ACCUMET

Tech Brief

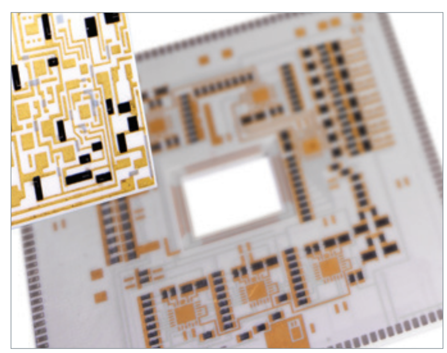
A Pre-metallization Guide to Lapping and Polishing Ceramic Substrates

INTRODUCTION

Lapping, polishing, and grinding are machining techniques that refine a substrate to exact dimensions and tolerances for optimal circuit metallization during both thick and thin film technology procedures. Because the "as-fired", or as delivered, condition of ceramic, fused silica, or titanate substrates are most often imperfect (wavy, pitted, bumpy, varied in thickness), one or more of these processes is employed to create the exact parallelism, camber, thickness, and surface finish needed. Designers working in high power, and/or high frequency microwave applications, for example, require their ceramic substrates to be consistently reliable and repeatable to meet the quality standards of their scrutinizing instrumentation, test and measurement, commercial communications, military radar, and aerospace customers. To do so, an optimal base substrate is key. In this brief our primary focus will be on lapping and polishing.

Why Lap or Polish Ceramic Substrates?
There are several justifications for lapping and/or polishing the ceramic substrates for your microelectronic circuits. Some of these considerations include achieving consistency from part to part, as well as meeting tolerance requirements for specific yield levels needed in thick or thin film device fabrication. For instance, the camber or flatness tolerance of a substrate may impact the resolution of the trace tolerance during the transfer of the photomask onto a substrate. Additionally, for high power and high frequency applications, the substrate itself becomes a significant contributor to mechanical, thermal, and electrical behavior.

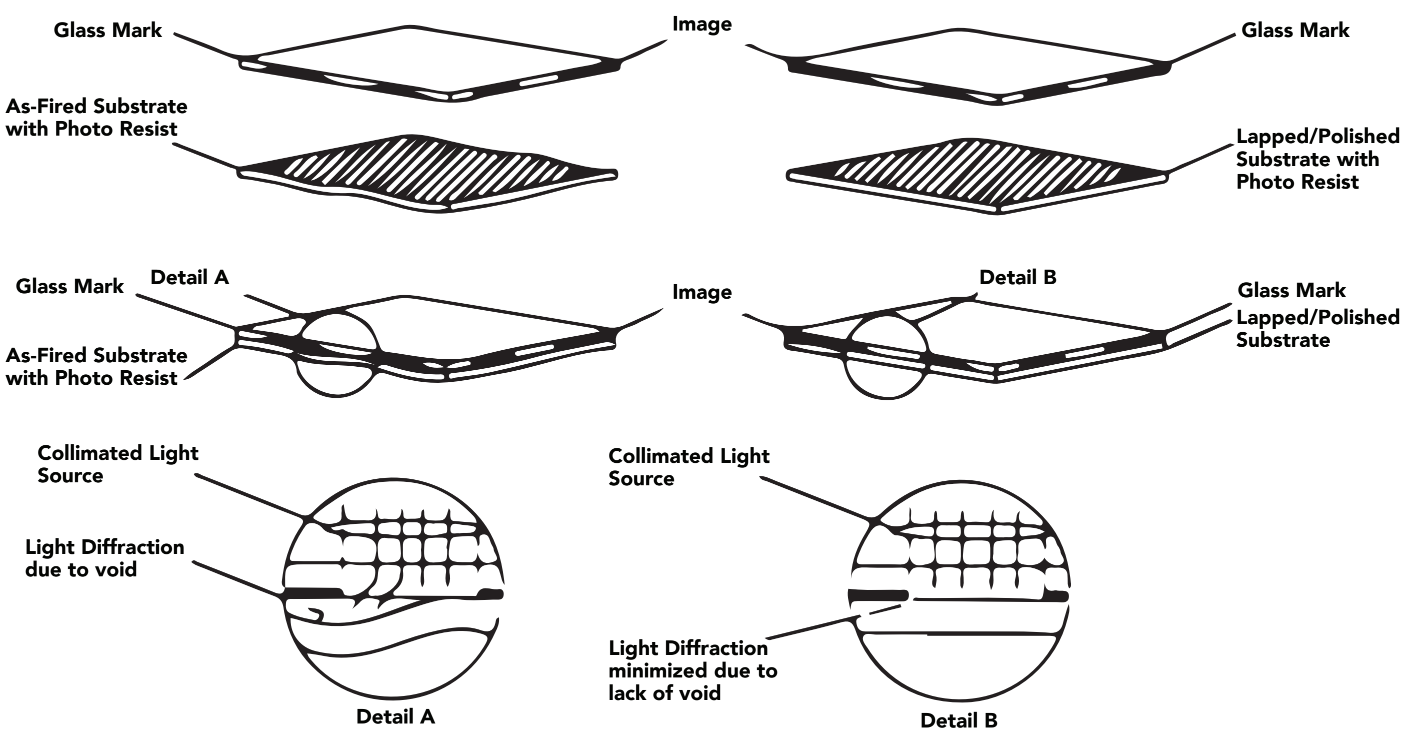
For example, inductors and capacitors are highly influenced by the dielectric permittivity and magnetic permeability properties of a substrate. Moreover, the exact electrical performance of these components depends upon the metallization developed on the substrate. Hence, the capacitance and inductance of an inductor or capacitor can be influenced by the parallelism, thickness tolerance, and flatness of the substrate. As these components are critical factors in filters, power dividers, circulators, and impedance matching circuitry, the tolerances and behavior of the devices are directly related to the substrate condition.



