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주파수와 대역폭 조정이 가능한 bandstop 공진기

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Frequency and bandwidth tuneable bandstop resonator

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Abstract - This paper presents a tuneable bandstop resonator with two possible configurations, it can be used to tune its center frequency, or it can be used to tune its bandwidth. The tuneable bandstop resonator has potential application in microwave communications receivers, where it can be used to tune out interfering signals. The proposed resonator is comb actuated, where the resonator's displacement produces different values of frequency or bandwidth, this is achieved by decoupling electromagnetic energy from a main transmission line. The proposed fabrication process for the resonator is by anodic bonding pyrex glass and low resistivity silicon, where the comb resonator structure is patterned by deep reactive ion etching (DRIE). This paper presents the resonator and actuator design in both configurations, as well as the fabrication process intended for its development.

1. Introduction

A tuneable bandstop resonator can play a very important role in wireless communication receivers, where it can be used to reject, or tune out interfering signals at the RF stage of the receiving communications system. Here we propose the use of a half wavelength resonator mounted on a shuttle, which is then comb actuated [1], and designed to produce a 30 micrometers total displacement. The resonator is placed in a bandstop configuration, where it is electrically coupled to a main transmission line or main signal path. The resonator then de-couples electromagnetic energy from the main transmission line, producing a bandstop effect, rejecting signals at a given frequency, with a certain bandwidth, according to the resonant frequency of the half wavelength resonator, and the degree of coupling between the resonator and the main transmission line. The proposed tuneable resonator is designed to change its reactance slope parameter and effective electrical length as it moves over the main transmission line, this is how we obtain the different resonator configurations to obtain a tuneable frequency, or a tuneable bandwidth. The general theory related to the design of the tuneable bandstop resonator presented in this paper, can be found in [2].

2. Resonator design

This section is divided in two parts, in part one we discuss a configuration where the bandstop resonator is used to continuously change its center frequency, while in section two, we present an alternative configuration where the resonator is used to produce a change in bandwidth. The proposed bandstop resonator is shown in figure 1, where the resonator mounted on the low resistivity silicon shuttle, moves towards the main transmission line, by means of the combs located at the sides of the shuttle. For both configurations the resonator has been designed to exhibit a total displacement of 30 microns.

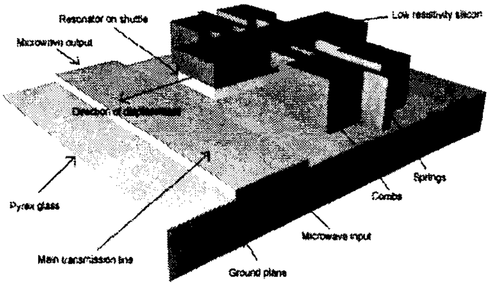


Figure 1. Schematic of the tuneable bandstop resonator

2.1 Frequency tuneable resonator

In order to maximize the frequency shift of the resonator, the resonator is initially placed 10 micrometers apart form the main transmission line, in such a way that when the resonator moves towards the main transmission line, the effective electrical length of the resonator changes, producing an alteration in the resonant frequency of the resonator. Figure 2 shows the frequency response of the frequency tuneable resonator, where it can be seen, that as the resonator moves from its initial position towards the main line, different values of center frequency are obtained. It is worth mentioning that as the bandwidth becomes narrower, the dissipation effects on the bandstop resonator become more critical, for this reason, it is good to pack the resonator inside a micromachined grounded metalized cavity, in order to obtain improved overall stopband rejections.

