SMART LIGHTING

SMART LIGHTING ENGINEERING RESEARCH CENTER

The Evolution of LED Packaging

Robert Karlicek

Director,

Smart Lighting Engineering Research Center,

Professor, Electrical, Computer and Systems Engineering

Rensselaer Polytechnic Institute

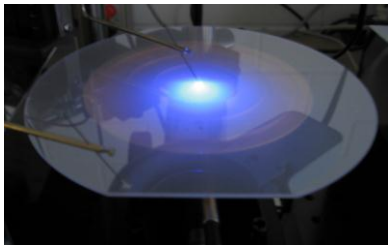
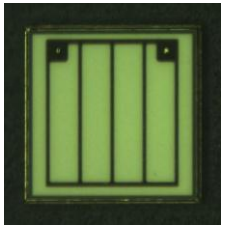
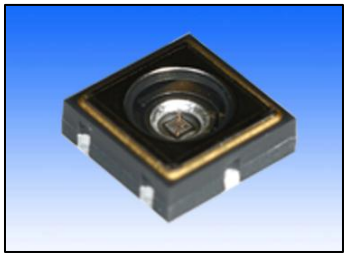
OUTLINE

SMART LIGHTING

- The way things are…
- New things on the horizon
- Drivers of change
- Possible new directions

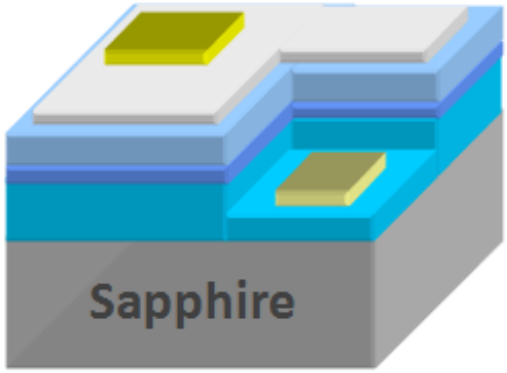
THE TRADITIONAL LED SUPPLY CHAIN

Materials Processes Devices → Materials & Subsystems → Materials & Subsystems Integration → Full Systems Integration

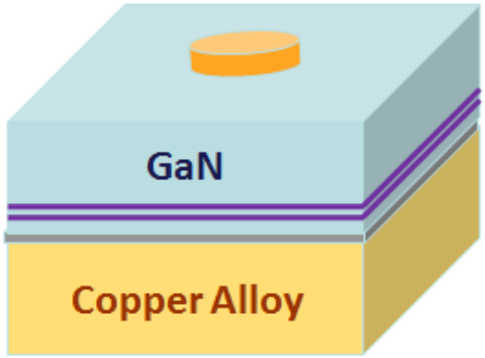





- **Old Supply Chain structure is disappearing**
  - End Users need to more design flexibility and reduced margin stack up
- **LED chip companies entering traditional end user markets**
  - Almost every LED company has a lighting division
- **Display companies entering the Lighting Space**
  - An LCD TV Back Light Unit is a lot like a Fluorescent Lighting Fixture

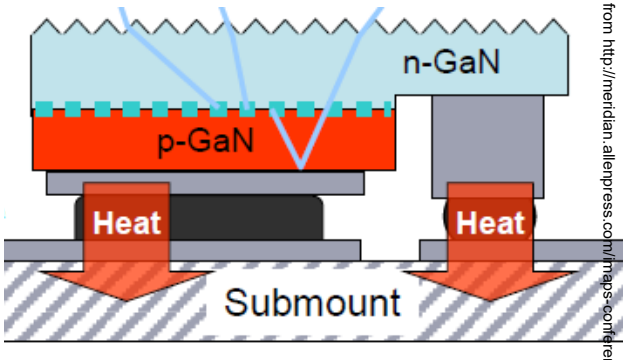
KEEP YOUR EYE ON THE DIE



- Very small to 1 mm chips
- Most use Patterned Sapphire Substrates
- EQE goes down with increasing chip size (volume emitter)
- Insulating Substrate useful for isolation
- Most established LED design

