Research Article

Journal of Environmental Nanotechnology

Development of Lift-off Process using Plasma-enhanced Chemical Vapor Deposition Silicon Dioxide

Yatish Prasad, Chiranjeevi Lakavath*, H. M. Raghvendra, Selvaraj, B. Bhattacharyya, P. Sathish Kumar

Semiconductor Technology and Applied Research Centre, Dooravaninagar, Bengaluru, KA, India

Received: 16.01.2020 Accepted: 27.02.2020 Published: 30-06-2020

*chiranjeevi.sitar@gov.in

ABSTRACT

Lift-off is a simple, easy method for realizing metal patterns on a substrate, especially for thin metal films such as platinum, gold and titanium, difficult to be etched by conventional methods. Defining metal lines at sizes below 2 µm is difficult by wet and plasma chemistry. We have carried out lift-off process experiments using positive photoresist Fuji Film OiR 906-17HD, PECVD silicon dioxide of 1µm, and metal thickness of 1000, 1500 and 2000 µm on silicon and quartz wafers. Different dimensions of metal patterns were achieved with 3% accuracy on silicon and quartz wafers. This method can be used for the realization of various Micro-electro mechanical system devices.

Keywords: Lift-off, Photoresist; Micro-electro mechanical systems (MEMS); Plasma-enhanced chemical vapor deposition (PECVD).

1. INTRODUCTION

Lift-off is a technique for patterning metal lines on a substrate like silicon and quartz wafers. Most of the noble metals are used as connectors in MEMS (Slaughter *et al.* 2017) devices such as accelerometer, pressure sensor and temperature sensor in the current scenario (Bharathi Sankar Ammaiyappan *et al.* 2019). Etching metals like gold, chromium and titanium by wet chemical and plasma chemical methods is difficult. The general Lift-off process includes desirable patterning with photoresist, and metal lines are deposited on photoresist pattern. During the actual lifting-off, the photoresist under the film is removed with a clean solvent process, taking the film with it and leaving only the film or metal deposited directly on the substrate. Defining nano-level metal lines at sizes below 2 µm is difficult by wet etching or plasma to etch method. The lift-off process is an economical and alternative method to avoid wet chemicals and plasma gases damaging the device metal lines (Pandey *et al.* 2016). In this study, we developed a process using positive photoresist Fuji Film OiR 906-17HD, silicon dioxide of 1 µm, the metal thickness of 1000, 1500 and 2000 µm on silicon and quartz wafers.

2. MATERIALS AND METHODOLOGY

The following process sequence illustrates the PR lift process using a positive tone photoresist and sacrificial silicon dioxide (SiO_2) as assisting layer. A thick layer of SiO_2 (the thickness of SiO_2 should be greater than that of the thin-film device material ~1µm) was first deposited, followed by a spin-coat of photoresist (OiR 906-17HD, ~3µm). The mask pattern was defined into the photoresist layer. By using the patterned photoresist as the etch mask, the SiO_2 layer was wet chemically etched. In order to create an overhang structure with the photoresist, the SiO_2 layer was intentionally over-etched (Fig. 1). Lift-off was done by dissolving the photoresist in acetone in an Ultrasonic bath.

2.1 Lift-off on Silicon Wafer

1 µm PECVD oxide was deposited on fresh Si wafers, followed by photolithography and removal of 1 µm PECVD oxide by buffer oxide solution for undercut profile and subsequent metal deposition and photoresist lift-off was done. Metals like chromium, titanium and sandwich of titanium and platinum were used in the experiments. Photomask patterns with dimensions of 5, 10 and 50 µm were used in the experiment.

2.2 Lift-off on Quartz Wafer

Stack of 1520 ºC LPCVD silicon nitride and 1 µm PECVD oxide were deposited on quartz wafers, which was followed by photolithography and removal of 1 µm PECVD oxide by buffer ox ide solution for undercut profile and subsequent metal deposition and photoresist lift-off was done. Metals like chromium, titanium and sandwich of titanium and platinum were used in the experiments. Photomask patterns with dimensions of 5, 10 and 50 µm were used in the experiment.

