Outline

- Corning company overview and history
- Corning innovation approach
- Process innovations and related products
- ISS experiment proposal on honeycomb extrusion
Company overview

• Corning is one of the world’s leading innovators in materials science
  – For more than 165 years Corning has applied its unparalleled expertise in glass science, ceramic science, and optical physics to develop products that transform industries and enhance people’s lives

• Corning’s businesses and markets are constantly evolving. Today, Corning’s products enable diverse markets such as mobile consumer electronics, display, optical communications, automotive, and life sciences vessels

• ~50K employees worldwide

• 2018 revenue: $11.2B
Corning history of innovation

Railroad lantern using “Nonex” (non-expansion) glass
Company approach: Continuous innovation in glass and ceramics materials and processes

- Corning succeeds through sustained investment in R&D, a unique combination of material and process innovation, and close collaboration with customers to solve tough technology challenges.
- This overview focuses on three Corning process innovations:
  - Flame hydrolysis for production of pure fused silica.
  - Fusion process and isopipe for creating large glass sheets.
  - Honeycomb extrusion process for making ceramic monoliths.

Flame hydrolysis  Isopipe  Honeycomb extrusion
Corning process innovation: Flame hydrolysis production of pure fused silica

- Prior to 1934 no practical process for fabricating pure fused silica existed.
- In that year Corning scientist Dr. Frank Hyde developed a flame hydrolysis process for making fused silica from silicon tetrachloride.

- SiCl₄ can be produced with ultra-high purity using repeated distillation steps, enabling production of ultrapure glasses.

HPFS (High Purity Fused Silica) – Spacecraft windows

• Applications
  – Spacecraft windows
  – Viewing windows and very high quality optics for the ISS WORF (Window Observatory Research Facility)
  – High energy laser optics

• Key attributes
  – High index homogeneity
  – High transmission
  – Resistance to radiation darkening
  – Low inclusions
HPFS (High Purity Fused Silica) – Mirrors

• Applications
  – Lightweight mirrors
  – Ground-based mirrors
  – Test structures

• Key attributes
  – Zero Expansion (0 +/- 30 ppb)
  – Low inclusions
  – Resistance to radiation darkening
  – Ability to fusion seal

Kepler space telescope mirror
Hubble space telescope mirror

Code 7972 ULE®
HPFS (High Purity Fused Silica) – Optical fiber

• Approach
  – Use flame hydrolysis process to create ultra-pure low loss glass
  – Draw glass down into precision diameter fiber

US3659915 Dr. P. Schultz, Dr. D. Keck, Dr. R. Maurer

Fibrance Light Diffusing Fiber
Corning process innovation: Fusion glass process and isopipe (1964)

• Approach
  – Two molten glass streams flow around both sides of tapered isopipe, meeting at the bottom to form a single pristine sheet of glass, avoiding subsequent polishing steps

• Key advantages
  – Precise thickness control and uniformity
  – Low warp and bow
  – Scalable to large sheet sizes

• Applications
  – LCDs, OLEDs and ultra-high definition televisions, smartphones, tablets, and other devices
Fusion glass – Display applications

- Corning® EAGLE XG® Slim Glass substrates
  - Enables panel manufacturers to innovate for larger, thinner, lighter, and more environmentally conscious display panels
  - Delivers dimensional stability and exceptionally clean, smooth, flat surfaces – qualities essential for successful manufacturing of LCD displays.
  - The glass composition includes no added heavy metals, reducing the environmental impact of manufacturing

- EAGLE XG Slim Glass is available in 0.25 mm up to Gen 5.5, 0.3 mm up to Gen 6, 0.4 mm up to Gen 8.5, and 0.5 mm up to Gen 10.5 (2.94 x 3.37 m)
Fusion glass – Thin flexible glass

• Fusion process enables fabrication of thin glass (0.1-0.2 mm thick, 1.3 m wide) for new applications
• Roll-to-roll manufacture: Available in 300 m rolls for automated electronics packaging and assembly
• Wearable electronics: Curved, flexible displays
• Automotive glass: Glass surfaces and trim for automotive interiors and exteriors
• Corning® Willow® Glass Laminates: Durable architectural interior surfaces with decorative backside coatings
Fusion glass – Chemical reactor fluidic modules

