Short Abstract

The development of 5G technologies, targeted at increasing data rate on a wireless communication network by a factor of 100, will impose on the radio frequency (RF) electronics some specifications such as large band width, high gain, temperature-independent performance, and small size. In millimeter-wave applications, especially dielectric resonator antennas (DRAs) are promising candidates to replace traditional radiating elements at high frequencies. This replacement is because the DRAs do not suffer conduction losses and are characterized by high radiation efficiency when appropriately excited.

The present thesis focused on developing pure and composite AlN ceramics for RF-window applications. RF window is an essential component of microwave tubes' output section like klystron, magnetron, and gyrotron. In high-power RF windows, basic problems are selecting window material, managing thermal and mechanical stresses, power handling capability, window flashing/ arcing, and physical damage. Optoelectronic devices contain specifical bandgaps of energies from the visible to UV region, which are theoretically possible by materials such as AlN, BN, GaN, and InN. These materials' wide band gap and strong atomic bonding make them suitable candidates for high-temperature and high-power devices. The pure and composite AlN ceramics are prepared using a solid-state reaction method by adopting a powder bed in conventional sintering at 1700 ℃. The structural properties are studied from XRD and Raman spectra. All pure and composite AlN ceramics exhibited pure wurtzite AlN phase without any secondary phase as oxides or alumina. The vibrational modes of all sintered pure and composite AlN ceramics confirm the wurtzite structure. Temperature-dependent dielectric properties are also measured. sintered AlN ceramics exhibited good microwave dielectric properties as $\varepsilon_r = 8.83$ and $\tan\delta = 2.69 \times 10^{-4}$ are suitable for RF-window applications. AlN-ZnO composite ceramics are studied by optimizing the amount of additive and its effect on structural and dielectric properties. The microwave dielectric properties of AlN-ZnO composite ceramics are as $\varepsilon_r = 7.20$ and $\tan\delta = 4.90 \times 10^{-3}$ for the best composite AlN-15ZnO ceramic. AlN-Er_2O_3 composite ceramics are prepared using a powder bed with pure wurtzite AlN phase in the conventional sintering method in nitrogen's presence. The AlN-Er_2O_3 composite ceramics exhibited microwave dielectric properties as $\varepsilon_r = 7.81$ and $\tan\delta = 5 \times 10^{-4}$. The dielectric window is designed in CST by using experimentally derived dielectric properties. The theoretical value of the window's insertion and return loss is better than 61.25 dB and 0.009 dB, respectively, at 3.7 GHz.

AlN-BN composite ceramics shows pure nitride phase sintered in conventional sintering at 1700 ℃, using powder bed. The Cole-Cole plots of impedance spectra of all AlN-BN composite ceramics show non-Debye type relaxations and are fitted with RCRCRC circuits corresponding to three parallelly with R and C circuits connected in series belonging to grain, grain boundary, and electrode. The best microwave dielectric properties at 12 GHz, ($\varepsilon_r = 7.38$ and $\tan\delta = 2.60 \times 10^{-3}$) is achieved for AlN-15BN composite ceramics with pure nitride phase without any alumina or intermediate phases are appropriate for electronic applications. The comparison study on sintering methods of AlN ceramics is discussed, and the effect of the sintering technique on structural, dielectric properties and hardness of the pure and composite AlN ceramics are investigated systematically. The composite ACZ2Y (AlN + Wt% $CaZrO_3$ + 2 Y_2O_3) composite ceramics sintered in microwave sintering method, shows best microwave dielectric properties ($\varepsilon_r = 9.02$ and $\tan\delta = 7.34 \times 10^{-4}$) at 12 GHz resonant frequency, with maximum hardness (1079.51 HV30) are appropriately suited for RF window and electronic applications.