From high to low permittivity glass-free materials for LTCC technology (Invited)

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In the last twenty years, a rapid development of various electronic devices (mobile phones, wireless local areas networks-WLAN, Bluetooth, etc.) for wireless communication has taken place. Such a progress led to the development of new materials and technologies, which enabled size reduction and increased functionality of various electronic components. Low Temperature Co-fired Ceramic (LTCC) technology has met the demands of miniaturization and integration by fabrication of 3-dimensional modules with integrated passive electronic components (capacitors, resistors and inductors). Because these modules are fired simultaneously, the development of a mechanically stable multichip LTCC structure having desired electrical performance requires the knowledge of chemical compatibility of the ceramics, their sintering behaviour as well as the dielectric and thermo-mechanical properties. This presentation elaborates the development of several glass-free LTCC materials in our Advanced Materials Department in the last two decades exhibiting a permittivity in the range from 5 to 90. In the first part of this presentation, an example of the combination of high and middle permittivity materials based on the system Bi_2O_3-Nb_2O_5, designed for the LC-filters is discussed. The multilayer structure of this LC-filter will be used as a model for exemplify the important issues related to the matching of materials in terms of their sintering behaviour and thermal expansion. The second part of this presentation will discuss the development of low-permittivity substrate LTCC materials. Because of the rigorous requirements for the electrical, mechanical and chemical properties, various materials have been studied. The first group of low-permittivity materials with promising dielectric properties (ε~6, Qxf> 100.000 GHz, τ_f = -20 ppm/°C) and sintering temperature ~ 900°C are based on gallogermanate-feldspars. In this respect, low price of the raw materials is often of high importance for practical applications. Thus, low permittivity materials based on the crystal structures of willemite (Zn_2SiO_4), scheelite, forsterite (Mg_2SiO_4) and wollastonite ($CaSiO_3$) were developed. Sintering at temperatures which meet the LTCC conditions was accomplished with additions of alkaline-earth oxides and/or zinc borates. The materials thus developed cover the whole range of thermal expansions coefficient (TCE) from 4-12 ppm/°C. Among these materials, willemite was used as a basis for the development of a low-permittivity material with low TCE (~4 ppm /°C), whereas a combination of scheelite and forsterite leads to a high TCE material (10-12 ppm/°C). Wollastonite based low-permittivity materials exhibited TCE of 5-7 ppm/°C. These materials exhibiting ε=7-9, Qxf=20.000-70.000 GHz and Ag-compatibility, are competitive with the commercially used glass-based LTCC materials.

Keywords: LTCC, glass-free, Ag-compatibility, high-low permittivity

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