

## Low Loss Dielectrics Based on Rare Earth-Modified Zinc Borates

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Low loss dielectric properties of zinc borate glasses modified with rare earth oxides ( $\text{La}_2\text{O}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Sm}_2\text{O}_3$  and  $\text{Gd}_2\text{O}_3$ ) were investigated for the purpose of developing a new low temperature co-fireable system. The lanthanum borate-based LTCC has been reported to provide unusual high quality factors after firing at 850°C. Several different batches of glass consisting of 60 mol%  $\text{B}_2\text{O}_3$ , 20 mol%  $\text{ZnO}$ , and 20 mol% rare earth oxide, i.e.,  $\text{La}_2\text{O}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Sm}_2\text{O}_3$  and  $\text{Gd}_2\text{O}_3$  were successfully prepared via the typical glass melting / quenching procedure. A fixed amount of 50 wt%  $\text{Al}_2\text{O}_3$  filler was then admixed with the glass to produce final samples. As a specific example of optimized dielectric characteristics, a high quality factor of ~1,090 and a dielectric constant of 8.3 were obtained at ~ 17 GHz for the lanthanum zinc borate materials. Understanding the influence of rare earths on microwave dielectric properties and crystallization behavior of zinc borate dielectrics is the main purpose of this presentation.

**Keywords:** low loss, microwave dielectric,

## Compatibility and Physical Properties of Protective Thick Films for Planar Heating Elements

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Planar heating elements have been spotlighted since their 20~40% lower power consumption is possible compared to conventional linear heating elements. High thermal conductivity of the planar package, which is required for effective operation of the heating elements, has been one of the critical properties since it lessens the power consumption of heating element. Recently, several materials, which are non-metals, i.e., SiC, MoSi<sub>2</sub>, LaCrO<sub>3</sub>, C, and ZrO<sub>2</sub>, were reported as candidates for heating elements. In this work, the compositions and properties of thick film over-coating layers deposited on 96% Al<sub>2</sub>O<sub>3</sub> substrate, which is needed to protect or buffer the MoSi<sub>2</sub>-based heating element from thermal shock, have been investigated over the testing temperatures of 500 to 800°C by focusing on mechanical and thermal stability. For the thick films, borosilicate glass was admixed with high thermal conduction fillers to optimize TCE and thermal conductivity. Good integrity between the thick films and substrates led to promising results on sustaining heating performance without mechanical breaks up to 800°C. The high thermal conduction filler is believed to be responsible for the promising observation.

**Keywords:** Planar heating element, BN, thick film, thermal conductivity