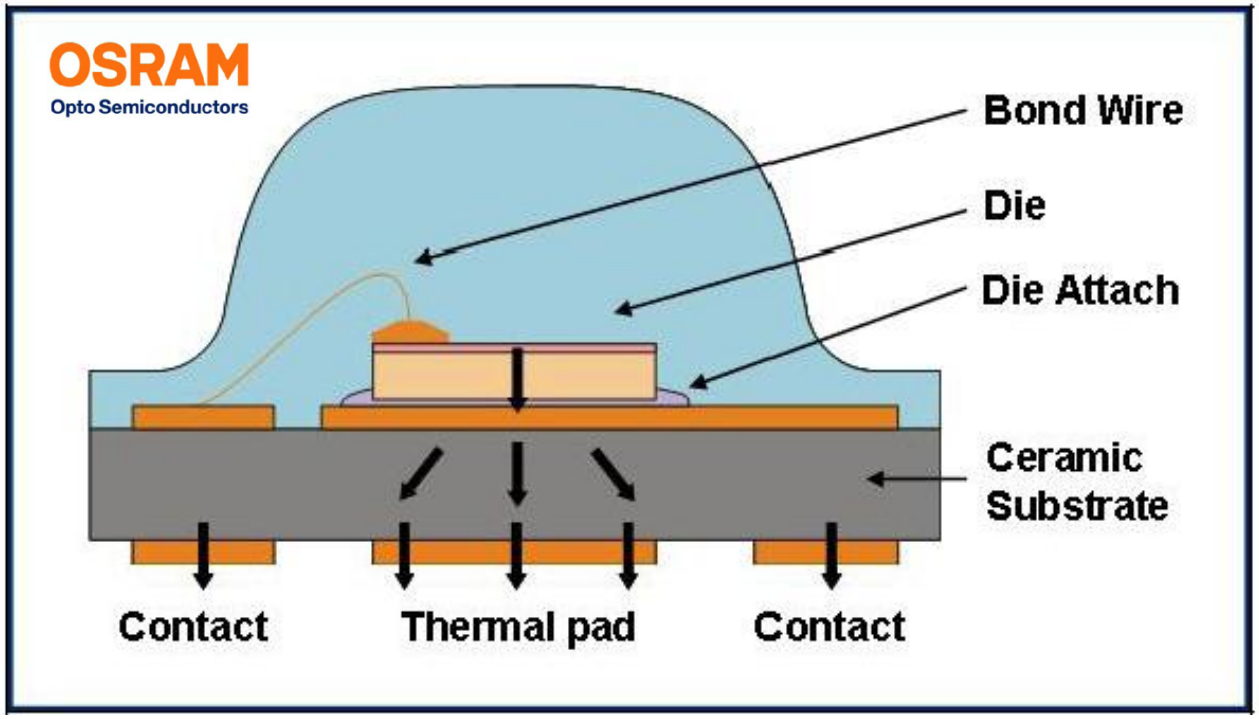


- Medium to very large chips (EQE independent of chip size)
- Preferred structure for high power LEDs
- EQE is independent of chip size
- Superior thermal performance
- Limited use (IP, leakage)



- Large chip
- Most flexible structure for packaging
- Challenging development process
- Good thermal performance
- Most compatible with wafer scale packaging

