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This issue of Tech Topics is devoted to a discussion of the two distinctly different layering methods currently in use in the manufacture of multilayer ceramic capacitors.

Both methods have their proponents and detractors. We hope a review of their arguments will be of interest.

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"Wet Vs. Dry" Multilayer Ceramic Capacitor Manufacturing Processes

The heart of a multilayer ceramic capacitor (MLC) is a layered monolith of dielectric ceramic and electrode metals as shown in expanded form in Figure 1. The ceramic monolith has terminations added to provide the finished capacitor shown in a cut-away view in Figure 2.

KEMET, like the majority of today's MLC manufacturers uses a "dry" or "tape" process for stacking the layers in the MLCs following the process steps shown in Figure 3. That is, we make a green ceramic sheet as a discrete process step, by casting and drying a slip made of ceramic powders and organic binders. Electrodes are printed on the sheet and layers of the sheet are stacked to form a "pad" of capacitors as a subsequent step or steps. The pad is laminated under heat and pressure, then diced to yield the individual green (unfired) ceramic chips. The electrodes and the ceramic fuse into a monolith during the subsequent firing process.

A significant volume of MLCs, however, are manufactured by "wet" processes where the pad is constructed directly from alternate applications of a ceramic slip and electrode ink using techniques such as screen printing. Drying steps occur between each layering step (Figure 4). Subsequent steps are similar in both processes. Obviously, there are numerous variations, manufacturer-to-manufacturer within the two genetic processes.

"Which is the better process?" is a natural question. Obviously, there is no clear answer or all manufacturers would have elected the same process. Also, it is clear that manufacturers using the "wet" process would promote its advantages. Those using the dry process would do the same. To the user, the result is unclear.

A few things are clear, however.

1) Excellent capacitors can be made by either process.
2) Public perceptions of product performance differences originate primarily from individual experiences with individual manufacturer's product not with generic process differences.
3) Neither process is ideal. They are different. Both processes have advantages and disadvantages.
4) The key to excellence lies in understanding and control, not the process itself.

Proponents of the wet process point out two primary advantages: green layer bonding, and the capability for constructing a single layer with multiple depositions of dielectric material.

The layers in the wet process adhere to each other in the green state very much like coats of paint with the solvents from the new layer interacting with the layer below to promote adhesion. In the dry process, basically ceramic (or metal) loaded plastic is laminated together to make the coherent green body.

Dry process layers must have sheet strength properties to withstand handling in a freestanding form. Wet process layers are constructed in situ. It is possible, then to use 2 or 3 separate very thin depositions to build up a single wet process layer. The effect of a pinhole or other defect in a single deposition is thereby minimized. Similar means for compensating for defects in a single as-constructed layer are feasible in dry processes but are more cumbersome. The proponents of the dry process in turn also point out two advantages; the ability in the process to inspect and remove misformed dielectric or electrode layers and the uniformity of the process.

The dry process permits individual electrode or ceramic layers, which are defective to be rejected prior to the stacking process. In the wet process, once a layer is made, it is an integral part of the semi-finished pad. The setting of high expectations for dielectric layer and electrode print quality is more achievable with the dry process.

In the dry process, typically each dielectric layer and each printed electrode experiences an essentially identical process: casting, drying, electrode printing, drying. Initial wet process layers in a stack experience more wetting and re-drying steps than layers deposited later.

There are, however, perhaps two major advantages, which explain the relative popularity of the dry process:

1) **Dielectric Thickness Control/Capacitance Control**
Continuous casting of green sheet lends itself to controls that lead to very uniform dielectric layers. Uniform green dielectric layers in turn assist capacitance target control. Wet processes in manufacturing have so far not exhibited similar uniformity of dielectric layer thickness.
2) **Manufacture of Very Thin Dielectric Layers for Low Voltage and High Capacitance Products**
Published articles (1,2) by other MLC manufacturers mirror KEMET's experience in indicating that the dry process has strong advantages in making capacitors with large numbers of very thin dielectric layers. The referenced articles de-

scribe two manufacturers' experiences in using the dry process to make MLCs with 5 - 6 µm thick dielectric layers.

