A structural and dielectric characterization of $Na_xCa_{1-x}Al_{2-x}Si_{2+x}O_8$ ceramics

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The development of low-temperature cofired ceramic (LTCC) technology enables the miniaturization and integration of passive components in 3D modules. Due to their low permittivity (ε~7) and high Qxf value, recrystallized anorthite-based commercial tapes have been widely used as substrate materials.

Anorthite is the end member of the plagioclase feldspar structural family, with the general formula $Na_xCa_{1-x}Al_{2-x}Si_{2+x}O_8$. We attempted to prepare polycrystalline plagioclase feldspars by solid - state synthesis. The investigations of $Na_xCa_{1-x}Al_{2-x}Si_{2+x}O_8$ solid solutions revealed that both the plagioclase formation and the sintering temperature decreased with the increase in the Na concentration from the anorthite $CaAl_2Si_2O_8$; x=0), which starts to form at 1200°C and sintered at 1300°C, to the albite ($NaAlSi_3O_8$; x=1), with formation at 800°C and sintering at 1000°C.

Besides the change in the structure, which occurred due to variations of x in the $Na_xCa_{1-x}Al_{2-x}Si_{2+x}O_8$, great emphasis was placed on their dielectric properties. Dielectric measurements in the microwave (MW) and radio frequency regions showed that the permittivity of the $Na_xCa_{1-x}Al_{2-x}Si_{2+x}O_8$ did not change significantly with x. On the other hand, the variations in x had a large influence on the dielectric losses. The dielectric measurements in the MW region showed that $CaAl_2Si_2O_8$ exhibited the highest Qxf value (19000 GHz). A large decrease in Qxf to ~4500 GHz was observed when x increased to x~0.2. With a further increase in x to x~0.6, the Qxf increased up to ~12900 GHz. After x~0.7, the Qxf again started to decrease to ~4500 GHz at x=1. The variations in Qxf were correlated to the crystallographic data.

Although the Qxf of the plagioclases never reached the Qxf of anorthite, the plagioclase solid solutions approached the LTCC requirements, since the sintering temperature and the temperature coefficient of resonant frequency were lowered with the substitution, and came close to zero for solid solutions with $0.4 \leq x \leq 1$.