

The Soft Substrate Option (Should You Break the Ceramic Habit?)

It ought to be possible to come up with a clear-cut and mathematically precise set of design rules that would tell us what material to use in any given microwave circuit design. This marvelous algorithm would allow a designer to go directly to Design-to-Market.com® (the soon-to-be online data base based on the IWPC EPDeS Project), pull out the materials data files from the various suppliers' websites and based on his design criteria and cost constraints have the optimum material for his design pop up almost instantaneously and automatically cascade the relevant data and Arlon part numbers down into his CAD software. That would end once and for all the angst that faces the designer every time he has to make a choice between ceramic and soft substrate materials for a millimeter wave or other high frequency design requiring high Dk material.

Between now and when that idealized merge of on-line data and fully compatible integrated design software becomes an everyday reality what can our hypothetical designer do? (Don't laugh – it's being worked on seriously by some of the best brains in the industry! Some details of the scope of data needed remain to be worked out between the design and material communities. Also there is the ancillary issue that in all the models so-far proposed by the OEM's and major PWB producers "Copper Clad Cardboard" laminate automatically pops up as the cost-performance first choice regardless of the actual technical requirements of the system.)

Meanwhile designers continue to design and both ceramic and soft substrates such as Arlon's AR-1000 (Dk 10) are available -- so there need to be some guidelines to help designers make an early and cost-effective choice of materials. There is good news and bad news on that front. The good news is there are clear-cut differences between soft substrates and ceramics that can help make that decision. The bad news is that it won't necessarily always lead to choosing the Arlon AR-1000 product. Ceramic materials have certain thermal, mechanical and electrical properties that are excellent despite the offsetting fact that there are cost and ease of handling factors that clearly favor soft substrates.

Let's look at the areas where soft substrates have a definite advantage. (Note the subtle technique of the soft substrate supplier touting the benefits of soft substrates first, so they will stick in your mind!)

1.) The use of a soft substrate (AR-1000) in a circuit almost always will be less costly than the use of an alumina ceramic product with an equivalent dielectric constant of around 10. While cost is tricky to tie down because it depends on the specifics of design and the various board suppliers' relative expertise with the different materials, the consensus is that on an "Apples to Apples" basis, soft substrates usually are lower cost in finished delivered circuits. Also in most cases the cycle time from design to prototype is much shorter for soft substrates through conventional PWB process.

2.) Soft substrates such as Arlon's AR-1000 are made from PTFE (Teflon®) with a ceramic filler loading to impart a controlled dielectric constant and low loss, and contain a woven fiberglass reinforcement that provides excellent physical stability, while ceramic materials shrink as much as 12-15% during firing in the LTCC process. Use of high temperature fired ceramic with copper plating eliminates shrinkage as an issue, but may be higher in cost.

3.) Soft substrates are relatively "flexible" and are forgiving of most physical abuse during processing and handling as well as in-use. (A ceramic panel that falls on the floor during process becomes a pile of "dumb chips.") Soft substrates also withstand much higher levels of shock and vibration. One of the drivers for the development of some of the first generation Dk 10 soft materials in the 1960's was that the G-forces that Navy jets encountered while "landing" on carriers (which is really executing controlled crashes) frequently damaged or destroyed the ceramic circuit boards then in use in certain on-board electronics.

4.) Soft substrates are based on coated glass fabric technology that enables us to make it available in large sheet sizes (up to 36" x 72") that can be processed through standard PWB processes. A lot more circuits can be made on a standard 12" x 18" or 18" x 24" panel of AR-1000 in a conventional PWB shop than can be made on a 6" x 6" or 8" x 8" ceramic piece, all other things being equal. This has a potentially large cost impact in high volume applications such as circuits for cellular phone boards.

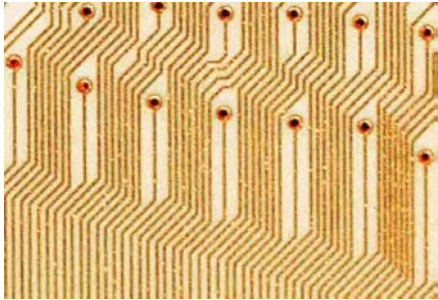
That being true, why would anybody choose to use ceramic material over the lower cost, easier to process soft substrate? Well there are several characteristics of ceramics that are not able to be duplicated readily (if at all) in soft substrates.

1.) Many ceramics have very low loss. High temperature fired alumina can have losses in the range of 0.0004 compared to 0.003 for AR-1000. LTCC's (Low Temperature Cofired Ceramics) will still have values typically at or around 0.001. Alternate materials being considered, such as liquid crystal polymer materials, may have low loss but will not have the thermal and mechanical stability of ceramic.

2.) Most ceramic materials have fairly high inherent thermal conductivity compared to soft substrates. Fired alumina ceramic can have a thermal conductivity up to 25 W/m-°K and LTCC 4 W/m-°K compared to about 0.25 to 0.3 W/m-°K for FR-4 and 0.65 W/m-°K for AR-1000. There is some debate about the significance of this, but in instances where

there are not thermal vias to remove the heat (Cu has a thermal conductivity over 400 W/m-°K) ceramic will diffuse heat much better than soft substrates.

3.) Ceramics have values of CTE (Coefficient of Thermal Expansion) as low as 6 ppm/°C which permits them to be expansion-matched with low-expansion chip materials such as pure silicon or gallium arsenide (near 4 ppm). While there are low expansion soft substrates such as those based on Thermount® or woven Kevlar®, none of them currently match the Dk of the ceramic.



4.) Thin film techniques or advanced LTCC (low temperature cofired ceramic) methods can produce circuits with very fine lines and spaces (25 and 50 micron) to take advantage of the opportunity to miniaturize complex circuitry. While the actual miniaturization depends on the dielectric constant, the fine line and LTCC processes permit better resolution than the norm for conventional PWB processes.

5. While soft substrate materials with dielectric constant 10 (and 6) are commonly available, ceramics may be available with much higher values, over 1000 if necessary.

With apologies to our colleagues in the ceramics business, we have oversimplified here to try to give the designer tools to make an initial cut. We generally talk about cost per panel or per square foot, while ceramics people talk in terms of price per square inch. Because it is not clear that there is a single clean cut “choice” between ceramic and soft substrates, We believe that there will be a substantial long-term need for both materials in various parts of the microwave and millimeter wave world. While in the long term the decision will be – as always – one of cost-performance, cost and price are best discussed between the designer and his board supplier since they are very much dependent on the design of the board rather than being simple multiples of raw material cost.

Above all, we would encourage you to look critically at the “design rules” you are using now. Are you using ceramic as a matter of inertia because that’s what you’ve always used and you are comfortable with it? Or are you using it because your designs really need their unique combination of properties? Could you try a soft substrate? Have you tried a soft substrate? Some major OEM’s have done so, and switched to soft substrates for high power amps and other applications with good success and serious cost savings.

We would like to hear from you, our readers, concerning this issue. How do you make these choices? Are there already in place some “design rules” that enable you to make this differentiation? If so, we’d like to hear from you, because we are actively involved in the industry-wide process of trying to establish a protocol for on-line data presentation (that’s those “best brains in the industry” we mentioned earlier) and do not yet understand fully what information you need or how to present it to be of most benefit to you.

Keep those e-cards and e-letters coming.

