A Consideration on Detection of Circulating Tumor Cells Using Ring Resonator Type of Electrode

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***Abstract*—Recently, development of a new Circulating Tumor Cells (CTC) detection device is desired instead of Cell Search System in Japan. Cell identification by the dynamic image analysis of the rotation speed based on the dielectric constant of the cell was considered using the electrorotation. Further aiming at detection sensitivity, the ring resonator type of the electrode was introduced, where the ring resonator was connected with the parallel electrode. As early study, it was confirmed that the cell identification was possible using this electrode by inserting the B and T-lymphocytes with known dielectric constant.**

Keywords—Microwaves; Circulating tumor cells; Ring resonator; Parallel electrode; Resonant frequency

I. Introduction

Recently, development of the Circulating Tumor Cells (CTC) detection device is desired instead of the Cell Search System because the Cell Search System is no longer available in Japan [1]. With this in mind, a new electrode has been devised using the microstrip line to identify the resonant frequency of the electrode, where the peculiar cell is inserted in the electrode connecting a ring resonator in parallel with the electrode [2][3].

In our research, the resonant frequency was evaluated by inserting some cells such as T and B lymphocytes and a possibility to identify the peculiar cell was investigated by calculating the related resonant frequency.

II. Structure of Proposed Electrode

Figure 1(a) shows a parallel electrode having the width, height, and spacing of D, the resist material being deposited around the electrode to fill solutions. The saline is assumed as filling solution between the electrodes because the ingredient is similar to that of the blood.

The electrode is set on the microstrip line connecting a ring resonator [4] in parallel as shown in Fig. 1(b). The gaps with a length of Wg were set between the microstrip line and the electrode so as to set a high Q factor.

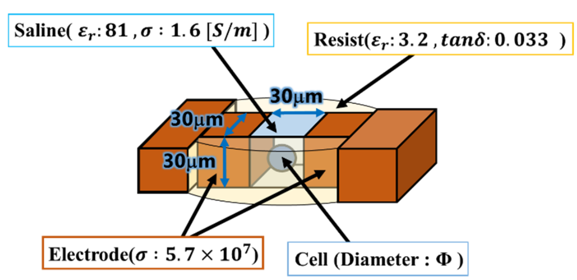
In this structure, the resonance condition is given by

$$\sqrt{\varepsilon_e} k_0 \ell + \theta_a = 2N\pi \quad (N = 1,2,3,\cdots) \tag{1}$$

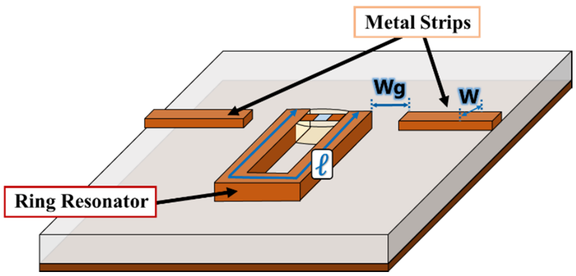
where ℓ, ε_e, and k_0 are the whole length of the ring resonator, the effective dielectric constant, and the free space wave number, respectively. And θ_a is the electrical phase angle of the electrode. From the Equation (1), the resonant frequency is given by

$$f_0 = \frac{(2N\pi - \theta_a)C_0}{2\pi\ell\sqrt{\varepsilon_e}} \tag{2}$$

where C_0 is the velocity of light. It is expected that the resonant frequency is decided by θ_a, so that it depend on the dielectric constant of the peculiar cell.



(a) Parallel electrode



(b) Whole view

Fig. 1. Structure of electrode for CTC detection

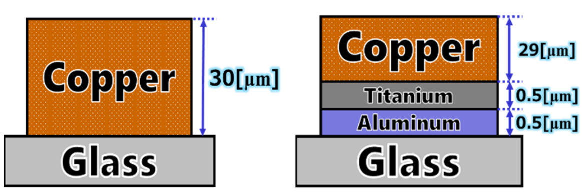
III. Calculated Resonant Frequency of Electrode

Figure 2 shows the side view of the center conductor of the microstrip line. The figure (a) shows the ideal case using just copper foil, while (b) shows the actual case using the layered metal pattern consisting of aluminum, titanium and copper.

Assuming an electrode dimension D, the width of the microstrip line W, the gap length Wg, the whole length of the ring resonator ℓ, and the diameter of cell Φ to be 30µm, 140µm, 50µm, 8.23mm, and 20µm or 30µm, respectively, the transmission coefficient S_{21} was calculated using the T and B lymphocytes as a peculiar cell instead of the CTC because the dielectric constants were known [5].

The results of the resonant frequency are shown in Tabs. I and II. It is confirmed that the resonant frequency has different value for with or without the cell in both cases.

As an example, figures 3 and 4 show the calculated S_{21} versus frequency when the diameter Φ is 20µm or 30µm. From these results, they indicate that the resonant frequency corresponding to each cell can be evaluate by using the electrode although the Q factor deteriorated in the actual case due to poor conductivity of Ti material .



(a) Ideal case (b) Actual case

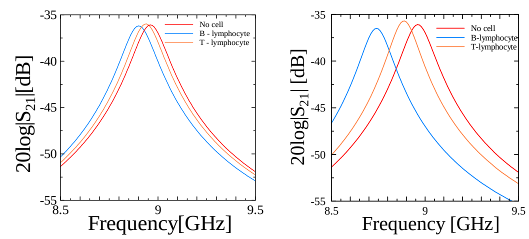
Fig. 2. Side view of cenetr conductor of the microstrip line

TABLE I. Calculated Resonant Frequency Using Copper Foil

	First order resonance	
	Resonant frequency [GHz]	
Diameter of cell	Φ = 20 µm	Φ = 30 µm
No cell	8.96	
B - lymphocyte	8.90	8.74
T - lymphocyte	8.94	8.89

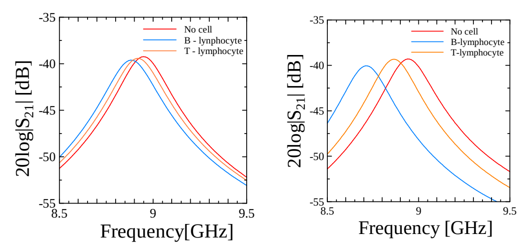
TABLE II. Calculated Resonant Frequency Layered Metal Strips

	First order resonance	
	Resonant frequency [GHz]	
Diameter of cell	Φ = 20 µm	Φ = 30 µm
No cell	8.95	
B - lymphocyte	8.88	8.71
T - lymphocyte	8.92	8.86



(a) Φ = 20 µm (b) Φ = 30 µm

Fig. 3. Calculated transmission coefficient versus frequency using copper foil



(a) Φ = 20 µm (b) Φ = 30 µm

Fig. 4. Calculated transmission coefficient versus frequency using layered metal strips

IV. Conclusion

A new type of electrode was devised for cancer cell detection based on the resonance technique and the possibility to evaluate the CTC could be confirmed.

The next step of this study will be to make the electrode and to measure the resonant frequency of a variety of the cells and the cancer cells.

References

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