High Power Multilayer Co-Fired Step-Up Piezoelectric Transformers

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Electromagnetic transformers (EMT's) belong to the larger and heavier side of the electronic components scale. As the size and weight requirements become more restrictive in the electronics industry, simply building more compact EMT's is not a viable option due to their efficiency problem. Piezoelectric transformers (PT's) are scalable and they can sustain their performance even in small scale due to their solid-state nature. However, PT's are not as cost effective as EMT's. Therefore, despite the high potential of PT's, their application is still limited.

As a high power application, PT's require the use of hard-piezoceramics (e.g. hard-PZT). Hard-piezoceramics have high processing temperatures (>1100˚C). Combination of multilayer technology with PT's improves the achievable power level. On the other hand, co-firing metallization is pretty much limited to quite expensive platinum (Pt) at hard-piezoceramic processing temperatures. If alternative electrode materials can become an alternative to Pt, not only the cost would go down significantly but also the practical PT performance could be increased due to decreased ohmic losses. Ag/Pd or Ag metallizations are popularly utilized for piezoceramic systems with low sintering temperatures for ambient conditions.

Yet, very attractive Cu metallization oxidizes under typical sintering conditions and reducing atmosphere is needed to keep Cu in the metallic form. In short, integration of base metal electrodes is a complex but solvable materials science and engineering problem considering the optimum cost/performance.[1]

As the first step, a commercially available hard-piezoceramic composition was chosen (APC 841, APC Int'l, PA, USA) and 1.1 wt% ZnO and 0.2 wt% Li_2CO_3 were added to lower the sintering temperature to 1000˚C. Initial bulk ceramics showed satisfactory high power properties (Q_m: 1000, k_p: 0.62, tan δ: 0.005, and K: 1000). Then ring-dot, step-up, and multilayer PT's were prototyped with 90/10:Ag/Pd co-firing. These PT's possessed power density levels around 40 W/cm^3 with high efficiencies ($P_{out}/P_{in}\geq 90\%$), 30˚C temperature rise, and a step-up ratio of 20.

By using these results as a benchmark, effect of the metallization thickness on ohmic losses due will be discussed for these PT's with high motional current and capacitance.

References

[1] C. A. Randall, A. Kelnberger, G. Y. Yang, R. E. Eitel, T. R. Shrout, "High Strain Piezoelectric Multilayer Actuators - A Material Science and Engineering Challenge", *J. Electroceramics*, *14*, 177–191 (2005).