Numerical analysis of high-index nano-composite encapsulant for light-emitting diodes

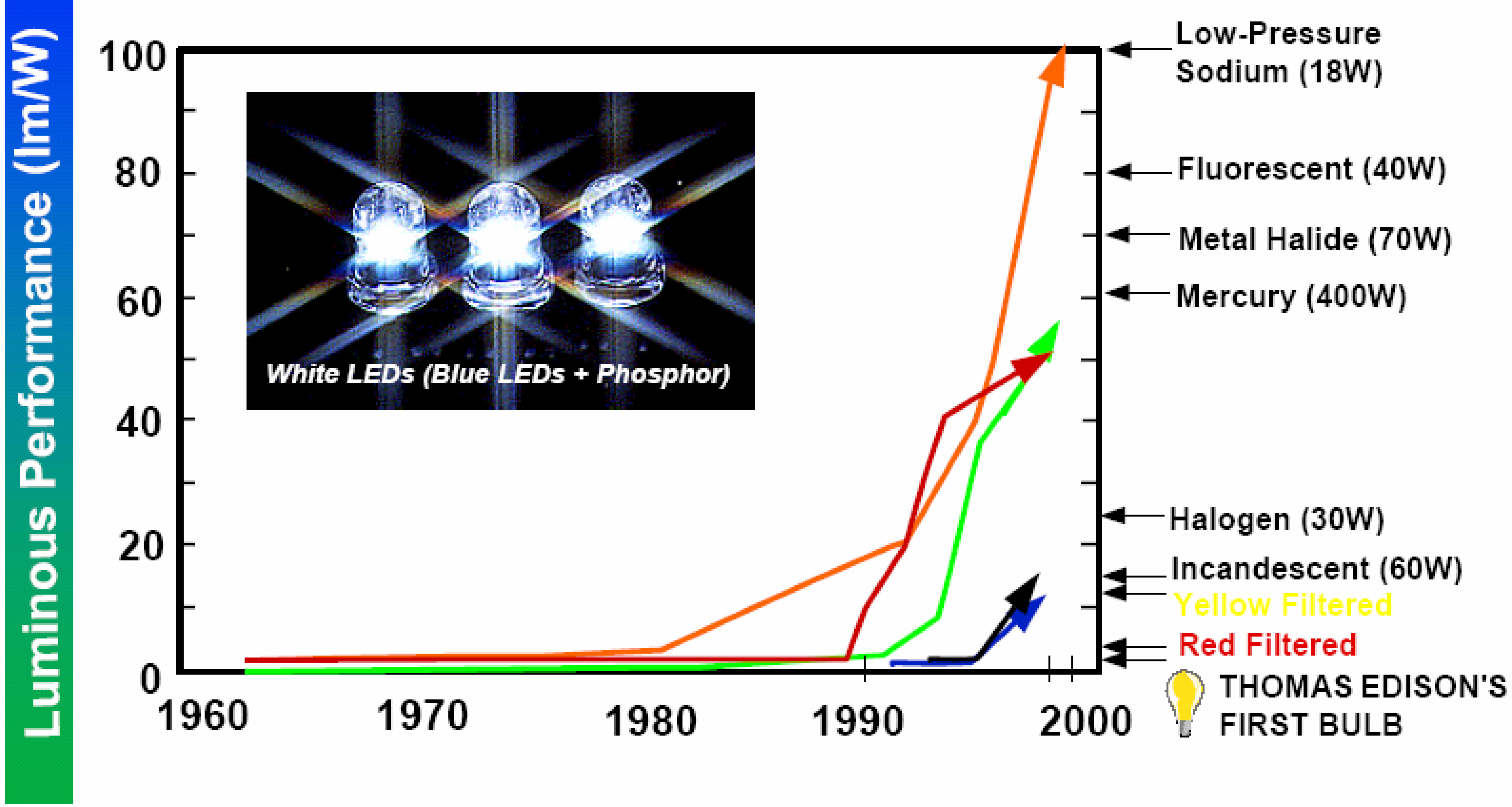
Young-Gu Ju
KyungPook National University, Sankyuk, Daegu 702-701 Korea
ygju@knu.ac.kr

