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Academic Progress Report

Corning Ribbon Ceramic: A Roll-to-Roll, Continuous Sintering Platform for Ultra-Thin Technical Ceramics and Applications

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Abstract: This review introduces Corning's Ribbon Ceramic process and the broader idea of ribbon ceramics—continuous, ultra-thin ceramic sheets made by tape or slot-die casting and fast, continuous sintering—covering key materials such as Al_2O_3, YSZ/ScSZ, PZT, LLZO, and LCO. Motivated by the need for scalable, energy-efficient ceramic components for electrification (green-hydrogen SOECs), next-generation Li-metal batteries, and compact piezo devices, we summarize capabilities and use cases using only publicly available information. Our main contribution is a clear platform view: continuous roll-to-roll conveyance with minutes-scale firing produces fully dense, fine-grained, high-purity ceramics at ~10–100 μm thickness with smooth native surfaces and controlled shapes, delivered as long rolls (up to ~300 ft), panels (~100 mm wide), or narrow strips (~0.5 mm). Illustrative results include 20–40 μm 3YSZ electrolytes for SOECs (high oxygen-ion conductance, ~1 GPa bend strength), LLZO garnet separators that cycle at 25°C with interlayers, and free-standing LCO cathode ribbons tunable from dense to ~30% porous. For piezo acoustics, 60–80 μm PZT sheets (d_{33} ~300 pC/N) enable fine metallization and on-screen speakers, while fast firing reduces volatile loss and yields smaller grains. Together, these advances point to high-volume, lower-footprint manufacturing and faster adoption of novel ceramic membranes and substrates in SOEC/green-hydrogen systems, solid-state or hybrid lithium batteries, RF/power electronics, and piezo applications.

Keywords: Ribbon ceramic, Corning, Fast firing process, Roll-to-roll process

1. INTRODUCTION

Ribbon ceramics are continuous, ultra-thin ceramic sheets produced as green tapes by tape casting or slot-die coating and then consolidated into dense, flat ribbons through lamination, burn-out, and sintering [1]. Unlike discrete wafers or bulk parts, this geometry is made to run roll-to-roll (R2R), enabling long lengths, tight thickness control in the ~10–120 μm range, and delivery in multiple form factors—long rolls, cut panels, and narrow strips—while maintaining smooth native surfaces and high dimensional uniformity. The approach is broadly compatible with many technical ceramics, including alumina and zirconia for substrates and membranes, piezoelectric compositions for actuators and acoustics, garnet-type solid electrolytes for batteries, and oxide cathode materials for free-standing electrodes.

Corning has decades of experience in continuous glass and ceramic manufacturing, and the Ribbon Ceramic process extends that know-how to technical ceramics by conveying continuous green tape through a sintering furnace to form a continuous, fully sintered ribbon. Fast firing on the order of minutes, enabled by the thin form factor, reduces loss of volatile constituents and promotes finer grain sizes, yielding fully dense, fine-grained, high-purity ceramics with controlled shape and smooth surfaces [2]. The process has been demonstrated across multiple chemistries and can produce ribbons up

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to hundreds of feet in length, supply panels at wafer-like widths, and even narrow strips down to sub-millimeter scale, offering "ceramics as you've never seen them" in unique geometries [3].

The motivation for this review is straightforward: electrification and clean-energy systems are demanding lighter, thinner, and more efficient ceramic components, while consumer and industrial devices seek compact, low-power piezo solutions. Continuous ribbon manufacturing speaks directly to these needs by combining high throughput with energy-efficient firing (only the product experiences the thermal profile), consistent microstructures, and native surface quality that simplifies downstream metallization and assembly. The same platform supports oxygen-ion membranes for electrolysis [4,5], thin solid-electrolyte separators for lithium-metal batteries, free-standing oxide cathodes tuned from dense to porous, and thin piezo sheets for on-screen speakers and haptics [6].

This article sets a practical baseline—using information available in the public domain—on what the Ribbon Ceramic platform can do today and where it is headed. Section 2 outlines the platform architecture and form factors. Section 3 summarizes the continuous process and key advantages relative to batch sintering. Section 4 reviews representative material families processed as ribbons. Section 5 highlights application examples across energy, electronics, and acoustics. The conclusion distills the implications for scale-up, reliability, and the adoption of novel ceramic membranes and substrates in next-generation systems.

