Emergence of Ceramic Dielectric Resonators in Wireless Communication

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The article focuses on the revolution of talking ceramics in the field of wireless communication, especially their applications, property requirements and recent R&D works on some talking ceramic materials which are ideally suitable for wireless communication.

In today's world, microwave dielectric materials play a vital role with a wide range of applications from terrestrial and satellite communication including software radio, GPS, and DBS TV to environmental monitoring via satellites. In order to meet the specifications of the current and future systems, improved or new microwave components based on dedicated dielectric materials and new designs are required. The recent progress in microwave telecommunication, satellite broadcasting and intelligent transport systems (ITS) has resulted in an increasing demand for dielectric resonators (DRs), which are low loss ceramic pucks used mainly in wireless communication devices. With the recent revolution in mobile phone and satellite communication systems using microwaves as the carrier, the research and development in the field of device miniaturization has been one of the biggest challenges in contemporary Materials Science. This revolution is apparent on a daily basis in the ever increasing number of cell phone users. The recent advances in materials development has led to these revolutionary changes in wireless communication technology. Dielectric oxide ceramics have revolutionized the microwave wireless communication industry by reducing the size and cost of filter, oscillator and antenna components in applications ranging from cellular phones to global positioning systems. Wireless communication technology demands materials which have their own specialized requirements and functions. The importance of miniaturization cannot be overemphasized in any hand-held communication application and can be seen in the dramatic decrease in the size and weight of devices such as cell phones in recent years. This constant need for miniaturization provides a continuing driving force for the discovery and development of increasingly sophisticated materials to perform the same or improved function with decreased size and weight.

A dielectric resonator (DR) is an electromagnetic component that exhibits resonance with useful properties for a narrow range of frequencies. The resonance is similar to that of a circular hollow metallic waveguide except for the boundary being defined by a large change in permittivity rather than by a conductor. Dielectric resonators generally consist of a puck of ceramic that has a high permittivity and a low dissipation factor. The resonant frequency is determined by the overall physical dimensions of the puck and the permittivity of the material and

its immediate surroundings. The key properties required for a DR are high quality factor (Qf), high relative permittivity (?r) and near zero temperature coefficient of resonant frequency (f). An optimal DR that satisfies these three properties simultaneously is difficult to achieve in a particular material.

Technological improvements in DRs have contributed to considerable advancements in modern wireless communications. Ceramic DRs have the advantage of being more miniaturized as compared to traditional microwave cavities, and have a significantly higher quality factor.

The low permittivity ceramics are used for millimeter-wave communication and also as substrates for microwave integrated circuits. The medium ?r ceramics with permittivity in the range 25–50 are used for satellite communications and in cell phone base stations. The high ?r ceramic materials are used in mobile phones, where miniaturization of the device is very important. For millimeter-wave and substrate application, a temperature-stable low permittivity and high Qf (low loss) materials are required for high speed signal transmission with minimum attenuation.1

Some of the ceramic materials that are used for DR application are $BaTi_4O_9$, $Ba_2Ti_9O_{20}$, $Ba[Zn_{1/3}Ta_{2/3}]O_3$ known as (BZT), $Ba[Zn_{1/3}Nb_{2/3}]O_3$ known as (BZN), $Ba[Mg_{1/3}Ta_{2/3}]O_3$ known as (BMT), $ZrTiO_4$ etc. As these ceramic materials have revolutionized the wireless communication, especially the cellular phone and GPS system, they are called “talking ceramics”.

Figure 1: Dielectric resonators used in base stations.