Microelectronic Substrates
The most common materials that are lapped and polished are ceramic substrates, such as varying grades of Alumina, Beryllium Oxide, Aluminum Nitride, Fused Silica, and Sapphire.

The metallization step in thin or thick film can also be largely dictated by the surface condition of a substrate. For example, variations in the surface condition of a substrate can cause variations in trace thickness. This directly affects the resistance of the trace which can lead to poor thermal performance in high power applications. A better surface finish can also enable tighter metallization tolerances, leading to more densely patterned resistors, finer pitch spiral inductors, and generally higher density circuits.

Lapping, and to a greater extent polishing, reduces the peaks and troughs of an as-fired substrate's surface, and provides and the thinnest metallization possible. In the case of thin film resistors, the ability to produce thinner metallization allows for much higher resistances. When plates of material, especially larger boards, are manufactured, there are often variations from board to board. These variations could be in terms of waviness (or camber), non-parallel top and bottom surfaces, and porosity of the surface pits, voids, and scratches (See detail A & B). Lapping will address all these potential characteristics of as-fired material.



Lapping 101

The lapping process begins with precision equipment and a well-trained and skilled technician. Material can be lapped down to as thin as .003" with a tolerance as low as ± .0001". Materials as large as 16" square or diameter can easily be lapped. Flatness can be brought to within 0.0005", depending upon overall size and thickness. Surface finish or average roughness (RA) is achievable anywhere from 5 micro-inches average roughness to 60 micro-inches (RA). Depending upon the substrate material and customer requirements, different grades of grit, used at several different stages of manufacture are key in achieving quality product on a timely basis. The substrate material, the grit of the abrasive, the lapping technique and processing time are all contributing factors in achievable parameters.

Material	Virtually any type
Finish	Controlled finishes from 5 micro-inches to 60 micro-inches
Thinness Min.	Min. 0.003" up to almost any desired thickness
Thickness Tolerance	Tolerances on thickness held as close as ±0.000025" (industry Standard Tolerance .0005")
Flatness	Can be held within the Helium light band range (11.6 millionths of an inch equals 1 band). Industry standard flatness is 0.0005"
Parallelism	Can be held within 0.000010" (ten millionths of an inch)

Lapping
Ultra precision initial step, possibly after grinding, in preparing materials from 6 micro-inches to 60 micro-inches on metals (ferrous and nonferrous), carbide, ceramic, sapphire, BeO, AlN, 99.6% Alumina, and other materials for industrial and scientific applications as well as for microelectronics. (6u-in = 0.000006")

Polishing 101

The polishing process is used as a good second step to further tighten the tolerance on thickness and surface finish. The surface finish tolerance limit with polishing is dependent upon the structure of the material used. This is why certain materials lend themselves to different applications, dependent on surface roughness. For example, low density 96% alumina can be lapped to 20 micro-inches and polished to less than 5 micro-inches, nominally. High density 99.6% alumina can be lapped to 10 micro-inches and polished to less than 1 micro-inch, nominally. Thickness tolerances with polished substrates can be brought down to ± .0005" or even lower, for especially demanding applications. Material defects, such as pits, can typically be lessened to a minimum diameter of 0.0125" for 99.6% alumina and even lower for other materials. Accumet's micro-fine polishing process can further reduce a pit diameter down to 0.01" for 99.6% alumina, and further for other material.