2. CORNING RIBBON CERAMIC PLATFORM OVERVIEW

2.1 Platform Summary

Corning's Ribbon Ceramic platform produces continuous, ultra-thin, flat ceramic sheets by conveying a green tape through a sintering furnace to form a fully sintered ribbon. Green tapes are made by tape casting or slot-die coating and handled roll-to-roll (R2R). Thin fired thicknesses (~10–100 μm) enable rapid heating/cooling in minutes, yielding fully dense, fine-grained, high-purity ceramics with smooth native surfaces and controlled shape.

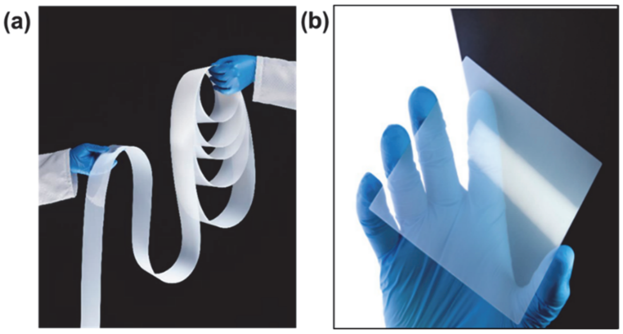

Fig. 1. (a) Photograph showing the flexibility of Corning Ribbon Ceramic and (b) photograph demonstrating that it can be cut to the desired size and handled [7].

2.2 Continuous Sintering and Fast Firing

The continuous sintering process heats only the product, improving energy efficiency and reducing the carbon footprint compared to batch firing. Short dwell times limit loss of volatile constituents and suppress grain coarsening, while maintaining full densification.

2.3 Materials and Delivered Form Factors

The platform is compatible with a wide range of technical ceramics, including alumina, stabilized zirconia, piezoelectric compositions, garnet-type solid electrolytes, and oxide cathodes. Ribbons are produced in long rolls (up to ~300 ft), supplied as wafer-like panels (~100 mm wide), or narrow strips (down to ~0.5 mm), enabling substrates, membranes, waveguides, and free-standing electrodes from a single process.

2.4 Continuous Sintering Process VS. Batch Sintering Process

Compared to batch sintering of plates or setter-stacked tapes, continuous ribbon firing offers shorter cycles (minutes vs. hours to tens of hours), lower volatile loss, finer grains, smoother native surfaces, and higher throughput with lower thermal mass. Batch may suit thick or complex 3D parts, but for ultra-thin substrates and membranes, the continuous approach delivers clear advantages in precision, energy efficiency, and unique form factors.

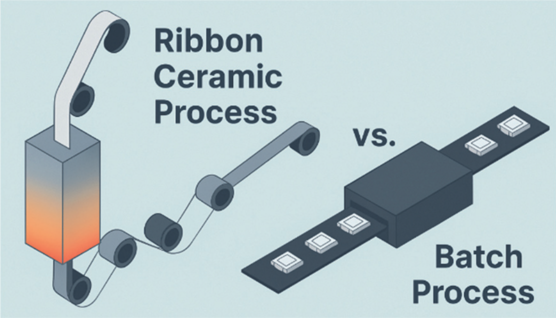

Fig. 2. Schematic comparing the Corning Ribbon Ceramic process with the conventional batch firing/sintering process.

3. RIBBON-CERAMIC PROCESS AND KEY ADVANTAGES

3.1 Process Overview

Ribbon ceramics are made by forming a continuous green tape via tape casting or slot-die coating, optionally laminating for multilayers, and conveying the web through a continuous sintering furnace to produce a fully sintered, flat ribbon. The fired product is delivered as long rolls, cut panels, or narrow strips, enabling downstream laser singulation, metallization, and assembly with minimal finishing thanks to its smooth native surface.

3.2 Fast Firing Enabled by Thin Geometry

Thin fired thicknesses (on the order of ~10–100 μm) heat and cool rapidly, allowing minutes-scale firing profiles (rapid ramp, short dwell, rapid cool). Short cycles reduce loss of volatile species, limit grain coarsening, and still achieve full densification. The result is fine-grained microstructures with high purity and improved mechanical robustness in ultra-thin formats.

3.3 Native Quality Attributes

Continuous, setter-free firing produces a smooth native surface and uniform thickness/shape across the web. Fine grains and full density yield high bend strength for membranes and substrates, while the clean surface simplifies fine-line metallization and double-sided coatings. Controlled shrinkage in the continuous path helps maintain flatness and dimensional accuracy, reducing post-process polishing and lapping.

