Microwave dielectric properties of spark plasma sintered dense and pure $CaAl_{12}O_{19}$ hibonite ceramics.

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Abstract: Dielectric oxide ceramics play a central role in the development of next-generation wireless communication technologies [1,2]. The fast growth of 5G systems requires materials with better performance than complex perovskites of the $Ba_3((Mg,Zn)(Ta,Nb)_2)O_9$ type, combining low permittivity and excellent quality factor ($Q \times f > 100{,}000$ GHz). Indeed, while low permittivity materials enable faster signal transmission; ideal ceramics should also exhibit a high $Q \times f$ and a near-zero resonant frequency temperature coefficient ($\tau f \approx 0$ ppm/°C). Calcium aluminates are attracting increasing interest due to their structural simplicity and promising dielectric properties. While data exists for $CaAl_2O_4$ [3], $Ca_3Al_2O_6$ [4] and $CaAl_4O_7$ [5], the microwave properties of $CaAl_{12}O_{19}$ (hibonite) have, to date, never been reported. Hibonite is the most aluminous compound in the $CaO\text{-}Al_2O_3$ system. Its hexagonal structure, thermal stability, high melting point (1850°C), and low coefficient of expansion make it an excellent refractory material. In this study, pure and dense hibonite ceramics were developed by plasma spark sintering (SPS) at 1700°C under 50 MPa. The relative density achieved was 99%, with a platelet microstructure favouring a fiber texture. Crystallographic analysis reveals a preferred <00ℓ> orientation with a texture index, F^2, of 1.63 m.r.d^2. Moreover, the sintered pellet is black due to oxygen vacancies. Oxygen annealing allows recovering the original white color. Microwave dielectric properties (ε_r, $Q \times f$, τ_f) will be presented for both black and white ceramics and will be discussed in relation to microstructure, phase purity and densification state. This study aims to explore for the first time the potential of hibonite as a dielectric material for microwave applications in advanced telecommunications.

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