THE BASICS ARE STILL THE SAME, BUT



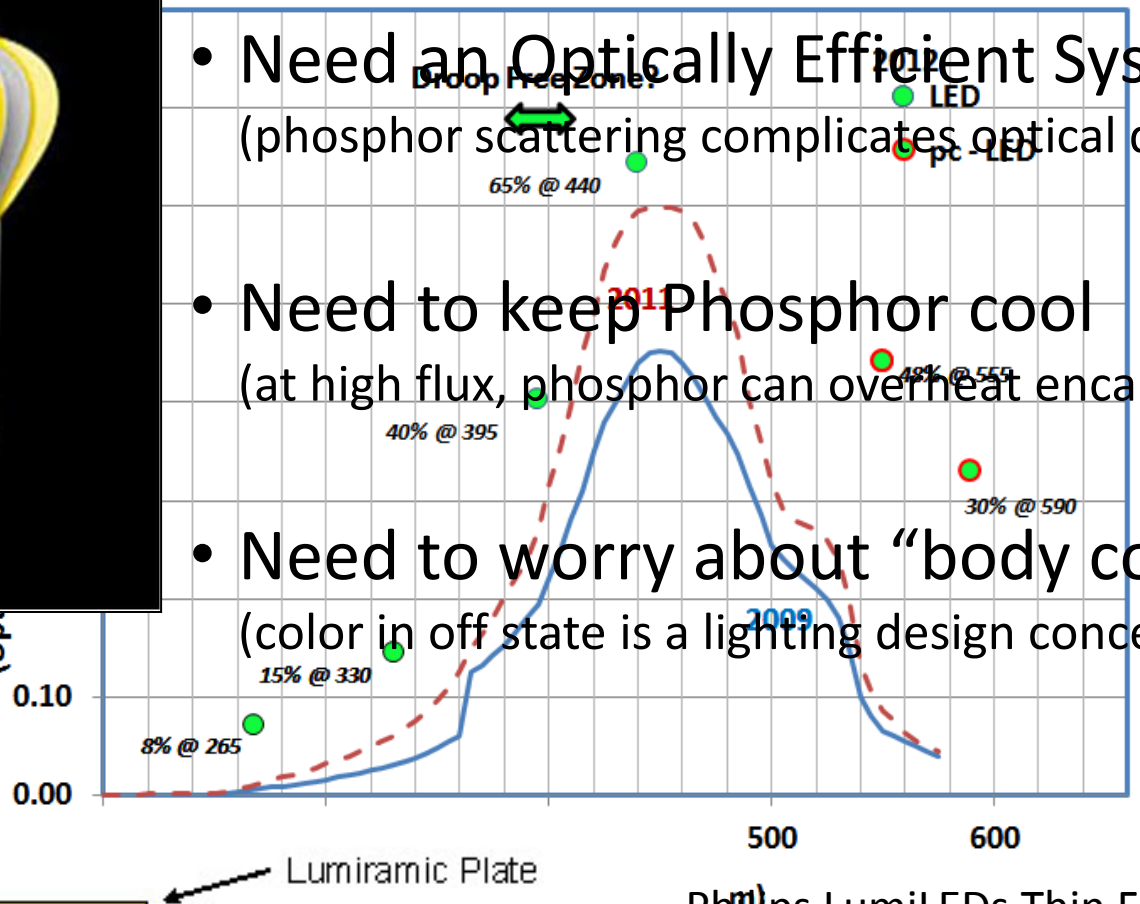
- New Materials
- Get Heat out
- High Speed Assembly
- Get Photons out
- No Bondwire
  new chip design

- Optical design is more important than ever
- Thermal management increasingly important
- Isolation between heat path and current path typically required

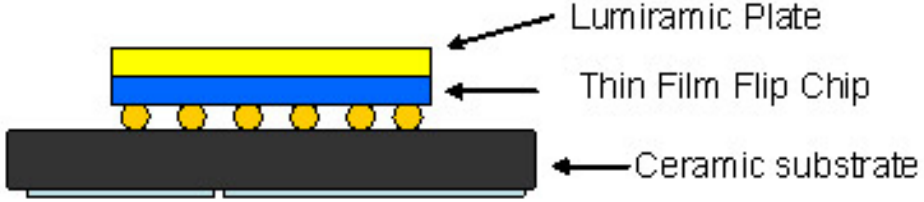
WHERE TO PUT THE PHOSPHOR???