- Fluidic paths are formed by sandwiching molded glass frit layers between glass sheets
- Heat exchange layers around reaction layer provide temperature control
Fusion glass – Chemically strengthened glass and antibacterial coatings for smart phone applications

- An ion exchange process is used to chemical strengthen fusion glass
  - Large ions are “stuffed” into the glass surface, creating a state of compression at the surface
  - Gorilla Glass’ composition enables potassium ions to diffuse deep into the glass, creating a high compressive stress region that helps resist cracks

- Antibacterial coatings
  - Durable antibacterial coatings can be applied to glass surfaces
  - An ionic silver component serves as an antimicrobial agent to keep glass clean
Adjacency – Chemically strengthened glass packaging with a low coefficient of friction external coating

• Damage resistant pharmaceutical packaging
  – Engineered with higher internal energy than conventional packaging
  – In laboratory testing Valor® Glass vials provide at least 30x protection against cracks as compared to conventional borosilicate glass vials

• Particulate reduction
  – Pharmaceutical glass vials and containers significantly reduce particle generation
  – Have demonstrated a 96% reduction in peak particle counts on commercial filling lines
Corning process innovation: Honeycomb extrusion process (1972)

- Invented low-expansion porous cordierite material and unique die extrusion process
- Became the global standard for emissions control solutions
- Inventors received the National Medal of Technology in 2003 for pioneering work on cellular ceramic substrates
Catalyst supports and diesel particulate filters, air purification filters

- **Automotive catalytic converter substrates**
  - Porous low-expansion cordierite honeycomb substrates coated with metal catalyst

- **Diesel particulate filters**
  - Porous ceramic honeycombs designed to trap soot in internal channels prior to burnout

- **Air purification**
Honeycomb extrusion monolith cell designs

- The extrusion process enables a variety of cell structures
Dense ceramic honeycombs for chemical reactors

- Corrosion-resistant ceramic materials can be extruded, machined, plugged and fired to create long internal serpentine paths
- Multiple paths enable chemical reactor heat exchange, liquid filtration and membrane separation applications
Thin ceramics – Alumina ceramic ribbons and wafers (99.99% purity)

- **Features**
  - Available in roll form or wafers as thin as 40 um, with precision laser cut via
  - High dielectric constant ~9-10 over 10-60 GHz
  - High thermal conductivity and CTE combined with high bending strength

- **Applications**
  - High frequency RF applications
  - Mounts for LEDs
  - High power electronics (breakdown ~4-5 kV)
  - Wafer level capping solutions
  - Curved/flexible substrates for mounting active components
Pyroceramics

• Based on 1952 discovery of glass ceramics by Dr. D. Stookey

• Applications
  – Missile nose cones
  – RF transmitting windows

• Key attributes
  – Outstanding dielectric/loss tangent
  – Low gas permeability
  – High strength and elastic modulus

Corning® Pyroceram® 9606
Dependable uniformity and strength throughout manufacturing process

Infrared Transmitting 9754
Clear germanate glass composition with excellent transmission abilities from ultraviolet to infrared
Molded plastics for Life Science applications

- Life Sciences business produces precision molded plastic components for bioprocessing, cell cultures, and labware
ISS experiment proposal on honeycomb extrusion - Motivation

• Extruded ceramic honeycombs and ribbons experience geometrical distortion due to gravitational forces during extrusion and drying operations
• Elimination of gravitational forces during extrusion should reduce geometric distortion, enabling fabrication of high precision ceramic parts
  – This would enhance our ability to observe small-scale geometrical distortions arising from other contributions during the extrusion process that would otherwise be masked by gravitationally-induced distortion
  – With improved fundamental understanding, extrusion dies might be better designed to yield more uniform geometrical results in extrusions on earth
ISS experiment proposal on honeycomb extrusion - Approach

• Proposed a self-contained experiment module for extruding ceramic honeycomb substrates in micro-gravity

[Diagram of the experiment module with labels for Motor, Drive screw, Extrusion paste, Cutter, Wet green honeycomb, Port, Cured green honeycomb, Return cured green honeycombs to earth for firing and precision distortion measurements.]

Experiment locker module

Curing chamber
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