Figure 2(a): Dielectric ceramics used in mobile phone

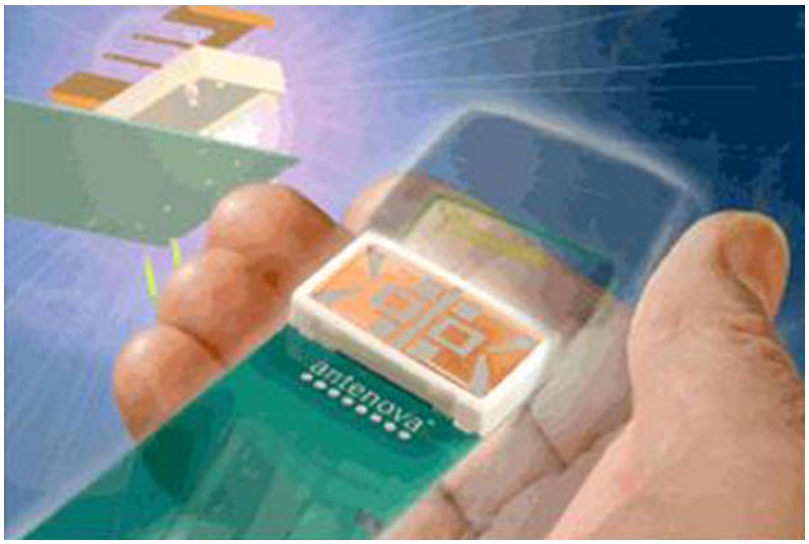

Figure 2(b): Dielectric ceramics used in mobile phone

Recent researches focus on developing ceramic materials with A[B’1/3 B’’ 2/3]O3 complex perovskite structure. By sintering under optimum conditions and optimum doping levels, these materials produce attractive properties, especially the ultra high values of the quality factor Qf. Some of these materials that are investigated in recent times for DR applications are BZT, BMT, BZN etc.

Ba[Zn1/3Ta2/3]O3 compound (BZT), a of the A[B’1/3 B’’ 2/3]O3 family of high Qf dielectric materials, has potential for applications in satellite broadcasting at frequencies higher than 10 GHz and as a very high Qf dielectric resonators (DR) in mobile phone base stations or combiner filter for PCS applications.2 The best density for BZT samples are achieved by sintering at 15000C for 4 hrs. But, at this sintering condition dielectric constant is really low while dielectric loss is high. The best properties for DR application is found at sintering near 16000C for 4hrs where the dielectric constant reaches about 31 and a quality factor normalized to 10 GHz

up to 13 500. These properties can be further improved by annealing at 14000C for 10hrs.3

Ba(Mg1/3Ta2/3)O3 compound (BMT), is another member of the A[B’1/3 B’’ 2/3]O3 family of high Qf dielectric materials.4 The best density and dielectric properties for BMT samples are achieved by sintering in the temperature range 1600–16500C. For BMT, Secondary phases play an important role in controlling the microstructure, density, grain growth, and microwave dielectric properties. A reduction of the barium content in BMT substantially improves the densification and ordering.5 A two-step process (Columbite route) consisting of first preparing MgTa2O6 and then reacting MgTa2O6 with BaCO3 markedly reduces the sintering temperature and soaking time required to densify BMT and to achieve a high Qf state.6 The two-step columbite route improves the sintering behavior with higher density at a relatively lower sintering temperature of about 15500C for 4 hrs. At this sintering condition the ?r of samples synthesized varied only between 27 and 32 while the Qf value reached up to 325 000GHz at a frequency of 13.25 GHz.

Similar to BMT, Ba(Zn1/3Nb2/3)O3 (BZN) is also a member of the A[B’1/3 B’’ 2/3]O3 family of high Qf dielectric materials. The BZN has ?r of 40, Qf of about 80 000 GHz and f of about 30 ppm/0C.7 For pure BZN, ideal sintering temperature is 13900C, where it can obtain a dielectric constant of 40 and Qf up to 87000GHz.

Microwave dielectric ceramics are being developed for a variety of applications such as miniaturization for mobile phones, a transmitter and receiver with high performance for base station, and millimetrewave applications for ultra speed wireless LAN and ITS. There is a huge scope for research in this field. This review will provide a guideline for further development.

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