3.4 Scalability and Energy Footprint

Only the product experiences the thermal profile in the continuous furnace, reducing thermal mass and energy consumption relative to batch processes. Long lengths (e.g., up to hundreds of feet) and wafer-like widths enable high throughput and consistent lot-to-lot quality, while roll-to-roll conveyance supports high-volume manufacturing and flexible supply formats.

3.5 Form-Factor Flexibility

The same process yields multiple form factors: long rolls for continuous downstream operations, panels at wafer-style widths for precision processing, and narrow strips for waveguides or micro-device elements. Thickness, porosity (dense to porous), and width can be tuned per application, supporting substrates, membranes, and free-standing electrodes within one platform.

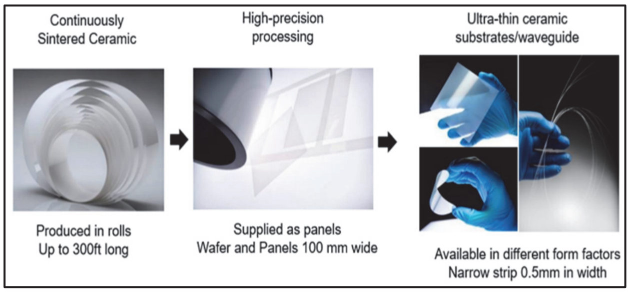

Fig. 3. Illustration showing that, after wafer or panel-level processing, Corning Ribbon Ceramic can be applied to waveguides and various substrates [8].

3.6 Comparison to Batch Sintering Process

Compared with batch sintering of plates or setter-stacked tapes, ribbon processing offers shorter cycles, lower volatile loss, finer grains, smoother native surfaces, higher throughput, and lower thermal footprint. While batch routes remain useful for thick or complex 3D parts, continuous ribbon firing is the preferred path for ultra-thin, high-precision substrates and membranes.

4. REPRESENTATIVE MATERIALS FOR RIBBON CERAMICS

4.1 Alumina (Al_2O_3)

Alumina is a workhorse for substrates, membranes, and waveguide-like narrow strips. In ribbon form, fired thicknesses in the ~10–100 μm range are typical, with smooth native surfaces that support fine metallization and minimal post-polish. Polished roughness commonly reaches ~0.2–0.5 μm, thermal conductivity is ~20–30 W/m·K, and CTE is ~7–8 ppm/K—values that align well with RF/power modules and microheater platforms. Form-factor flexibility is a key advantage: long rolls (up to hundreds of feet), wafer-like panels (~100 mm width), and narrow strips (down to ~0.5 mm) can be supplied from the same line, enabling precision processing or waveguide elements without changing the base process.

4.2 Stabilized Zirconia (YSZ/ScSZ)

Stabilized zirconias are prime candidates for oxygen-ion membranes in electrolysis and sensing. Ribbon electrolytes at ~20–40 μm thickness are fully dense and fine-grained, combining high oxygen-ion conductance with mechanical robustness; bend strengths near ~1 GPa have been demonstrated, which supports handling and assembly at scale. Gas-tightness (often checked by helium leak tests) and thermal-expansion matching (~10–11 ppm/K) with electrodes/supports are central to reliable stack integration. The thin form factor allows rapid heating/cooling, which helps retain stoichiometry and limit grain coarsening during firing, contributing to both performance and durability in SOEC and sensor use.

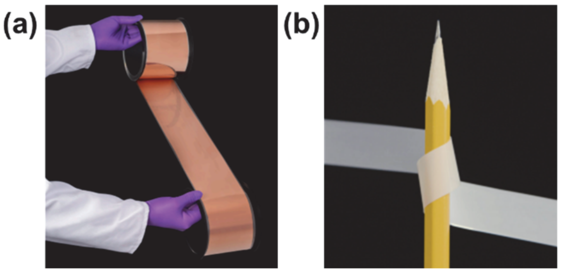

Fig. 4. (a) Photograph demonstrating that Zirconia Ribbon Ceramic can be implemented in a roll-to-roll (R2R) metallization format and (b) photograph demonstrating that Zirconia Ribbon Ceramic wrapped around a pencil with extremely high flexibility [9].

