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서브마이크론 빔 레조네이터 제작을 위한 바닥전극 형성방법

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Fabrication of embedded bottom electrodes for submicron beam resonators

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Abstract - We describe a fabrication method of submicron glass trenches which have embedded metal lines for the future application of nano-scale RF MEMS devices. The glass wafer was etched using two different conditions to identify the relationship between the slope of glass trenches and the slope of photoresist. A self-aligned metal photomask and negative photroresist (PR) slope were used to insert metal lines inside the glass trenches. The PR slope patterned by backside photolithography was affected by the profile of preformed glass trenches. Gold was well fabricated in the 0.7 μm wide trench thanks to the negative PR slope. Nano-scale glass trenches with embedded metal lines can be used as a bottom electrode in submicron beam resonators operating with a high resonant frequency.

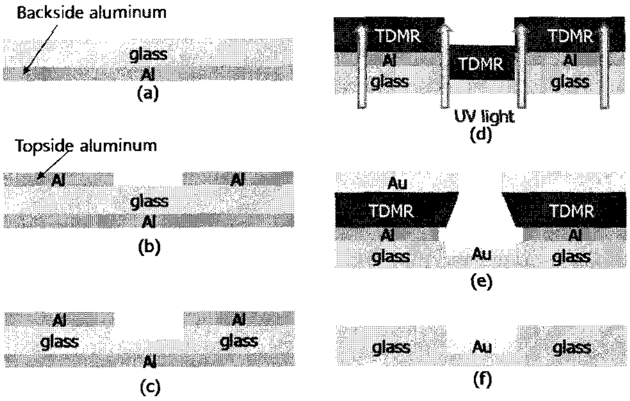
1. Introduction

Microelectromechanical systems (MEMS) resonators have been widely used in the applications of inertial measurement sensors, RF filers, mass sensors, etc. Recently many research groups try to reduce the size of resonators up to submicron scale because the size reduction can offer a lot of advantages such as high speed operation, low actuation force, high integration level, and high sensitivity [1-3]. Beam resonators are one of the representative devices in nano-scale RF MEMS due to its simple fabrication and structural stability. Vertical beam resonators have advantages over lateral beam resonators in the views of high integrity and easy fabrication in an array. One of the most challengeable issue in submicron resonators is an accurate alignment between layers less than hundreds nanometer.

In this paper, we propose a simple method to fabricate embedded metal lines inside glass trenches. Self aligned metal photomasks are used to form a photoresist mold for the lift-off process of the embedded metals. The relationship between glass trench slopes and PR mold slopes are investigated for different conditions during glass trench formation.

2. Experimental method

The fabrication process started with aluminum evaporation on the backside of a glass wafer (Pyrex #7740, Corning Co.) to make an optically opaque substrate in the first photolithography. We obtained submicron patterns less than 0.7 μm using a positive photoresist TDMR AR-87 (Tokyo-Ohka Kogyo Co.) (Fig. 1(a)). Then, a thin aluminum layer of 0.2 μm was evaporated on the top side of the glass wafer for an etching mask of the glass. This aluminum layer should be thick enough to block the UV light in the following backside photolithography. The deposited aluminum layer was patterned using a lift-off process by removing the underlaid photoresist in acetone (Fig. 1(b)). The glass wafer was etched with two equipments, Oxford RIE 80 and P-5000, to find out a correlation between glass trenches profiles and TDMR AR-87 profiles in backside photolithography (Fig. 1(c)). AZ 1512 was coated on the top side aluminum to passivate the top side aluminum when the backside aluminum layer was removed in phosphoric-acetic-nitric (PAN) solution. After removing the top side PR, the wafer was coated with TDMR AR-87 and UV was exposed from the backside. By then, the aluminum layer which is used as a glass etch mask also acts as a self-aligned photomask (Fig. 1(d)). Finally, a gold lift-off process was done with a negative slope of TDMR AR-87 after backside photolithography (Fig. 1(e) and (f)).



<Fig. 1> Fabrication process; (a) backside aluminum evaporation, (b) topside aluminum lift-off, (c) glass dry etch, (d) backside flood exposure using the self-aligned aluminum mask, (e) gold 0.2 μm evaporation (f) gold lift-off.

3. Results and Discussions

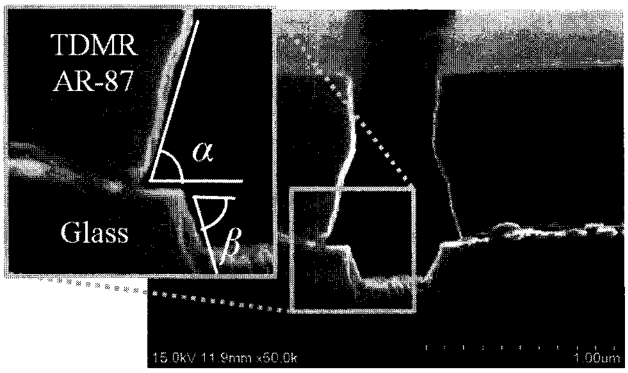
The glass trenches were etched with two different conditions to identify the relationship between glass profiles and slopes of the TDMR AR-87, as their experimental conditions summarized in Table 1.

