Water-Based Tape Casting Process: An Environmentally Friendly Process for Mass Production of Ceramic Substrates for Electronic Applications*

SEDAL has been involved for the last years in the optimisation of the water-based tape casting process to produce high-quality ceramic substrates for electronic applications. Water-based tape casting is a low-cost and especially an environmentally friendly process. But its main difficulty relies on the drying conditions and controlling the thickness of the tapes obtained, among others. Therefore, its mass production is a difficult task for the ceramic substrate's industry and the main reason for which the organic-solvent-based tape casting process predominates, even its complex installations, high cost and harmful effect on the environment. SEDAL optimised the water-based process for different thicknesses of alumina 96 substrates for mass production in the range 0,3–1 mm. The company can produce high-quality ceramic substrates that accomplish state-of-the-art standards required by electronic applications. Some results of SEDAL's ceramic substrates obtained in the mass production using the water-based tape casting process are shown.

Introduction

Tape casting process is a widely used process to produce ceramic substrates for electronic applications. Tape casting can be a water-based process or an organic-solvent-based process, the last one using as organic solvent methyl ethyl acetone or toluene, among others. The water-based process gained interest in the last years due to its lower toxicity and environmental safety REF [1–5] and many works have been dedicated to the slurry formulations and characterisation REF [5–7]. But despite the benefits for the health and environment, water-based slurries are more complex due to their high drying time having a smaller tolerance to changes in the slurry and process conditions. That is why tight tolerances within the thickness represent a challenge for all tape casting community.

SEDAL's goal is to produce in mass production alumina 96 substrates for electronic applications, square shape of 114 mm × 114 mm (4,5 in) and/or 127 mm × 127 mm (5 in) among others and a thickness range between 0,38–1 mm. The process SEDAL has chosen to produce substrates in mass production is a water-based process, which has shown up as an environmentally friendly process for water insensitive materials such as oxide ceramics (alumina, zirconia). The process turned out to be a valid alternative to organic-solvent-based processes REF [8, 9]. When an organic-solvent base is used, the toxicity of the process is higher, not only for the environment, but also for the staff involved. For instance, the equip-

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**Paper will be presented at ceramitec conference 2021* ment associated is more complex and has higher cost. SEDAL developed and optimised the water-based tape casting process for mass production of substrates with different thicknesses required by the market: 114 mm × 114 mm × 0,635 mm; 127 mm × 127 mm × 0,635 mm, but also with lower thickness such as 0,38 mm in different sizes.

Raw material and slurry preparation

The production of ceramic substrates started with the preparation of the raw material, which was an alumina 96 produced by SEDAL i.e Sedalox-WS. The starting powder was obtained by mixing different raw materials such as kaolin, talc, and alumina which were later spray-dried to get a homogeneous composition of each granule.

The second step consisted in the slurry preparation using water as solvent. Sedalox-WS was mixed with water and additives such as antifoam agents, dispersants, etc. by using a horizontal ball mill. The milling time depended on the quantity of slurry prepared, in the range of 3–7 h. The particle size of the alumina 96 slurry was in the range of d_{50} = 1,5–2,4 µm. Once the mixing step was completed, the slurry had to be bound in order to get a high strength, high flexibility and elasticity of the resulted green tape. By that, the tape could be removed safely from the carrier substrates and rolled up without breaking, withstanding the post processes such as cutting, dimensional control and handling for debinding and sintering. The authors used aqueous-based acrylic emulsion binders as well as other additives to improve the green tape flexibility.

Previous to the binding process, the slurry was sieved by an 100 mesh sieve with the aim to eliminate any agglomerate or hard particles that could exist within the slurry. The binders were added to the slurry to avoid the air created during mixing to be entrapped within the slurry which could result in pores, higher roughness of the substrate surface and reduction of material properties. Once completed the binding process, the slurry was maintained into homogenisation at slow mixing and under vacuum for several hours, time also depending on the quantity of the prepared slurry.

Tape casting

The tape casting equipment was custom-made and developed for SEDAL (Fig. 1). The total length of the machine was divided in three heating areas where the tape was dried gradually. Each area was optimised to a temperature for an efficient tape drying. Green tapes were casted with a doctor blade at a speed which is spanning in the range 40–75 mm/min onto a mylar tape of 0,188 mm which was pre-coated with a Si-layer to avoid sticking. The thickness of the wet green tape depended on the final size spanning from 0,42–1 mm. The wet tape was slowly dried to the temperatures defined and optimised within each heating zone.