Material	Surface Finish (u-inches)	Thickness Tolerance (typ)	Applications
Polished 99.6% Alumina	Less than 1u-in	±0.0005"	Used for low to medium power RF & Microwave circuits
Polished 99.5% Beryllium Oxide	Less than 4u-in	±0.0005"	Used for high power DC/RF/ Microwave circuits
Polished Aluminum Nitride	Less than 2u-in	±0.0005"	Used for high power DC/RF/ Microwave circuits
Polished Fused Silica	Less than 1u-in (60/40 optical)	±0.0005"	Used for high frequency circuits requiring extremely low loss of performance
Polished Sapphire	Less than 1u-in (60/40 optical)	±0.0005"	

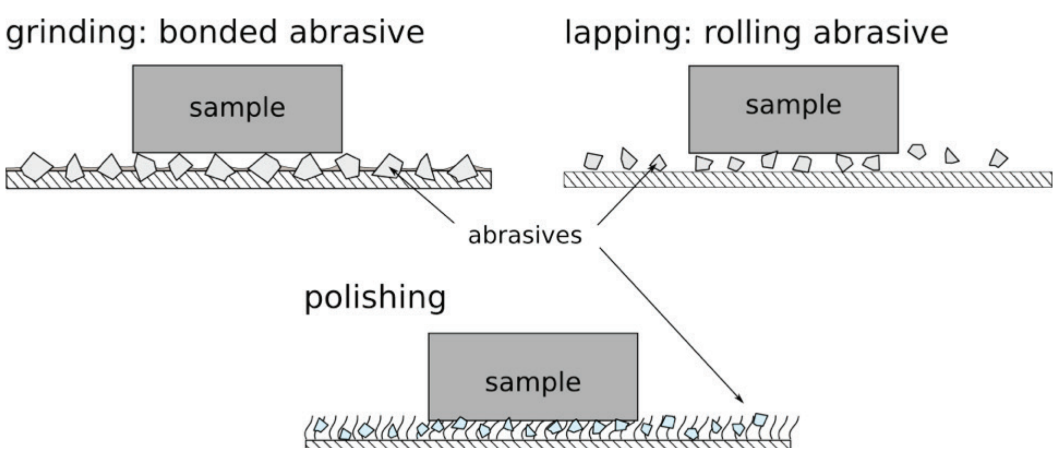
Accumet is the pioneer of the lapping and polishing process and took the polishing process to the next level.

Polishing

Ultra precision second or third step for further tightening tolerances from 0.1 micro-inches to 5 micro-inches on metals (ferrous and nonferrous), carbide, ceramic, sapphire, BeO, AIN, 99.6% Alumina, and other materials for industrial and scientific applications as well as for microelectronics.
Note: (1u-in = 0.000001")

When to Lap, Polish, or Grind

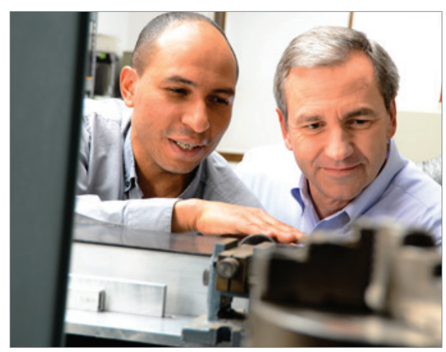
Typically, the end application and technology requirements dictate the optimal surface finish and thickness tolerance. If the application requires a surface finish greater than what can be achieved with grinding, the next steps are lapping then polishing (if needed). Common applications where the additional precision of the surface finish and thickness are more critical are high frequency RF and microwave, high power, and optical applications including infrared, visible, and ultraviolet (UV). Other applications that require extreme surface finish requirements, thickness tolerance, and identical consistence from part to part are direct chip attach on boards (COBs), multichip modules (MCMs), and systems in package (SIP) technologies. The continual densification and miniaturization of monolithic microwave integrated circuits (MMICs), chip capacitors, chip inductors, chip resistors, filters, and other microwave and power components is also driving the need for tighter control over surface finishes and substrate thickness.



For much smaller dimensioned thin film applications, a surface finish tolerance of less than 5 micro-inches may be required. This is achievable by selecting 99.6% alumina as the base material with the added process step of polishing. For even finer finishes for thin film substrates, even more advanced polishing may be necessary. Methods such as Accumet's micro-fine polishing process, can bring the surface finish for 99.6% alumina down to less than 1 micro-inch RA, and BeO to less than 4 micro-inch RA. For optical applications, fused silica substrates will need to be polished to achieve 60/40 scratch/dig tolerances.

CONCLUSION

Many market segments, from military and avionics to commercial and communications demand precision substrates. The surface finish, thickness, parallelism, and defect tolerances of the substrate material are all critical in the design of the end product. Lapping and polishing processes help to ensure that these substrates are machined to the precise metrics necessary to fulfill the demanding requirements of the space, defense, scientific and commercial technologies. When necessary, greater precision polishing techniques exist to enhance the surface finish and thickness tolerances to the grade necessary to meet the needs of the next-generation of highly advanced microelectronics.



Next Steps:
Learn more by downloading this piece of related content: 5 Keys to Successful Processing of Ceramic Substrates Brief.

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