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Functional advances of microwave dielectrics for next generation

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Abstract

In coming age, new technologies for survivals of human beings on our earth are required. These technologies include for energy and natural resources conservation, waste disposal techniques, and reduction of global warming gases. To achieve this advanced functions of materials are essential. In this paper, new frontiers of microwave dielectrics are presented in relations with these energy issues.

The microwave dielectrics are familiar with radio frequency wave. The low loss dielectric materials are resonated by microwaves in air and change it to electric current in circuit, and vice versa. It is well known that the microwave materials have three important characteristic properties such as high quality factor Q, dielectric constant ε_r and temperature coefficient of resonant frequency TCf. These properties enable the following functions: (1) electromagnetic resonance, (2) electromagnetic-wave shortening, (3) electromagnetic-wave delay, (4) temperature variation of resonant frequency, (5) electromagnetic-wave absorption, and (6) other functions: such as transparency and refractive index. In this paper, for future excellent usages of these functions, some applications are presented showing the fundamental explanations. The content in this paper is planned for the publication in a handbook of advancements of functional ceramics.

Keywords: C. Dielectric properties; D. Silicate; E. Functional applications; Microwave dielectrics

1. Introduction

Microwave dielectrics are interesting materials which are friendly with electromagnetic waves. When it is irradiated with an electromagnetic wave, polarization is produced in these materials by alternative electric field of high frequency wave. The microwave dielectrics cause resonance which releases electromagnetic wave energy and vice versa. Fig. 1a shows an example of filter which consists of two column resonators made from microwave dielectrics between two electrodes. The introduction of an electric current through the left electrode, causes resonance in the column resonator at constant frequency and forms an electromagnetic field. Other column resonator causes resonance by the electromagnetic field, and output the electric current to a right electrode by the electromagnetic field. In the case of SAW filters (Fig. 1b) which have been replacing the role of dielectric resonator filters, must be fabricated by complex precise patterns such as comb-type electrode for resonance. On the contrary, the column dielectric resonator has simple structure.

In this paper, new and special functions based on the properties of the microwave dielectrics are presented as follows:

(1) Electromagnetic resonance
(2) Electromagnetic-wave shortening
(3) Electromagnetic-wave delay
(4) Temperature variation of resonant frequency
(5) Electromagnetic-wave absorption
(6) Other functions: transparency, refractive index

It is planned to publish these contents in the form of a hand book for advancements of function on ceramics. The papers in Refs. [1–7] are useful in understanding these functions of the ceramics.

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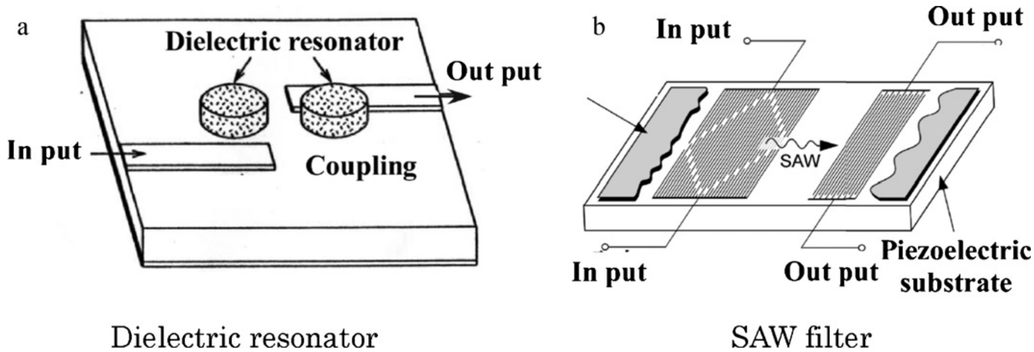

Fig. 1. (a) Dielectric resonator with resonate coupling. (b) SAW filter.

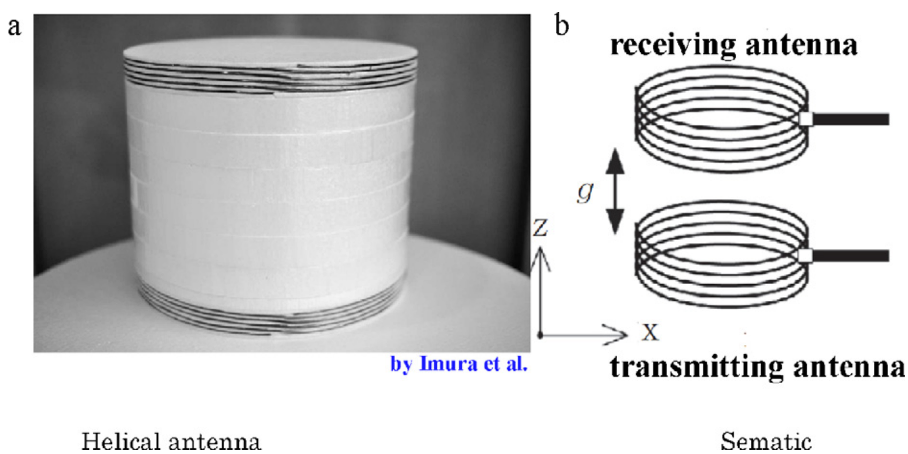

Fig. 2. Helical antenna with resonant coupling [9].

2. Three important microwave dielectric properties [1–4]

2.1. Quality factor Q

The most required properties of microwave dielectrics are quality factor: $Q = 1/\tan\delta$ which is related to how easily the dielectrics resonate when the materials are irradiated in an electromagnetic wave. Resonance is produced by alternative electric field of high frequency wave, by which the polarity is easily reversed with low energy loss such as in paraelectrics.

2.2. Dielectric constant ε_r

The ε_r has two important effects. One is reducing the wavelength λ in dielectrics according to following equation:

$$\lambda = \frac{\lambda_o}{\varepsilon_r^{1/2}}.$$

where, λ_o is wave length in vacuum. This effect is very important for reducing the size of mobile equipments. Another is time delay T_{PD} according to following equation:

$$T_{PD} = \frac{\varepsilon_r^{1/2}}{c},$$

where c is the velocity of light. As the ε_r decreases the time delay decreases and the signal transmission speed increases.

2.3. Temperature coefficient of the resonance frequency TCf

The TCf is expected to be near 0 ppm/°C for global usage with different temperature environments. The TCf has relationship with temperature coefficient of dielectric constant $TC\varepsilon$ as follows:

$$TC\,f = -\left(\alpha + \frac{TC\varepsilon}{2}\right).$$

where α is thermal expansion coefficient.

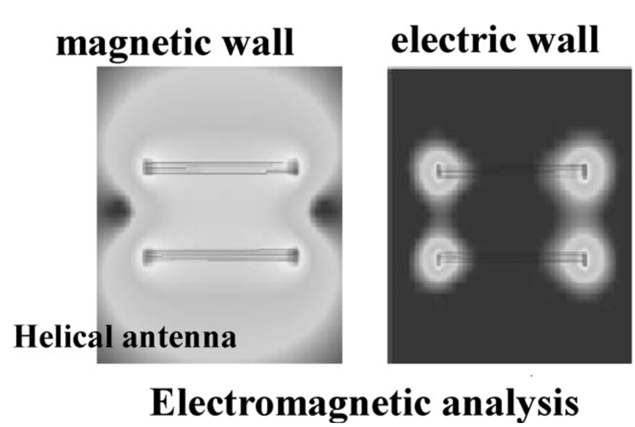

Fig. 3. Electromagnetic analysis of helical antenna with resonant coupling [9].