The process allowed that, when the green tape was out of the last heating zone, before cut into right dimensions and rolled on, there could be obtained a green tape with a humidity less than 1 %. For the company's process, this was a safe humidity in order to avoid breakage, sticking, deformation, etc. The maximum speed which has been achieved up to now within the actual configuration of the machine in mass production was 75 mm/min. The rolled-on tape was later cut into the desired length.

The produced green tapes with a thickness of 0,74 mm were afterwards submitted to

Fig. 1
Continuous production of green tapes in the SEDAL facilities

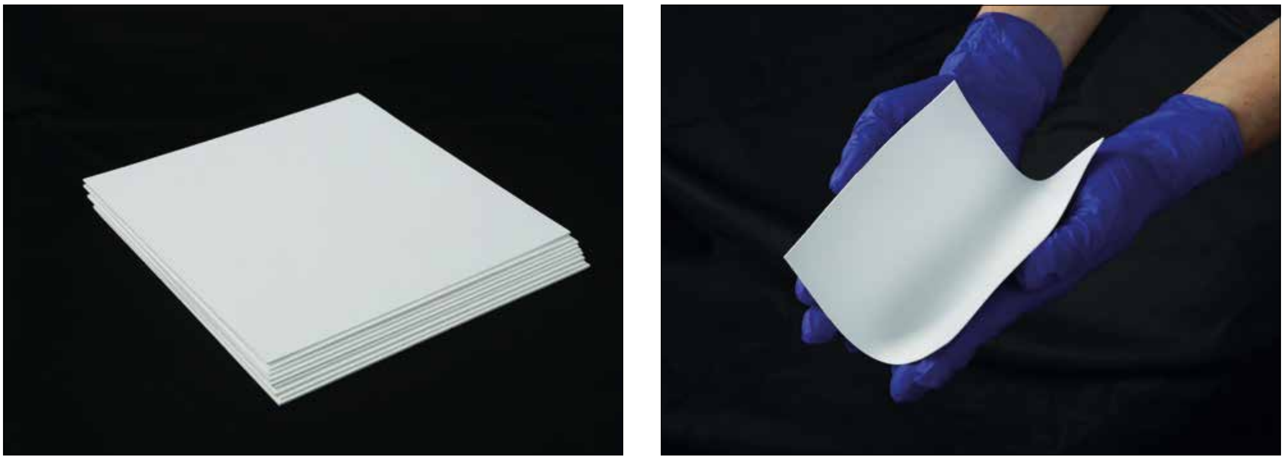

Fig. 2
Green tapes

Fig. 3
Sintered tapes

Tab. 1
Substrate parameters measured applying standards

Property	Test Condition	Value	Standard
Material	–	96 % alumina	–
Colour	–	White	–
Alumina content [mass-%]	–	96	–
Density [g/cm^3]	–	3,75	ASTM C20
Water absorption	–	0	ASTM C373
Bending strength [MPa]	–	330	ASTM F417
Coefficient of Linear Expansion (COE) [10^{-6} K^{-1}]	25–600 °C	6,7	ASTM C372
	25–600 °C	7,5	
	25–1000 °C	8,2	
Thermal conductivity [W/m·K]	15 °C	24	ASTM C408
Breakdown voltage [kV/mm]	–	15	ASTM D149
Surface roughness (R_a) [µm]	Profilometer	0,33	–

a debinding and sintering process. These two thermal processes were optimised to be done in one single process in a continuous electric kiln using specific refractories that have been carefully designed to avoid deformations, scratches on the tape during sintering, cross contamination, etc.
Fig. 2 shows the green tapes, Fig. 3 shows the sintered substrates obtained through the water-based mass production tape casting process. A flexible, high strength and free-defect tape can be obtained.
The as-fired substrate parameters are depicted in Tab. 1, where most critical parameters required for the electronic substrates are characterised: density, water absorption, bending strength, COE, breakdown voltage, thermal conductivity, and surface roughness (R_a). Tab. 1 also shows the standards under which each parameter was determined along with the technical specification required according each standard. All parameters obtained for the final substrate accomplished with the standard GBT 14619-2013, alumina ceramic substrates for thick-film circuit.

Conclusion

SEDAL is able to produce alumina 96 substrates with different thickness and dimension (width and length). Future focus will be to increase the production capacity by enlarging the machine and increasing the speed of casting and working on optimisation of the alumina 996 substrates process.

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