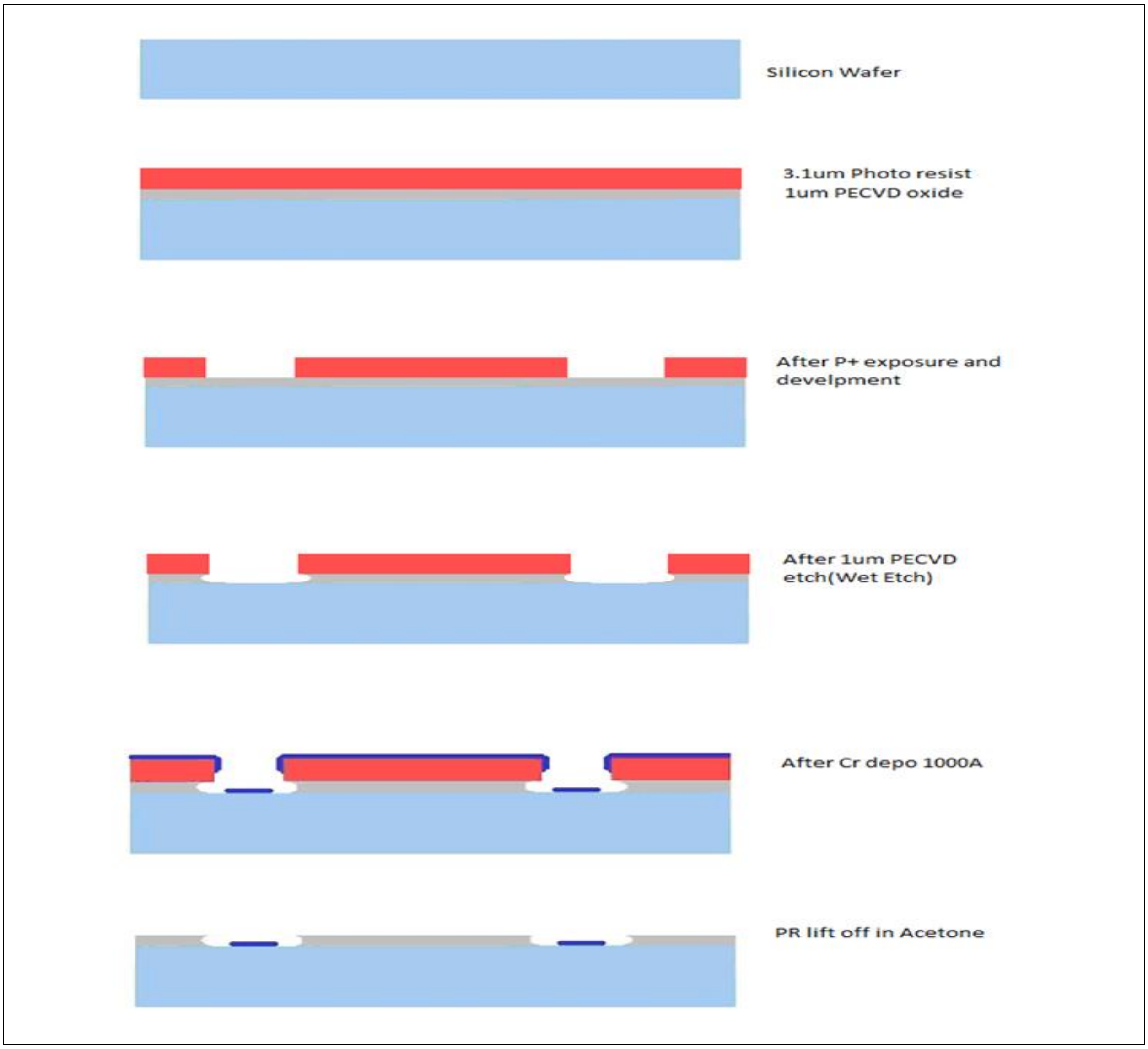

Fig. 1: Processing steps of the lift-off method based on photoresistor oxidedDouble layer scheme.

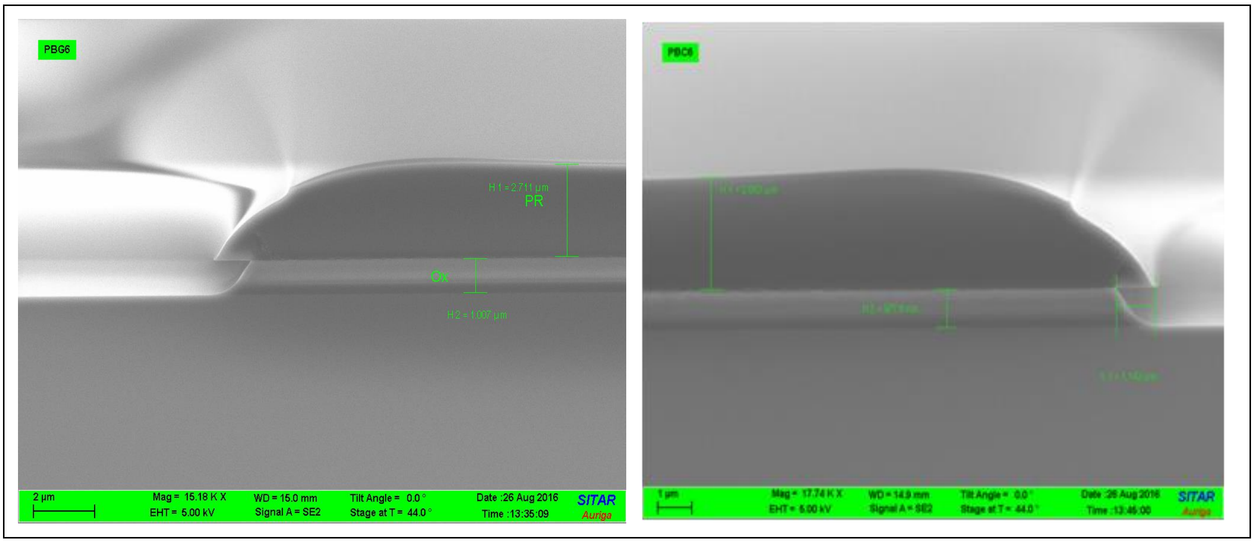

Fig. 2: Scanning Electron Microscopy (SEM) images after SiO_2 etch.