KEMET's experience is similar. As part of its efforts in evaluating alternative technologies, KEMET developed a prototype line for manufacture of wet process capacitors with large layer counts and a 10 µm target dielectric thickness. Dielectric layer thickness control proved to be unacceptable at high layer counts. Through this process line and other studies we were also able to make other comparisons. Ceramic layer bonding in fired capacitors (of either process) was not found to be dependent on generic process, but was a function of contaminants trapped between layers. Voltage breakdown characteristics, a measure of defects in dielectric layers were primarily determined by materials preparation processes, not layering methods. In fact, as these processes have improved, manufacturers have been able to gradually increase their design voltage stresses on the dielectric layers.

In summary, dielectric thickness control particularly as the industry proceeds toward thinner dielectric layers favors the dry process. From an MLC users point of view, the best part is manufactured by a manufacturer who demonstrates high regard for cleanliness, workmanship, consistency, and process control. These are obtained by the manufacturer's understanding and familiarity with the advantages and disadvantages of his process and material system. Wet or dry is not an overriding factor.

Reference

1. 5. Saito, *IMC 1988 Proceedings*, Tokyo, May 25-27, 1988, p. 211-218
2. J. Borzych, et al, *ECTC 1991 Proceedings*, Atlanta, May 13-15, 1991, p. 442-445.

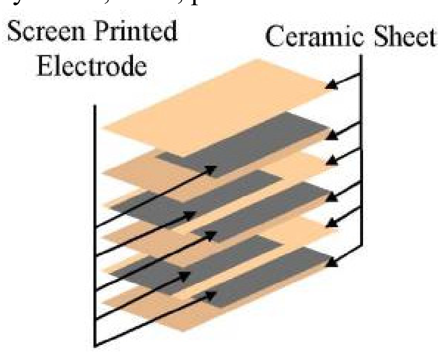

Figure 1 **Expanded Multilayer**

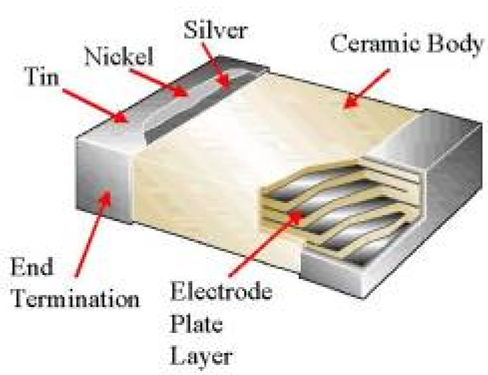

Figure 2 **Cutaway drawing of a Multilayer Ceramic Chip**

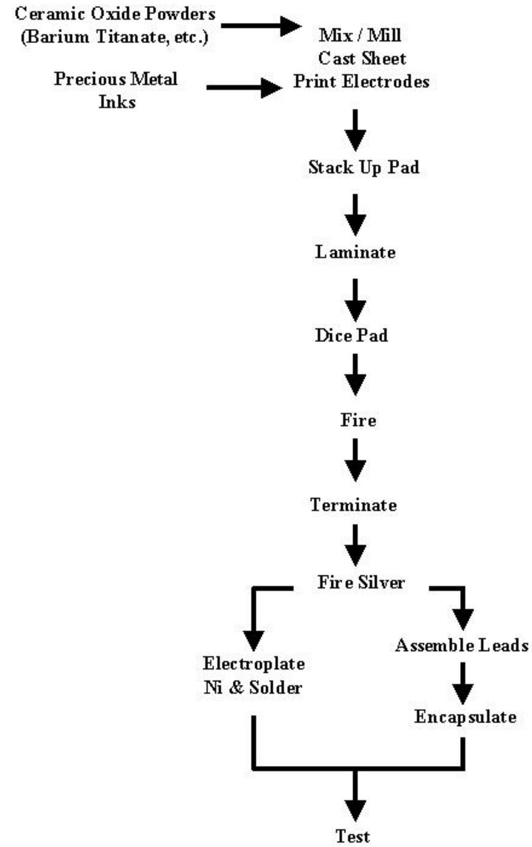

Figure 3 **Typical 'Dry" Ceramic Capacitor Process**

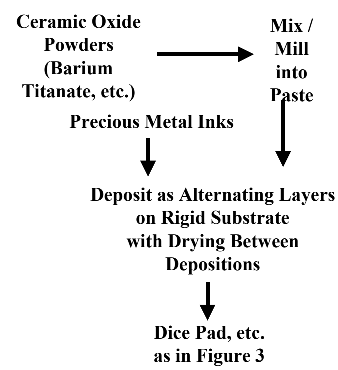

Figure 4 **Typical "Wet" Ceramic Capacitor Process**