4.3 Piezoelectric Compositions (PZT Ribbon Ceramic)

PZT in ribbon form targets thin, flexible actuators and acoustics. Typical fired thicknesses are ~60–80 μm, with relative density >98% and average d_{33} around ~500 pC/N; Young's modulus near ~50 GPa is reported for thin sheets. Smooth native surfaces enable fine metallization, including double-sided copper coatings, and the continuous process can produce sheets on the order of 50 mm × 26,000 mm in a single run. Fast firing (less than ten minutes vs. ~20 hours conventionally) reduces lead loss and yields smaller grains, supporting stable piezo properties at thin dimensions. A prominent use case is on-screen speakers for OLED displays, where thin, wide PZT ribbons can reduce power consumption, improve sound quality, and meet compact form-factor demands.

4.4 Garnet-Type Solid Electrolytes (LLZO Separators)

Garnet-type solid electrolytes in ribbon form address thin, dense separators for solid-state or hybrid lithium batteries. Thicknesses typically fall in the ~10–100 μm range, and dense microstructures are produced roll-to-roll. Room-temperature cycling of lithium/garnet cells is often enabled by a simple interlayer that improves wetting, distributes current uniformly, and reduces interfacial resistance, allowing lower external pressure during operation. Continuous processing gives consistent separator thickness and smooth surfaces, which helps standardize interlayer application and stack assembly. Together, these attributes support the push toward Li-metal or "anode-free" designs with higher energy density at the same cell size [10].

4.5 Oxide Cathode Ribbons (e.g., $LiCoO_2$ Free-Standing Cathodes)

Free-standing oxide cathode ribbons can be made continuously, then tuned for dense or porous microstructures depending on energy vs. rate requirements. Typical thicknesses are ~10–100 μm, with porosity adjusted from dense to ~30%. Electrochemical performance has been demonstrated in liquid and solid-state (with solid electrolytes such as LiPON) coin-type cells. Thicker, denser ribbons raise energy density at a trade-off in rate; thinner or more porous ribbons favor power.

The ability to deliver cathodes without metal current-collector substrates opens pathways to lighter, simpler cell stacks [11,12].

4.6 Other Candidates and Cross-Compatibility

Beyond the core families above, the platform's fast firing and setter-free path are applicable to additional technical ceramics that benefit from thin, smooth, uniform sheets. Narrow strips at sub-millimeter widths can serve as waveguides or micro-device elements, while panel formats support wafer-like handling for patterned devices. The same continuous line can produce dense membranes, compliant piezo sheets, or porous electrodes by tuning thickness, porosity, and atmosphere—allowing multiple material systems to share tooling and workflows within one R2R platform.

5. POTENTIAL APPLICATIONS OF RIBBON CERAMICS

5.1 High-Efficiency Electrolysis and Oxygen-Ion Devices (SOEC/SOFC)

Ultra-thin stabilized-zirconia ribbons (~20–40 μm) serve as oxygen-ion membranes with low area-specific resistance, enabling higher hydrogen production efficiency in solid oxide electrolysis and higher power density in fuel cells. Fully dense, fine-grained microstructures deliver mechanical robustness (reported bend strengths near the gigapascal range) and gas-tightness suitable for planar stacks. The native flatness and smooth surfaces support reliable electrode deposition and sealing, while wafer-like panels simplify precision stacking and perimeter sealing. Thin membranes also reduce thermal gradients, aiding faster start-up/shut-down and mitigating thermal cycling stress, which is critical for durability and cost per kilogram of green hydrogen.

5.2 Lithium Batteries: Solid-State and Hybrid Architectures

5.2.1 Garnet-Type Solid-Electrolyte Separators

Thin, dense garnet separators (~10–100 μm) produced roll-to-roll enable compact, high-energy lithium-metal cells by shortening ion-transport paths and improving packaging efficiency. Smooth, uniform surfaces facilitate application of simple interlayers that improve wetting, distribute current uniformly, and lower interfacial resistance, supporting room-temperature cycling at reduced stack pressure. Consistent thickness and large-area format aid scale-up from coin-type to pouch-type cells, while fine grains and controlled stoichiometry bolster mechanical integrity against filament penetration.

5.2.2 Free-Standing Oxide Cathode Ribbons

Substrate-less cathode ribbons (e.g., layered oxides) in the ~10–100 μm range can be tuned from dense to ~30% porous to balance energy and rate capability. Dense films maximize volumetric energy, whereas tailored porosity enhances electrolyte access and high-rate performance. Roll-to-roll production simplifies lamination and stacking, reduces inactive mass (no metal current collector), and supports both liquid and solid-state configurations (e.g., with solid thin-film electrolytes such as LiPON).