Guilhem Almuneau
LAAS-CNRS

Tae-Hoon Kim
Korea Photonics Technology Institute

Baek-Woon Lee
LCD Business Unit, Samsung Electronics Corporation

Revolution in LED Luminous Performance



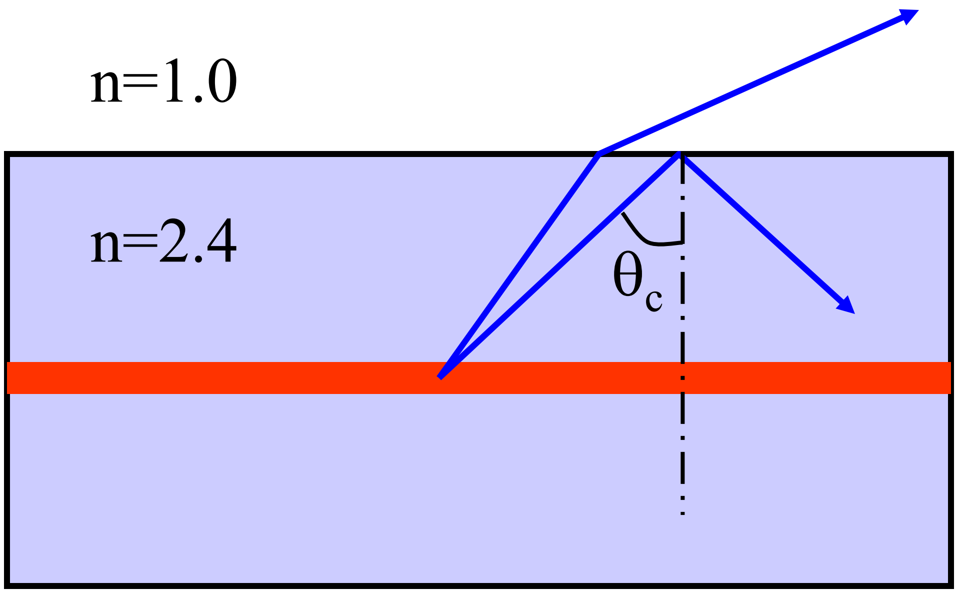
How to improve luminous efficiency

1. Improve crystal quality
   - Reduce the non-radiative recombination.

2. Improve electrical property
   - Reduce Joule heating

3. Improve optical extraction efficiency
   - Reduce the optical loss due to internal reflection.

Internal reflection in GaN

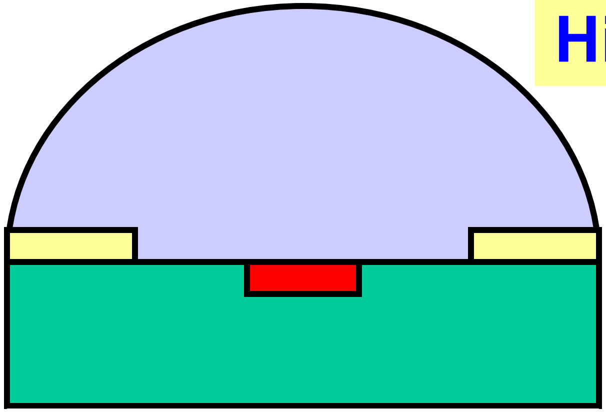


$$\sin\theta_c = \frac{n_1}{n_2} = \frac{1.0}{2.4} \Rightarrow \theta_c = 0.43\,\text{rad} = 24.6\,\text{deg}$$

$$\frac{P_{escape}}{P_{gen}} = \frac{1}{2}(1-\cos\theta_c) = 4.55\%$$

Strategies for high extraction efficiency

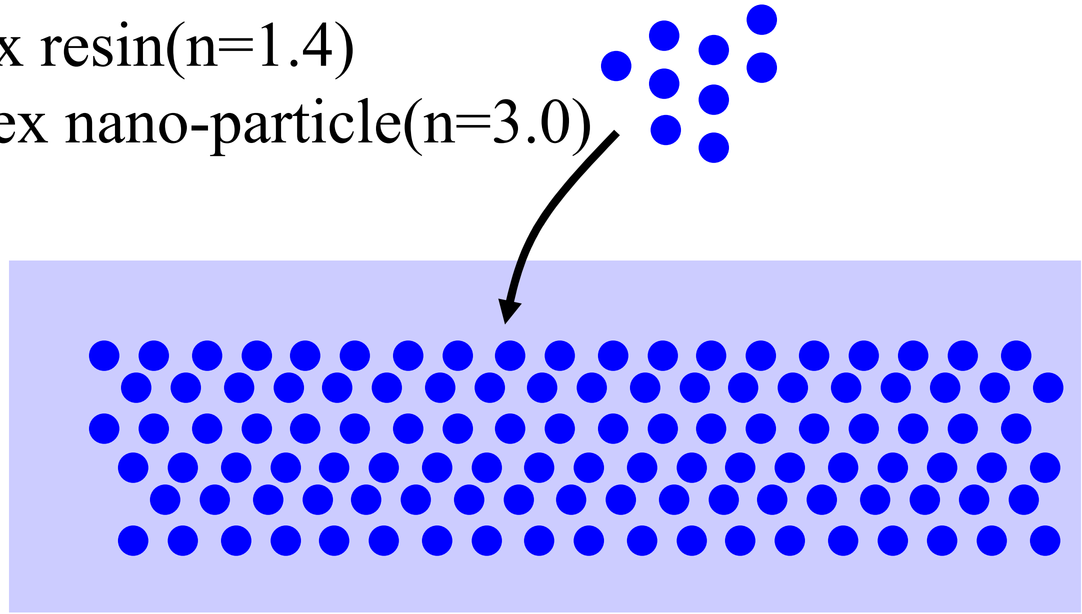
- Increase the Aperture Ratio(R_a).
- Photonic crystal surface
- Index match the resin with GaN(n=2.4).