Philips Lighting

- Need an Optically Efficient System
  (phosphor scattering complicates optical design)
- Need to keep Phosphor cool
  (at high flux, phosphor can overheat encapsulant)
- Need to worry about "body color"
  (color in off state is a lighting design concern)



Philips LumiLEDs Thin Film Flip Chip



Phosphor cooled through LED die

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RAPIDLY EVOLVING TECHNOLOGY 1ST WAVE BULBS

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Cree R&D Results, August 2011

- **Current Technology getting better**
  - First Wave Performance Saturation
- **Reliability getting better**
  - Socket Saturation???
- **Solid State Lighting Markets changing**
  - Commoditization
  - Vertical Integration from die to fixture
- **Strategy for Future Growth?**
  - Creative, systems level innovation

NEW KINDS OF CHIPS - RAPID EVOLUTION

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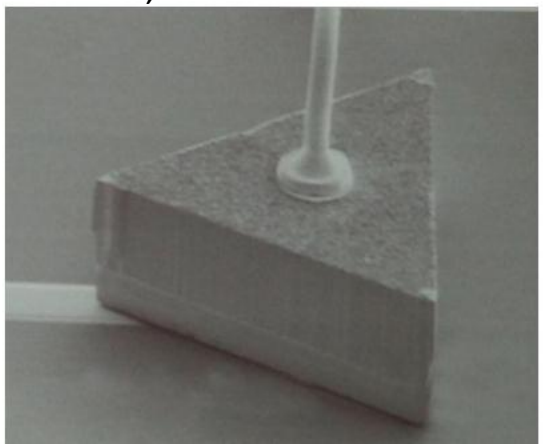
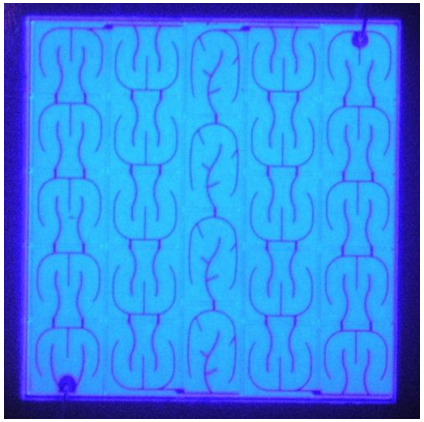
Vertical, volumetric emitter



Vertical, surface emitter

Blue Light Emission from
Separated Honeycomb™ Chip

Lateral, Volumetric emitter



Epistar HV LED

- Soraa GaN on GaN™ small, triangular chip
  - Shaped for light extraction
  - High J Operation, droop-free (?)
- Verticle Hexagonal Chip – vertical LED design
  - Shaped for light extraction
  - Shape improves current Spreading
- High Voltage and AC LEDs
  - Shaped for light extraction
  - Shape improves current Spreading

System Performance Requirements are driving next Generation die design

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INTEGRATION WITH WAVEGUIDES – DESIGN FLEXIBILITY

Prototype reference designs with embedded light engines (courtesy of Rambus)

- Concept taken directly from edge lit LCD TV
  (except it doesn't need to be flat)
- Novel designs, new materials can "hide" heat sink
  (significant design flexibility)
- The Optic is a logical extension of the package
  (why not put the LED die directly into the waveguide for greater efficiency?)

DIRECT VIEW LED PIXEL DISPLAYS?

