

## Large-surface monolayer micro- or nano-sphere deposition and cost-effective periodical patterning technique (photonic crystal substrate preparation)



**Technique description**: This technique provides a method to form an etching mask on polished substrate with periodically arranged pattern in polymer or SiO<sub>2</sub> material. No photolithography process and no vacuum chamber are required for the patterning. Highly uniform spheres are first deposited on substrate with very cost-effective method. The key feature of the technique is the fact that only one layer of spheres is deposited on the wafer with periodically arranged hexagonal pattern. Using this key technique, we have succeeded to deposite the spheres on full 2-inch GaN and sapphire as well as full 4-inch Si wafers. The size and the material of the wafer are not limited to use this key technique. By different dry etching recipes, the patterns can be transferred into the wafer surface. The SEM photographs show that different patterns can be obtained.







EL image of GaN LED (a) reference (b) with texture in n-GaN (etching depth=900nm). Efficiency enhancement after packaging=30%

## Advantages:

- 1. No metal mask is required. No photolithography and no vacuum chamber are required.
- 2. High etching depth can be achieved up to  $1.8\mu$ m.
- 3. The materials and the diameter of wafer are not limited.

**Substrate Material criterion**: any solid material. Ex: GaN, sapphire, GaAs, silicon, SiO<sub>2</sub>, LiNbO<sub>3</sub>, Au, etc. **Substrate diameter criterion**: up to 4 inches. But in principle, diameter is not the limit of the technique. **Etching technique**: dry etching

Materials of spheres: SiO<sub>2</sub> or Polystyrene

**Diameter of spheres (lattice constant)**: 200-700nm(SiO<sub>2</sub>) and 1-2micrometer(Polystyrene).



With different etching recipes, different patterns can be generated.

## **LEDs**



Monolayer of microspheres on 2" sapphire



Patterned GaN



Patterned GaN

**Patterned Sapphire** 



Patterned GaN



Solar cells

Thin-film solar cell









Rough TCO substrate

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