<Table 1> Glass dry etch coditions

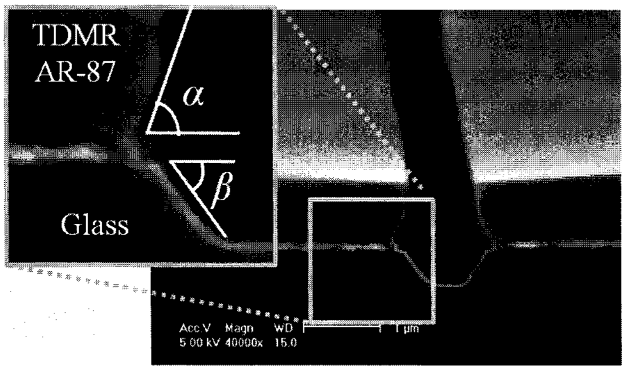
Conditions	Gas flow rate	Pressure	Etch time
Oxford RIE 80	SF_6: 100 sccm Ar: 50 sccm	0.1 Torr	180 sec
P-5000	CHF_3: 25 sccm CF_4: 5 sccm Ar: 50 sccm	0.13 Torr	100 sec

Figure 2 and 3 show the cross sectional views of a 0.7 μm trench after backside photolithography, where the glass was etched with Oxford RIE 80 and P-5000, respectively. The slopes of TDMR AR-87 and the glass were measured to quantify the glass and PR profiles, and they were defined as α and β, respectively.

The slopes of glass trenches (α) and the slopes of TDMR AR-7 (β) were summarized in Table 2 and plotted in Fig. 4. The result using P-5000 shows lower slopes of both glass trenches and patterned PR than those of Oxford RIE 80.



<Fig. 2> Cross sectional view of a 0.7 ㎛ trench after backside photolithography, where the glass was etched with Oxford RIE 80.

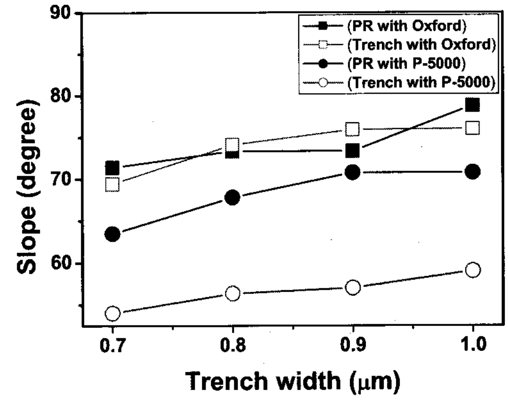


<Fig. 3> Cross sectional view of a 0.7 ㎛ trench after backside photolithography where the glass was etched with P-5000.

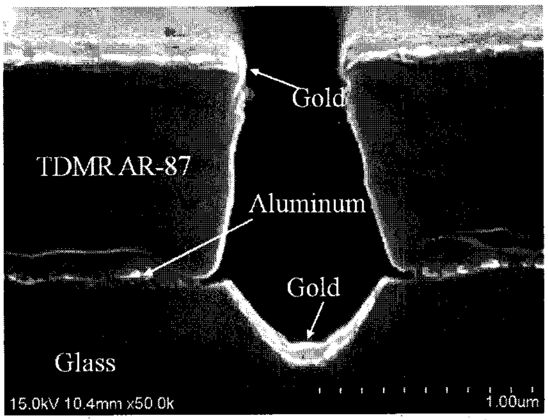
<Table 2> Sidewall slopes of glass trenches and photoresist

	Sidewall slope			
	Oxford RIE 80		P-5000	
trench width	TDMR AR-87 (*a*)	glass (*β*)	TDMR AR-87 (*a*)	glass (*β*)
0.7 ㎛	71.39 °	69.42 °	63.47 °	54.00 °
0.8 ㎛	73.34 °	74.09 °	67.76 °	56.34 °
0.9 ㎛	73.34 °	75.89 °	70.75 °	57.01 °
1.0 ㎛	78.73 °	76.00 °	70.75 °	59.01 °

UV light path was affected by the refraction on the interface between glass and TDMR AR-87. If the sidewall slopes of the glass trenches decreased, the UV light refracted more leading to decreased slopes of TDMR AR-87. This explanation is possibly confirmed by the above experiment where the increased slope of TDMR AR-87 results in the increased slope of the glass trench. More negative slopes are helpful to the following lift-off process. From the experiments, low sidewall slopes of the glass and TDMR AR-87 obtained by P-5000 will be effective for the embedded metal formation. We also found the slope slightly increased as trenches became wide, which can be explained several reasons, however they don't show clear correlation. After defining the negative slope of TDMR AR-87, a gold layer of 0.2 ㎛ was well patterned using a lift-off process inside the glass trench (Fig. 5).



<Fig. 4> Slopes of glass trenches and TDMR AR-87 with respect to trench widths.



<Fig. 5> Cross sectional view after gold evaporation.

4. Conclusion

Glass slope of 54.00 ° was obtained using P-5000 dry etcher, which resulted in 63.47 ° slope of TDMR AR-87. The slope of TDMR AR-87 became larger according to the increased slope of glass trenches. The gold layer was successfully patterned using a lift-off process with a well defined negative slope of TDMR AR-87. The development of the self aligned backside photolithography is expected to be adopted in micro-fabrication of bottom electrodes combining floating structures with highly accurate alignment for the applications such as vertical submicron beam resonators.

[Reference]

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