- 55” Display contains about 6M LEDs
- RGB LEDs directly addressable to create video image
- Can be very efficient, touted as possible OLED killer

Sony Crystal-LED prototype photo

From Consumer Electronics Show (CES) 2012

Sony's Crystal LED technology is self-emitting, uses ultra-fine LEDs

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DRIVERS OF FUTURE LED PACKAGING DESIGN

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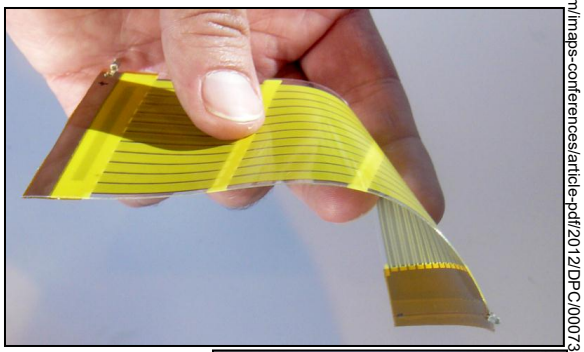
- Cost: Packaging needs to happen at the fixture level
  - Higher packaging speeds needed **(10K die/minute!)**
  - LED die integrated directly into secondary optics
- Integrated Functionality:
  - Integrated sensors and controls
  - Key drivers will be reliability & cost
- Fusion of video and illumination technologies
  - Color tuning will become important
  - Immersive, synthetic environments
  - Key driver will be new services with lighting



Nth Degree Screen Printed LED Lighting

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10K DIE/MIN? MAGNETICALLY ASSISTED PLACEMENT

- Fab die with soft magnetic material (e.g. Ni) in bond pad stack
- Use magnetic write head to position die on receiver (waveguide?)
- Many details need to be worked out

US 20110281375A1

(19) **United States**

(12) **Patent Application Publication**

Swaminathan et al.

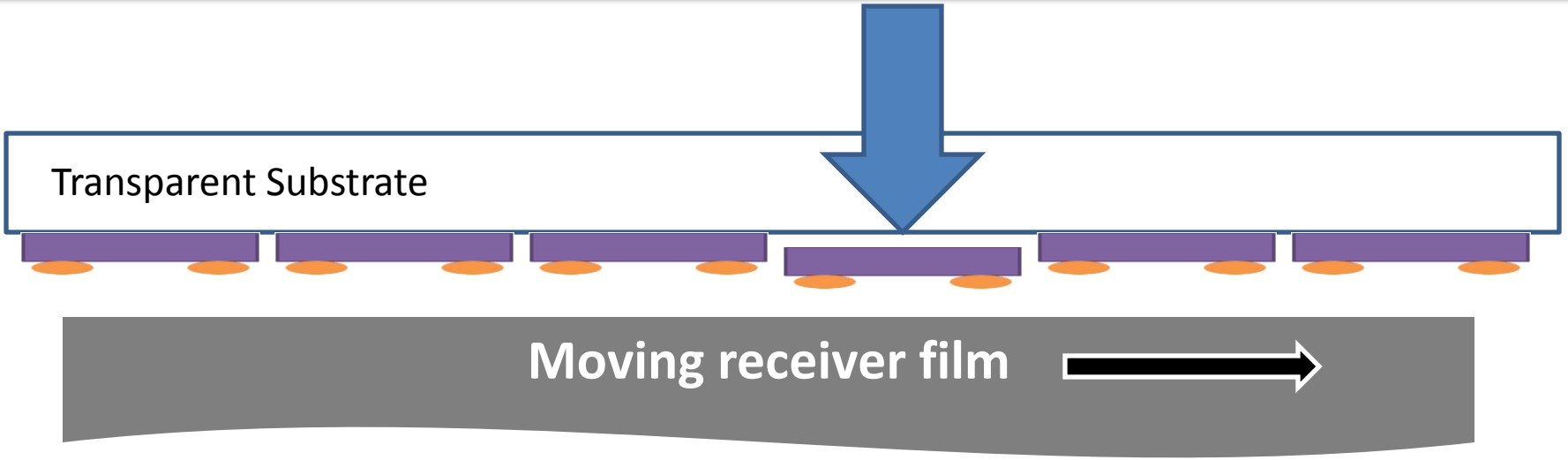
(10) **Pub. No.: US 2011/0281375 A1**

(43) **Pub. Date: Nov. 17, 2011**

(54) **MAGNETIC MICROELECTRONIC DEVICE ATTACHMENT**

(52) **U.S. Cl.** **438/3**; 257/E21.499

10K DIE/MIN? LASER DIE PRINTING



- Similar to techniques under development for thinned Si die (e.g. RFID)
- Capable of very high speeds
- Compatible with binning (transfer only the die needed)
- Many details need to be worked out

