Double-side Polished Silicon Cantilever Fabricated from Silicon-on-Insulator (SOI) Wafer

Huang-Wei Pan, Hsin-Chieh Chen, Ling-Chi Kuo, and Shiuh Chao*
Institute of Photonics Technologies, National Tsing Hua University
No.101, Section 2, Kuang-Fu Road, Hsinchu, Taiwan 30013, R.O.C.
*schao@ee.nthu.edu.tw

Introduction

Cantilever ring-down method provides a convenient and fast turnaround means to measure the mechanical loss of thin films. Photo-lithographic method was commonly used to fabricate silicon cantilever from conventional silicon wafer[1], and the cantilever was one-side roughened due to the etching process. There are situations where both side of the silicon cantilever are required to be smooth such that coatings can be deposited on both side, for example, measuring the mechanical loss of high stress films[2], and coatings for the double end-mirror sloshing cavity [3]. A silicon-on insulator (SOI) wafer is formed by firstly forming a thin SiO_2 layers, either by thermal oxidation or by ion-implantation and thermal treatment, on a regular silicon wafer. Same method is then applied to form SiO_2 layer on a thinner silicon wafer. Both wafers are then attached from the SiO_2 layer side by wafer-bonding technique to form the silicon-on-insulator (SOI) wafer. Here we introduce a method to fabricate double-side smooth silicon cantilever from the silicon-on-insulator (SOI) wafers.

Fabrication method

- Conventional Silicon cantilever [1]:

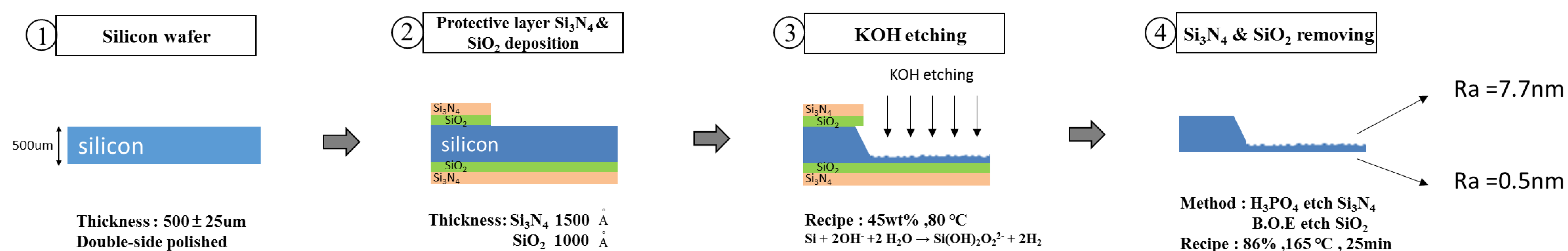


Fig. 1 shows schematically the fabrication process of silicon cantilever. Starting with a 500 um thick silicon wafer, SiO_2 and Si_3N_4 films were deposited in sequence on both side of the Si wafer. Photo-lithographic method was used to expose the silicon surface on one side and then KOH was used to etch off the silicon down to the required thickness, 92 um in our case. Subsequent etching off the remaining Si_3N_4 and SiO_2 films by H_3PO_4 and BOE (buffered oxide etch) yield a silicon cantilever with one roughened surface with ~7 nm roughness due to KOH etching. The coatings was then deposited on the un-etched side that has a genuine roughness of 0.5 nm.

- Cantilever from SOI wafer :