High index resin

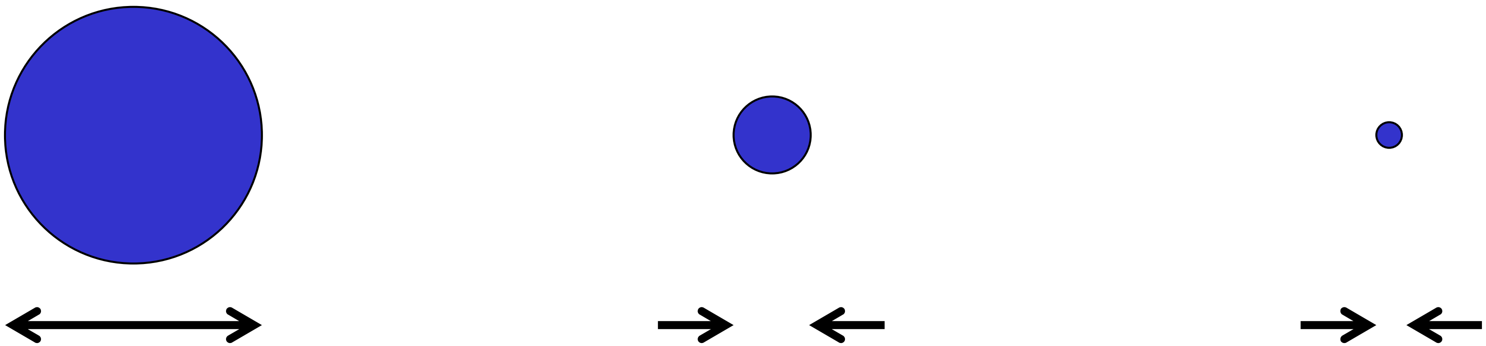
How to make high index resin

Mix low index resin(n=1.4)
with high index nano-particle(n=3.0)



How small should the particle be to avoid significant scattering?

Optical behavior v.s particle size



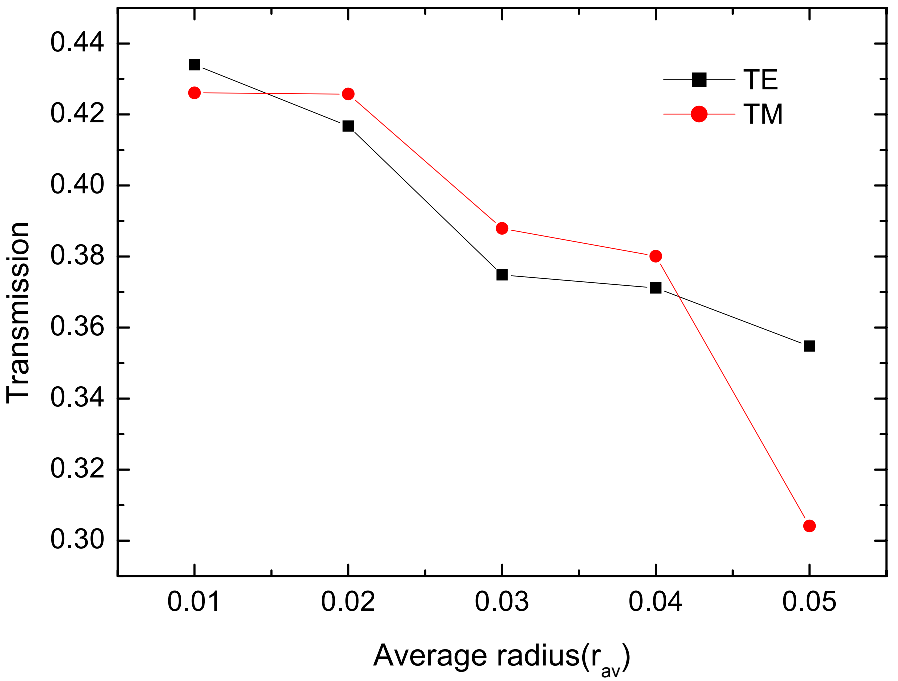
1 μm | ? nm | 1 A

Scatter

Nano-particle, Optically uniform medium

Atomic dipole, Uniform medium

Try FDTD(Finite Difference Time Domain) to simulate the situation



Transmission efficiency as a function of the average radius of nano-particles(r_{av}). a_{av} is adjusted at every point so that the simple average index is 2.0.