Sensitivity Improvement of Split-Ring Resonators for Thin-Film Sensing using Floating Electrodes

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***Abstract*—An implementation of split-ring resonators for thin-film sensing is proposed. By creating a cavity with a floating electrode and under-etching of the gap of the split-ring resonator, the electric field lines are concentrated in the material under test. Simulations of the proposed structure yield a relative frequency shift of 19 % for a variation of the relative permittivity between 1 and 5 at an operation frequency of 303 GHz.**

I. Introduction

SPLIT-RING RESONATORS in a periodic arrangement have been used as planar sensor element for the thin-film sensing, e.g. for biomedical applications. If excited from the broadside, an electric field drives a current in the resonant rings. The permittivity of the material over the gap of the split-ring resonator determines the resonance frequency f_{res}, which can be exploited in sensor applications to sense permittivity changes of a coating material.

For single metallic ring layers, the sensitivity is limited since only a part of the electric field penetrates the material under test, while a great part is confined in the substrate or in air above the material coating. To confine the electric field in the material under test, a cavity together with under-etched electrodes can be introduced in the substrate [1], [2]. However, especially for thin material coatings, a great part of the electric field does not interact efficiently with the material under test.

To further concentrate the electric field in the material under test, a floating metallic electrode is implemented in the cavity yielding a strong field concentration on within the material coating. This approach is exemplified for a split-ring resonator but can be employed for any planar configuration where a capacitance variation is sensed.

II. Sensitivity Investigation

Fig. 1a shows the simulated electric field distribution near the gap of a split-ring resonator and under-etched electrodes. The ring diameter is $100\,\mu\text{m}$ with a single gap of $10\,\mu\text{m}$ and ring width of $10\,\mu\text{m}$, while the height of the cavity and the thickness of the material coating is $1\,\mu\text{m}$. This yields an unloaded resonance frequency of $f_0 = 328\,\text{GHz}$. A great part of the electric field is outside the material under test in the air above and the underlying substrate, respectively. By adding a floating gold electrode at the bottom of the cavity as depicted in Fig. 1b, the electric field is confined between the floating electrode and the end of the ring.

Fig. 2 shows a summary of the relative frequency shift depending on the permittivity of the coating material with a thickness of $1\,\mu\text{m}$. A cavity with an under-etching of $d = 2\,\mu\text{m}$ yields a frequency change of 5%, if the relative permittivity of the coating material varies between 1 and 5. Using a cavity with a floating electrode on the ground and without under-etching of the ring ($d = 0\,\mu\text{m}$), a similar frequency change can be achieved. Additionally, an under-etching of $d = 2\,\mu\text{m}$ increases the relative frequency change to 19% for an unloaded resonance frequency of $f_0 = 303\,\text{GHz}$.

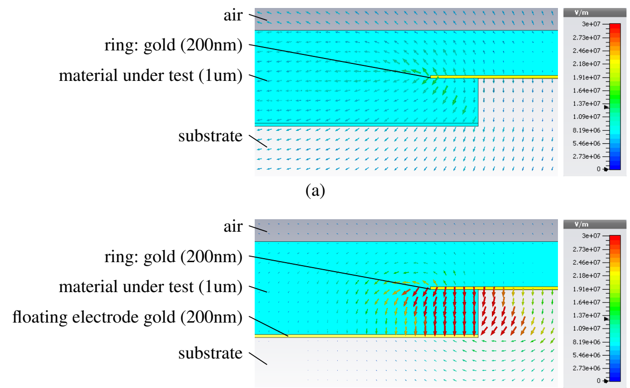

Fig. 1. Simulated electric field distribution: (a) glass substrate with cavity, (b) glass substrate with cavity and floating electrode (the scaling of the electric field is the identical for both plots).

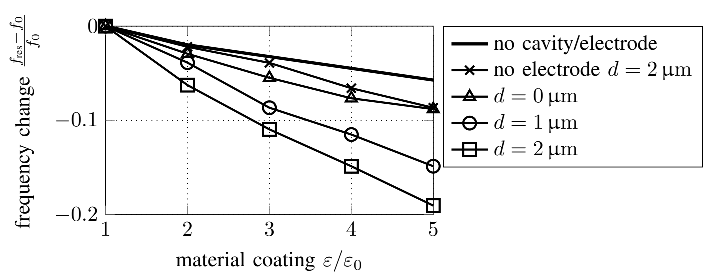

Fig. 2. Simulated relative change of resonance frequency for different structures.

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References

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