5.3 Piezoelectric Actuators, Sensors and Transducers

Thin piezo ribbons (~60–80 μm) with high relative density and stable piezo coefficients are well-suited to on-screen speakers for OLED displays, low-power micro-speakers, haptic surfaces, energy harvesters and capacitors [13,14]. The native smoothness supports fine metallization, including double-sided electrodes for efficient drive schemes, while the flexible, wide-area format allows tiling and arraying to tailor acoustic modes and SPL over 20 Hz–40 kHz. Compared with bulk ceramics, thinner ribbons lower drive voltage and mass, improving bandwidth and power consumption; compared with thin films, they offer higher displacement and simpler, scalable processing for larger apertures.

5.4 RF/power Electronics, Sensors, and Thermal Platforms

Alumina ribbons provide thin, flat substrates for RF modules and power electronics, with polished roughness in the sub-micrometer range enabling fine-line metallization and low insertion loss. Narrow strips can function as dielectric waveguide elements or resonators in compact microwave assemblies. In sensing, thin alumina or zirconia ribbons serve as microheater carriers and gas-sensor membranes, where low thermal mass accelerates warm-up and duty-cycling, reducing power draw. For precision thermal platforms, the combination of flatness, smoothness, and controlled CTE supports reliable die attach and cycling.

5.5 Gas Sensors and Electrochemical Sensing

Oxygen-ion-conducting ribbons enable compact oxygen sensors with fast response and stable operation at elevated temperatures. Their thinness reduces diffusion time constants and improves signal-to-noise, while mechanical robustness eases packaging. In mixed-potential or potentiometric sensors, uniform electrolytes and smooth interfaces enhance reproducibility and reduce baseline drift, aiding calibration and long-term stability.

5.6 Photonics and Waveguide-Like Elements

Sub-millimeter-wide ceramic strips act as robust waveguide-like elements or carriers for optical coatings in harsh environments. The combination of geometric precision, smooth native surfaces, and thermal stability supports passive photonic components, frequency-selective structures, or integrated heater traces for tuning. While ceramic transparency varies by composition, coated or hybrid stacks can leverage the mechanical and thermal benefits of the ribbon form.

5.7 Filtration, Catalytic and Porous-Electrode Architectures

Where process conditions are tuned for porosity, ribbon forms can serve as thin catalytic supports or gas-diffusion electrodes. The ability to set porosity from dense to ~30% enables control over pressure drop, mass transport, and active-site density. Compared with thick monoliths or foams, thin porous ribbons can be stacked to create short diffusion paths and rapid thermal response, which is valuable in cyclic or start-stop operation.

5.8 System-Level Integration Advantages

Across these sectors, common ribbon attributes—ultra-thin geometry, smooth setter-free surfaces, fine grains, and controlled shapes—translate into lower internal resistance (electrochemical), lower drive power (piezo), faster thermal response (sensors/heaters), and tighter dimensional tolerances (RF/power). Long-roll supply and wafer-like panels streamline high-volume assembly, while narrow strips unlock compact layouts. In each case, the same continuous platform reduces post-processing and simplifies quality control, shortening the path from materials development to manufacturable devices.

6. CONCLUSION

Corning Ribbon Ceramic platform brings continuous, ultra-thin ceramic sheets to mainstream manufacturing by pairing roll-to-roll conveyance with fast, setter-free sintering. It delivers fully dense, fine-grained, high-purity ribbons at ~10–100 μm with smooth native surfaces and controlled shape, supplied as long rolls, wafer-like panels, or narrow strips. Across materials, the platform enables low-resistance oxygen-ion membranes for electrolysis and sensing, thin piezo sheets for on-screen speakers and haptics, solid-electrolyte separators for lithium-metal cells, free-standing oxide cathodes, and flat alumina substrates for RF/power modules. Minutes-scale firing reduces volatile loss and grain coarsening, while focusing heat on the product lowers energy use and supports high throughput; native surface quality cuts polishing, cutting, and metallization steps. Looking ahead, wider ribbons, tighter thickness control, standardized thin-membrane/interface tests, and streamlined interlayers/metallization will further ease adoption. As device teams integrate these ribbons into SOEC stacks, lithium-metal batteries, RF/power electronics, and acoustic modules, the combination of volume, lower footprint, and new form factors should accelerate the path from materials innovation to manufacturable products.

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