Improvement of Poly-Si Wet Etching for Fusion Bonding of MEMS Pressure Sensor

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1. Introduction

The fusion bonding technique is well adopted in fabricating Micro-Electro Mechanical System (MEMS) devices. However, utilizing fusion bonding with polysilicon (Poly-Si) as a device membrane and Si as a second electrode to form a capacitive sensor is not a common technique in the industry or yet to be established. This is perhaps due to the poly-Si being rough surface and difficult to bond directly unless the surface planarization by using chemical-mechanical Polishing (CMP) to produce roughness (R) below 5.0 nm [1]. Moreover, poly-Si membrane requires certain annealing temperature to release its residual stress [2] and fusion bonding temperature either match it or not exceed it. Apart from those difficulties, bonded structure offers performance advantages. Therefore, wet chemistry is requires to remove poly-Si from bonding interfaces. However, wet chemistry roughens the oxide surface and posing treat to fusion bonding.

In this paper, the effects of volume of NH_4F in HNO_3:DIW:NH_4F mixture to the etch rate and etch selectivity of poly-Si and SiO_2 were studied. The roughness of SiO_2 film after etched was investigated.

2. Experimental Procedure

In this experiment, poly-Si membrane is buried inside a cavity to avoid direct bonding to oxide surface as shown in an inset of Fig. 1. To investigate the etch rate and etch selectivity of poly-Si, 2.0 μm thick thermal oxide was grown on 6 inches Si wafer. Then, 0.6 μm thick *in-situ* poly-Si was deposited on SiO_2 layer. Later, poly-Si pattern was etched by reactive ion etching to form etch opening area. A wet chemistry of HNO_3(70%):DIW:NH_4F(40%) mixtures with arbitrary ratio of 126:60:x and 150:80:x by volume was used to etch poly-Si for 3 mins at RT.

Based on Iso-etch curve of Si [3], the NH_4F volume was varied from 1.0 to 5.0 mL to optimize the etch selectivity between poly-Si and SiO_2. After photoresist ashing, the remained film thickness was measured by ellipsometer and the surface roughness was measured by atomic force microscope (AFM).

3. Results and Discussion

The initial thickness of poly-Si and SiO_2 films are 6884±75 A° and 1064±5 A°, respectively. The poly-Si film was completely etched within 3 mins for both chemical mixtures with 126:60:5 and 150:80:5 volume ratios. Figure 1 showed that the chemical mixtures of 150:80:x vol. ratio is more suitable than the chemical mixtures of 126:60:x vol. ratio due to its higher etch rate and etch selectivity. By changing the volume of HNO_3 from 150:80:1 to 150:80:4 mL, the poly-Si etch rate has increased from 388 to 1847 A°/min and etch selectivity between poly-Si and SiO_2 has increased from 17.2 to 29.4. Figure 2 showed that R_{max} of oxide layer etched by the poly-Si

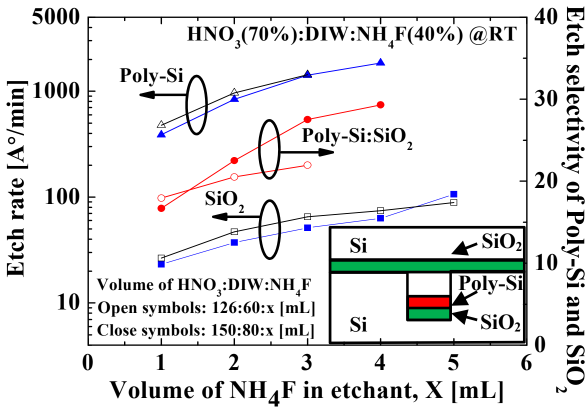

Fig. 1. Effects of volume of NH_4F in HNO_3:DIW:NH_4F mixture to the etch rate and etch selectivity of poly-Si and SiO_2. Inset is the cross-section of fusion bonded device.

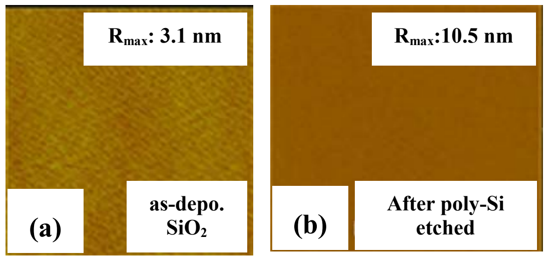

Fig. 2. Oxide surface roughness (a) as-deposited and (b) after poly-Si etched by using HNO_3:DIW:NH_4F mixture of 150:80:5 vol. ratio and after removing poly-Si layer.

etchant with 150:80:5 vol. ratios for 3 mins after fully removing a poly-Si layer from its surface is 10.5 nm, which is almost three times the roughness of as-deposited oxide layer. It is suggested that poly-Si etchant with 150:80:4 vol. ratio is suitable to suppress the oxide roughness due to higher etch selectivity. However, the oxide surface roughness and bonding will be further evaluated.

Conclusions

The effects of volume ratio of HNO_3:DIW:NH_4F mixture to the etch rate and etch selectivity of poly-Si and SiO_2 were studied. The poly-Si etchant with 150:80:4 vol. ratio increased etch selectivity and decreased oxide roughness, which is able to improve performance of fusion bonding for MEMS devices.

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References

[1] C. Gui, *et.al.*, Microsys. Technol., pp. 122-128 (1997).
[2] N. Sharma, *et.al.*, J. Mater., pp. 1-8 (2014).
[3] K. R. Williams and R.S. Muller, J. Microelectromech. Sys., **5** (4), pp. 256-269 (1996).