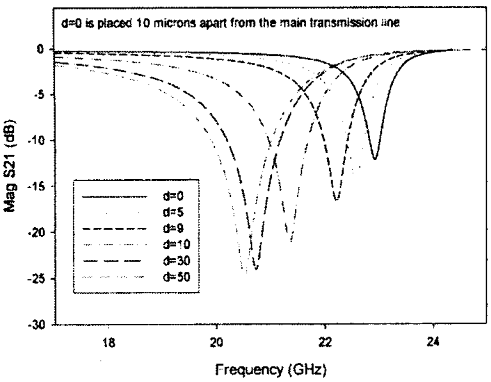


Figure 2. Frequency tuneable bandstop resonator response

In figure 3 we can observe the frequency and bandwidth characteristics of the resonator, against the resonator's displacement. Where it can be seen that the frequency shift becomes large, as the effective electrical length of the resonator varies for different spacings from the main transmission line. The bandwidth of the resonator is also affected, as the reactance slope of the resonator coupled to the main line also changes for each resonator's position.

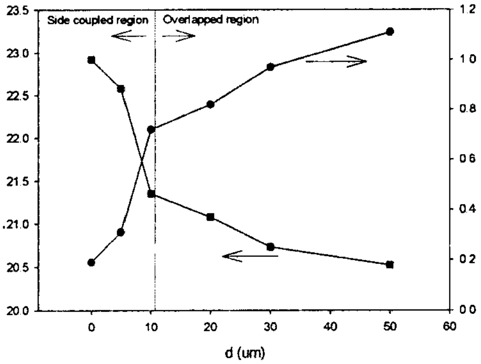


Figure 3. Characterization of the frequency tuneable bandstop resonator

2.2 Bandwidth tuneable resonator

To obtain a tuneable bandwidth, the resonator is now initially placed overlapping the main transmission line by 60 micrometers. The effect of the movement is now minimum in terms of the change in total effective electrical length of the resonator, and produces a change in the reactance slope of the coupled resonator to the main transmission line [3]. Figure 4 shows the response of the bandwidth tuneable bandstop resonator, where in this configuration, the bandwith becomes larger as the resonator moves towards the main transmission line. Here as the bandwidth is large, dissipation effects become less critical on the resonator, thus the effect of shielding the resonator may not be so significant, but can improve the overall stopband rejections.

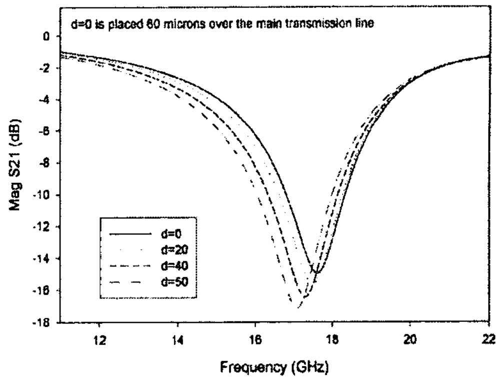


Figure 4. Bandwidth tuneable bandstop resonator response

Figure 5 shows the frequency and bandwidth characteristics of the tuneable bandwidth resonator, where it can be seen that the resonator's bandwidth varies, while the center frequency of the resonator is kept within a smaller frequency shift, compared with the configuration presented in section 2.1.

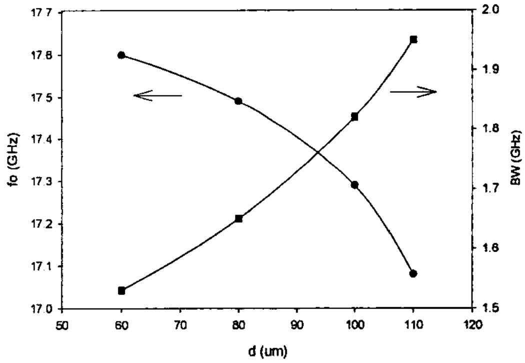


Figure 5. Characterization of the bandwidth tuneable bandstop resonator

3. Comb actuator design

Figure 6 shows a top view of the proposed tuneable bandstop resonator. Where it can be seen that the tuneable resonator has four identical comb-drive actuators, designed to have an x-direction actuation. We used a conventional folded beam comb-drive actuator in order to obtain a large displacement. A static displacement linearly proportional to the control voltage was obtained by the introduction of a bias voltage, and a differential driving signal to the driving electrode; giving good linearity between control signal and displacement. The relationship between displacement and control voltage for the comb drive actuator with differential driving is given by;

