Ceramic Multilayer Integration of Power Electronic Capacitors and Inductors

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Low temperature cofired ceramic (LTCC) circuit boards have passed a number of evolutionary phases since their invention. Their mechanical and thermal robustness was initially exploited for printed wiring boards in mainframe processors and automotive electronics. Excellent high frequency properties later paved the way into passive integration of distributed RF components and intimate combinations of passive and active functions in system-in-package (SIP) modules, e.g. for military and civilian communication systems. Furthermore, the relatively high ceramic permittivity conveniently leads to miniaturization of distributed, wavelength-related RF components. The SIP idea has recently been introduced back into medium power electronics, where it has spurred the development of new materials and processes. Different from RF, this field deals with lumped components at lower frequencies and miniaturization is pursued by embedding, i.e. by moving components from the surface into the board volume. While RF works in homogeneous dielectric multilayers, the higher currents, voltages, and electrical sizes of power components enforce the combination of materials specifically optimized for each function, e.g. ferrites for inductors and dielectrics for isolation and capacitors.

The performance of capacitive and mainly inductive power components will be discussed in relation to their materials properties. To this end, single ferrite-embedded power line inductors, ferrite-embedded transformers and dielectric-embedded transformers with external ferrite core were fabricated from NiZnCu and MnZn ferrite tapes, which were recently developed for LTCC-based switched mode power supplies with switching frequencies in the lower MHz range. Such components find increasing in-house interest for a number of applications, particularly lighting. The sintering temperature of the ferrite materials was reduced to 900°C by optimizing powder milling, sintering additives and sintering profiles.

The measured device characteristics will be shown to reveal materials properties as well as generic and indispensable design rules beyond those accessible by standard ring core measurements as a basis for the structure and the technology of power electronic SIP modules. The current capacity of embedded inductors is determined by self-heating, ferrite conductivity and magnetic saturation. In transformers, stray capacitances appear tolerable but a shaped ferrite core is mandatory for low leakage inductance. Magnetostriction yet challenges mixed dielectric-ferrite integration, but this will be ultimately required to handle conductor isolation, flux shaping, and inductor-capacitor combinations.