FERROELECTRIC THIN FILM MICROWAVE EXAMINATION

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Paraelectric/ferroelectric films are perspective tunable component for monolithic microwave integrated circuits (MMIC) where they can be applied as linear and nonlinear capacitors, microwave tunable resonant filters, integrated microwave phase shifter, etc. All these devices need reliable evidence of film microwave dielectric constant ($\varepsilon$) and loss tangent (tan$\delta$). Therefore, integrated film examination at microwave frequencies is an urgent question. Pre-existing studies of ferroelectric films usually use an inter-digital capacitor method or coplanar waveguide line section. Both methods require a metal electrodes deposition, thus “natural film” $\varepsilon$ and tan$\delta$ remain unknown because a complex system of “film–electrode” is investigated. Metallic electrodes strongly affect measured tan$\delta$ and $\varepsilon$ through the mechanical stress in film, and skin effect in metal.

To improve film deposition technology as well as to elaborate device based on this film, its intrinsic electrical properties are urgent just before the electrode deposition, and certainly at microwaves. Moreover, accurate and reliable measuring of ferroelectric films dielectric properties is an actual problem not only of electronic industry but for material science as well. Film-to-bulk properties comparison is an interesting problem in physics of ferroelectrics, and microwave spectroscopy would help to trace the change of dielectric polarization and dielectric loss mechanisms when the free-stress volumetric (3-D) ferroelectric is transformed into a thin planar layer (2-D film) that is stressed by its forced accommodation to a rigid substrate.

Microwave testing procedure for thin film with large dielectric constant ($\varepsilon = 102–104$) and considerable loss ($\tan\delta = 1–10^2$) has been elaborated. Studied ferroelectric film, being deposited onto low-$\varepsilon$ dielectric substrate, constitutes a “sandwich” that should be lengthwise located in the center of rectangular waveguide. Film dielectric parameters are determined by the elaborated software using frequency dependence of scattering parameters recorded by the network analyzer. Proposed method of film investigation is electrode-less, so film intrinsic features are obtained. This is a vital importance for following stages of film processing.

Figure 1. Thin films test cell, and example of data processing.