$$X_d = \frac{2\epsilon_0 NVr}{Eg}\left(\frac{L}{b}\right)^3 \qquad (1)$$

Where X_d is the static displacement, g (4 μm), h (80 µm) and N (200) are the gap, thickness and the number of comb fingers, respectively. E is Young's modulus (190 GPa), L (1 mm) and b(5 µm) are the length and width of the springs, respectively. V and v are the bias and control voltages, respectively. The designed parameters are: spring constant of 3.8 N/m, a bias voltage of 30 V, a control voltage from 5 to 30 V. The maximum displacement is 30 µm, and the mechanical resonant frequency is 1.3 kHz.

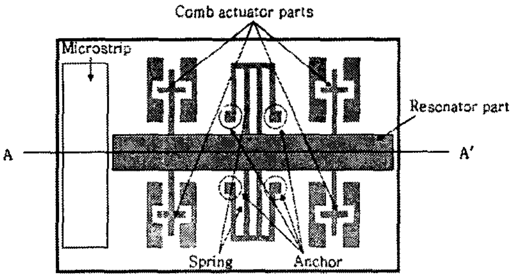
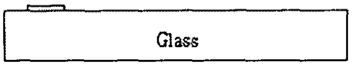


Figure 6. Top view of tuneable bandstop resonator including comb actuator parts

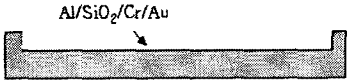
4. Fabrication process

Figure 7 shows the fabrication process flow for the tunable bandstop resonator. First the 1 µm-thick microstrip line is patterned using thermally evaporated gold and lift-off. In order to form the air-gap between the microstrip line and the resonator, a silicon pre-etch process is performed. After the pre-etch, aluminium is thermally evaporated with a total thickness of 5000 Å. The aluminium layer will play the role of an etch-stop mask, at the final step to release the structure. To isolate the silicon structure from the gold resonator, silicon dioxide is patterned on the aluminum layer. The next step involves the evaporation of the Cr/Au layer, followed by the anodic bonding process. Now the silicon comb-drive and resonator are released after lapping and CMP the bonded silicon substrate. Finally the 1 µm-thick gold microstrip ground plane is evaporated on the backside of the glass substrate.

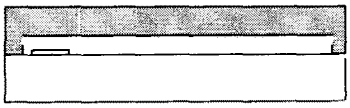


(a) Ground patterning on glass substrate

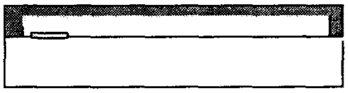
(b) Silicon pre-etch



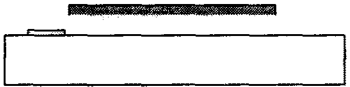
(c) Al/SiO_2/Cr/Au deposition



(d) Anodic bonding



(e) Silicon lapping & CMP



(f) Release using DRIE

Figure 7. Fabrication process

5. Conclusions

In this paper we have presented a new type of comb actuated resonator. The proposed resonator was presented in two possible configurations, where it can be used to produce either a tuneable center frequency, or a tuneable bandwidth. The tuneable resonator can be used in a continuously tuned filter topology. The intended fabrication process for the proposed device has been discussed. Future work includes the development and testing of the proposed device.

[참 고 문 헌]

[1] Che-Heung Kim, Yong-Kweon Kim, "Micro X-Y stage using silicon on a glass substrate", *J. Micromech. Microeng.*

[2] Jia-Sheng Hong and M.J. Lancaster, "Microstrip filters for RF/Microwave applications", John Wiley and sons Inc. 2001.

[3] Ignacio Llamas-Garro, Jung-Mu Kim and Yong- Kweon Kim "Micromachined overlapped resonators for wide electromagnetic coupling ranges", this conference.