Smart LED Fabrication Materials

A Lower-Cost-of-Ownership Alternative to Equipment-Based Process Solutions

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Looking Ahead

2010 Total Cost Index = 100

2015 Total Cost Index = 20

Based on calculations for downlights in the DOE SSL 2011 Manufacturing Roadmap
LED Forecast

• Device production will grow significantly over the remainder of the decade, but dramatic price reductions will be expected over the same period.

• Therefore, LED manufacturers must:
  – Reduce cost of ownership for key processes
  – Reduce manufacturing complexity, improve scalability
  – Produce more die per wafer
  – Improve yields
Materials to the Rescue!

Brewer Science® ARC® organic anti-reflection technology branched the semiconductor industry roadmap in 1981 by enabling the extension of optical lithography, saving manufacturers millions, if not billions, of dollars in capital investment over the past 30 years.

• Spin-applied coatings
  – Easy to scale across different wafer sizes
  – Simple implementation on common track systems
  – Fewer inter-bay transfers
Smart Materials for LED Fabrication

- Temporary Bonding Materials and Processes for Carrier-Assisted Ultrathin Layer Handling
- Wafer Etching Protection Coatings
- Trench Filling and Planarization Coatings
Temporary Bonding Solutions

• **Demonstrated LED Applications**
  – Epitaxial layer transfer
    • Successful laser debonding and transfer of sub–5 µm GaN
  – Wafer thinning and thin wafer handling

• **High-temperature thermoplastic bonding materials**
  – Good TTV control and facile solvent cleaning
  – Glassy, tough bonding systems for grinding hard substrates such as SiC and sapphire
Material Requirements for Layer Transfer Processes

- Stability during high-temperature processing (~250°C)
- Ability to withstand acid or alkaline treatments
- Stability during high-vacuum CVD processes
- Thin wafer handling capability to support epitaxial layers and chip carrier
- Support to protect against high shear stress during backgrinding (if not using LLO process)

Post-processing
- Permanently bond to Cu/metal alloy substrate
Debonding Modes

**Chemical Release Technology**
- Low initial investment
- Short cycle time to production
- Suitable for low-volume operations
- Commercial technology using WaferBOND® CR-200 bonding material

**Slide Debonding Technology**
- Wafer sizes of 50 to 300 mm
- Automated and manual debonding tools available
- Commercial technology using WaferBOND® HT-10.10 bonding material
- Bonding material capable of withstanding higher temperatures available

**ZoneBOND® Technology**
- *Low stress - Room temperature debonding*
- Wafer sizes of 50 to 300 mm
- Automated and manual debonding tools available
- ZoneBOND® bonding materials capable of withstanding high temperatures
Designed for maximum protection of the thinned device wafer
- Debonding occurs at room temperature.
- Separation occurs at the carrier-to-adhesive interface, not the adhesive-to-device interface.
- Device is mounted in the film frame and is firmly supported on a vacuum chuck during debonding.

Allows higher-temperature-capable bonding materials
• Thermally stable in bonded pair to 240° - 260° C (depends on processing parameters)
Evaluation through TSV Process

High-temperature slide technology

ZoneBOND® technology

CEA-Leti
Thin Wafer Handling Equipment

Coat
- Cee® 200X

Bake
- Cee® 1300X

Bond
- Cee® Bonder
  - Coming soon

Debond
- Cee® 1300DB
  - ZoneBOND® separation

Clean
- Cee® 200XD
Wafer Etching Protection Coatings

• Demonstrated LED Applications
  – GaN roughening
  – Silicon cavity sub-mount etching

• Processing Benefits
  – Reduces processing cost vs. ICP etching by about 50%
  – Improves etching yield
  – No scaling issues with wafer size
  – HVM verified

Etch protection technology with proven process yield improvement of > 8%
GaN Roughening

Patterned ProTEK® PSB

ProTEK® PSB

Sapphire

GaN

After KOH exposure and ProTEK® PSB removal

Protected GaN

GaN exposed to KOH
ProTEK® Wafer Etching Protection Coatings

**Base Protection**
- resists KOH, TMAH, NaOH, and other basic chemistries at elevated temperatures

**Acid Protection**
- resists HF, HCl, HNO₃, and other acidic chemistries at elevated temperatures

**Scratch Protection**
- protects backside features from damage without contaminating the chuck

**ProTEK® coatings are:**
- Organic polymer–based
- Spin-applied
- Wet or dry removable

**ProTEK® coatings can provide:**
- Patternable protection (directly photo-imagable)
- Blanket protection (cover entire wafer face)
- Edge protection (wrap around wafer bevel)
ProTEK® B3 Coating - Wet Etching Results in TMAH

Images of edge delaminating on SiN wafers after etching in TMAH
Etch conditions: 25% TMAH, 100°C, for 24 hours

No lifting under extreme conditions
ProTEK® PSB Coating - Wet Etching
Results in TMAH

1.2% undercut was obtained after etching in 25% TMAH at 90° C for 3 hours

Top-down view of 250-µm vias

Cross-sectional view of 250-µm-deep trenches
Blanket Protection from Acids

Wafers blanket-coated with ProTEK® A series material. No damage to aluminum test structures after 1 hour of acid exposure.

Now investigating photosensitive materials for hot phosphoric acid etching of GaN.
EdgeWRAP® Process

Dispense Nozzle

Wafer

Spin Chuck

Baffle

Backside Dispense Nozzle
Results after Wet Etching

Edge-protected wafer etched 100% through

Edge-protected wafer partially etched
ProTEK® Scratch-Resistant Coatings

- Apply ProTEK® SR coating
- Flip wafer over
- Place in DRIE etch tool
- Create via or trench by DRIE (220° C)
Trench Filling and Planarization Coatings

• Potential LED Applications
  – Filling dicing streets
  – Packaging multi-die arrays

• Coating Features
  – High-solids with inherent self-leveling properties
  – Removable (temporary) and curable (permanent) formulations
  – Photosensitive and aqueous-develop types available
High-Aspect-Ratio Trench Filling
High-Aspect-Ratio Trench Filling
Large and Deep Trench Filling
Large and Wide Trench Filling

- Triple coating at 40-wt% solids
- Double coating at 50-wt% solids
Planarization Solutions

Brewer Science planarization coatings are spin-applied materials that level the surfaces of processed wafers so that photolithography processes can be performed.
Brewer Science

- Privately owned corporation founded in 1981 by Dr. Terry Brewer
- Pioneer and market leader in bottom anti-reflective coatings for photolithography with ARC® product brand
- More than 120 US patents and more than 300 international patents issued
- **Core competencies in polymer chemistry, materials science, coating formulation, and thin-film processing and characterization**
- Processing solutions for fabrication of integrated microdevices
- Trusted HVM supplier to top-tier semiconductor manufacturers for > 30 years

Dr. Terry Brewer
President/CEO & Founder
Brewer Science Worldwide

A global supplier of materials and process solutions to the microelectronics industry since 1981
In Summary

• Spin-applied polymer coatings can enable new, low-cost LED fabrication processes that are readily scalable to different wafer sizes.

• Brewer Science offers a broad portfolio of smart fabrication materials that have proven HVM capability for wet etching protection, structure-filling, and ultrathin layer handling.