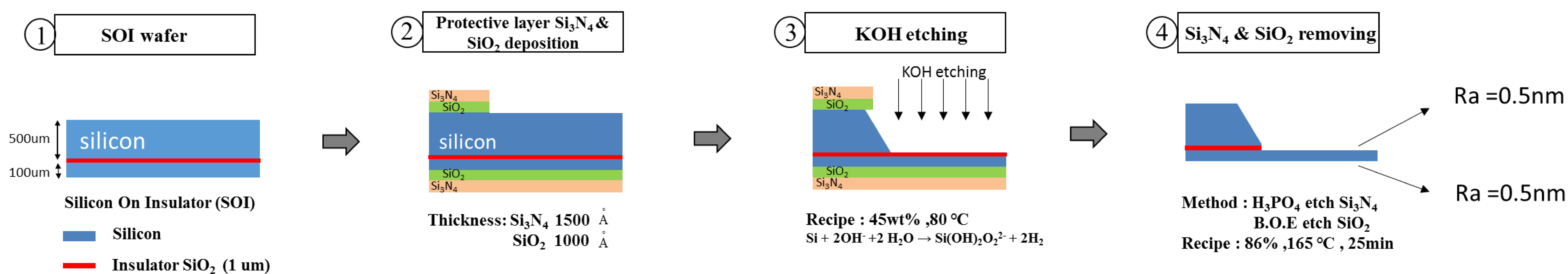
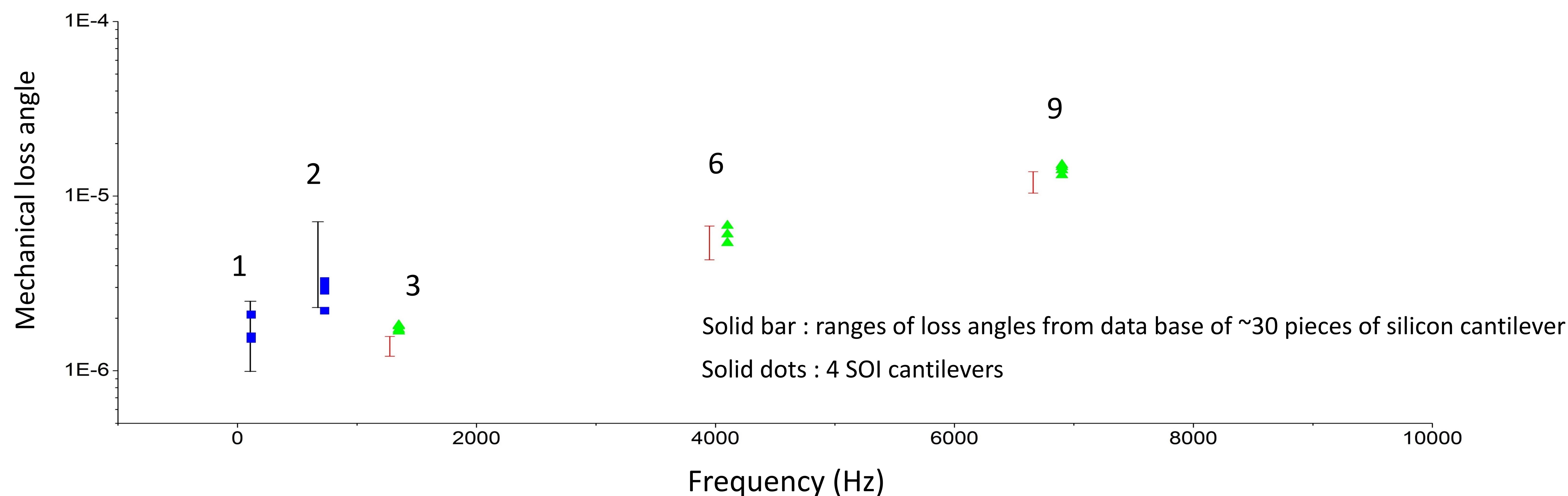


Fig.2 shows schematically the fabrication process of the SOI cantilever. Same as the conventional method that one surface of the thick silicon is exposed by using the photo-lithographic method. KOH is then used to etch off the thick silicon completely down to the SiO_2 layer (SiO_2 is inner to KOH etching). The remaining Si_3N_4, and SiO_2 on the pad and on the thin silicon are removed by H_3PO_4 and BOE etching to form the cantilever. Both surfaces of the cantilever has the genuine roughness of 0.5 nm. Coatings can then deposited on both side.

Mechanical loss of the SOI cantilever in comparison to the conventional cantilever



The differences between the conventional silicon cantilever and the SOI cantilever is that both side of SOI cantilever are smooth but the pad of SOI cantilever contains a thin SiO_2 that might affect the loss angle measurement of the coatings. Therefore. We have measured the mechanical loss angle of the SOI cantilever and comparing to that of the conventional silicon cantilever. Figure above shows the results. Data dots are the loss angles of 4 SOI cantilevers and bars are the range of loss angle from our data base of nearly 30 pieces of conventional silicon cantilever. Thermo-elastic loss were subtracted. Figure above shows that SOI cantilever has the loss angle comparable to that of the conventional silicon cantilever.

Conclusion

We showed fabrication method for forming the SOI cantilever. We also showed that the SOI cantilever has about the same mechanical loss angle as the conventional silicon cantilever regardless of that there is a thin SiO_2 layer in the pad. The advantage for using the SOI cantilever is that double-side coatings can be deposited on smooth surfaces for application such as measuring the loss of high stress films and in the formation of double end-mirror sloshing cavity.

Reference
[1] S. Chao, et al, "Progress of coating development at NTHU", LVC meeting , Rome, Italy, Sep. 10th ,2012. LIGO-G1200849. [2] S. Chao, et al , "Room temperature mechanical loss of high stress silicon nitride film measured by cantilever ring-down method on double-side coated cantilever" LVC meeting, Budapest, Hungary, Sep. 1st ,2015. LIGO-G1501068. [3] M. A. Page, et al, "Towards thermal noise free optomechanics", J. Phys. D: Appl. Phys. 49, 2016 455104.