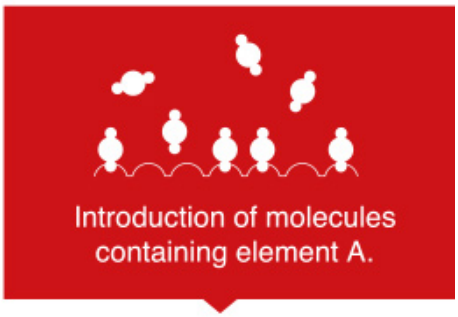
THE PRINCIPLE OF ALD



CONTACT INFORMATION

Main HQ

Picosun Oy
Tel. +358 50 321 1955
Fax +358 9 297 6116
info@picosun.com

European HQ

Picosun Europe GmbH
Tel. +49 1522 449 49 11 (Germany)
Tel. +33 60 785 1176 (France)
sales@picosun.com

North American HQ

Picosun USA, LLC
Tel. +1 214 790 0844
Mobile +1 972 482 1433
sales@picosun.com

Asian HQ

Picosun Asia Pte. Ltd., Singapore
Tel. +65 9830 1709
sales@picosun.com

Picosun Taiwan Co. Ltd.
Tel. +886 90 515 2985
sales@picosun.com

Picosun China Co. Ltd.
Tel. +86 139 2640 6106
sales@picosun.com

Picosun Japan Co. Ltd.
Tel. +81 3 6431 9500
sales@picosun.com

Picosun Korea Ltd.
Tel. +358 40 825 1703
sales@picosun.com

Picosun Oy - India Liaison Office
Tel. +91 96000 28593
sales@picosun.com