Miller, R., V.R. Marinov, O. Swenson, Zh. Chen, M. Semler. "Noncontact Selective Laser Assisted Transfer of Thinned Semiconductor Tiles Using a Two Part Dynamic Releasing Layer." (to appear in *IEEE Transactions on Components, Packaging and Manufacturing Technology*, 2012)

LOTS OF ROOM FOR SYSTEM IN PACKAGE

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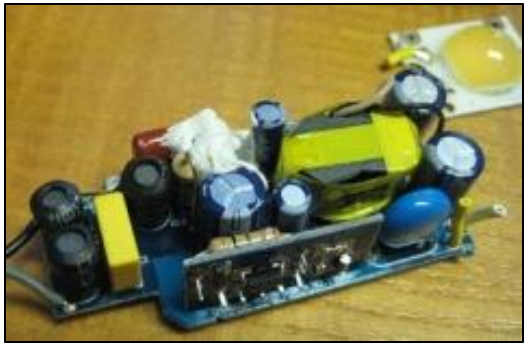
First Wave on the inside….



System in Package

- Reduced size
- Reduce cost
- Improve reliability
- Wafer level packaging approach
  (pre-fabricated driver and controls on receiving wafer package)

http://www.edn.com/blog/PowerSource/41611-Samsung_LED_light_bulb_teardown_includes_objective_dimming_numbers.php?cid=EDNToday_20120208

FUSION OF VIDEO AND ILLUMINATION

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- **Replicates Daylight**
- **Intense enough to give bright light**
- **Efficient enough to save energy**
- **Fast enough to communicate data**
- **Adaptive to ambient lighting requirements**
- **Affordable**

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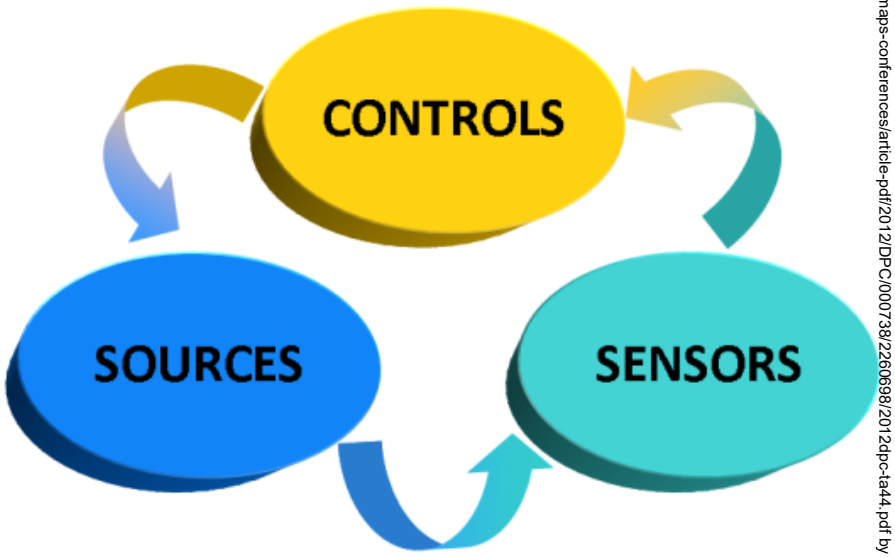
The Right Light Where and When You Need It



LED Packaging will be a key enabler of future lighting systems