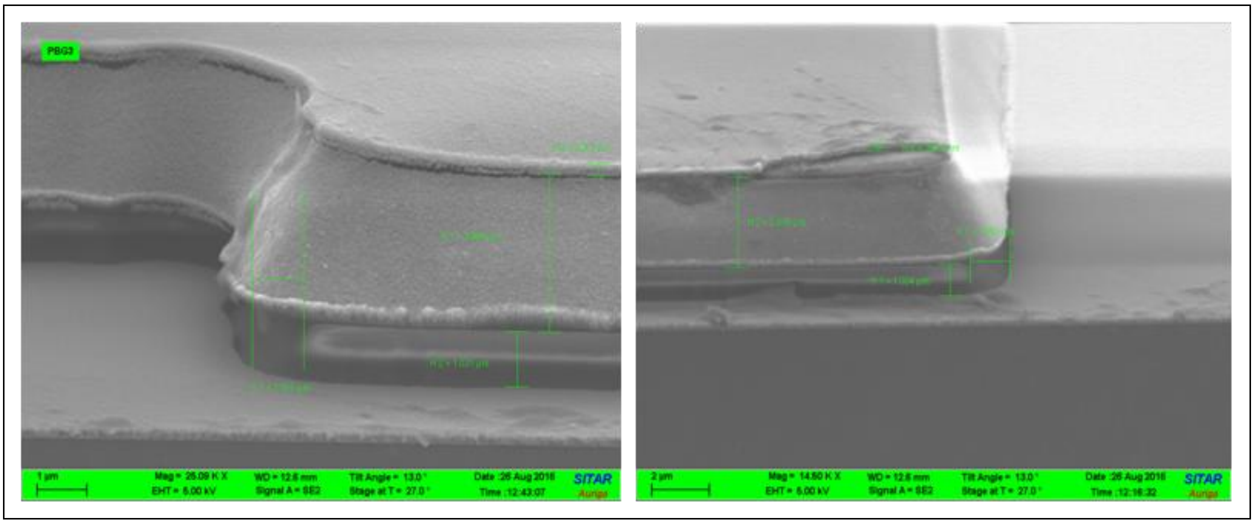

Fig. 3: SEM pictures after chromium and titanium deposition.

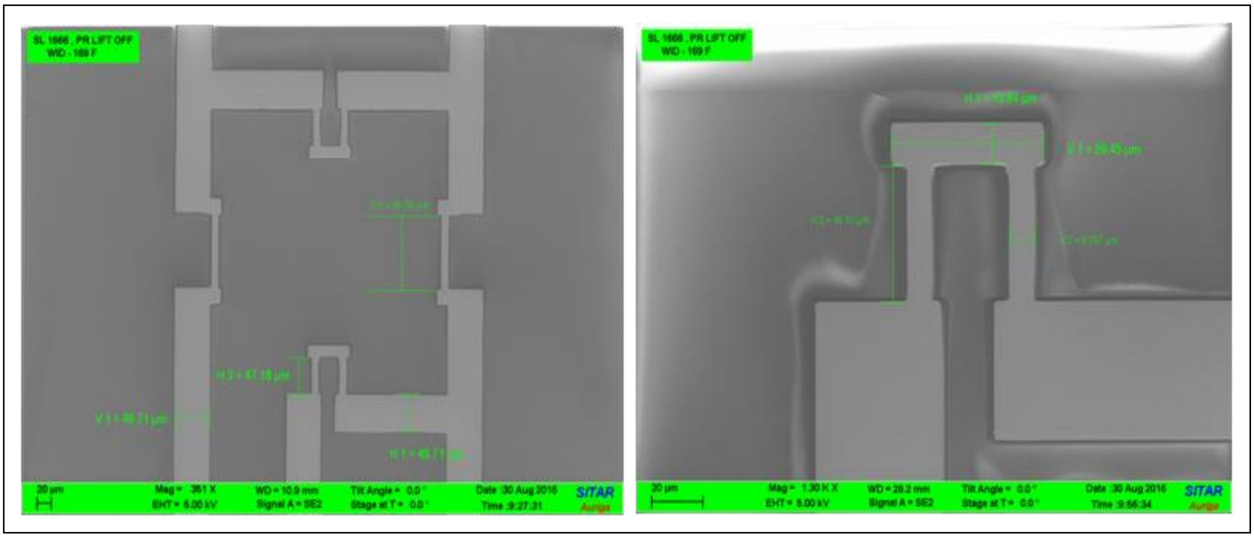

Fig. 4: SEM image of metal after lift-off process on Si wafer.

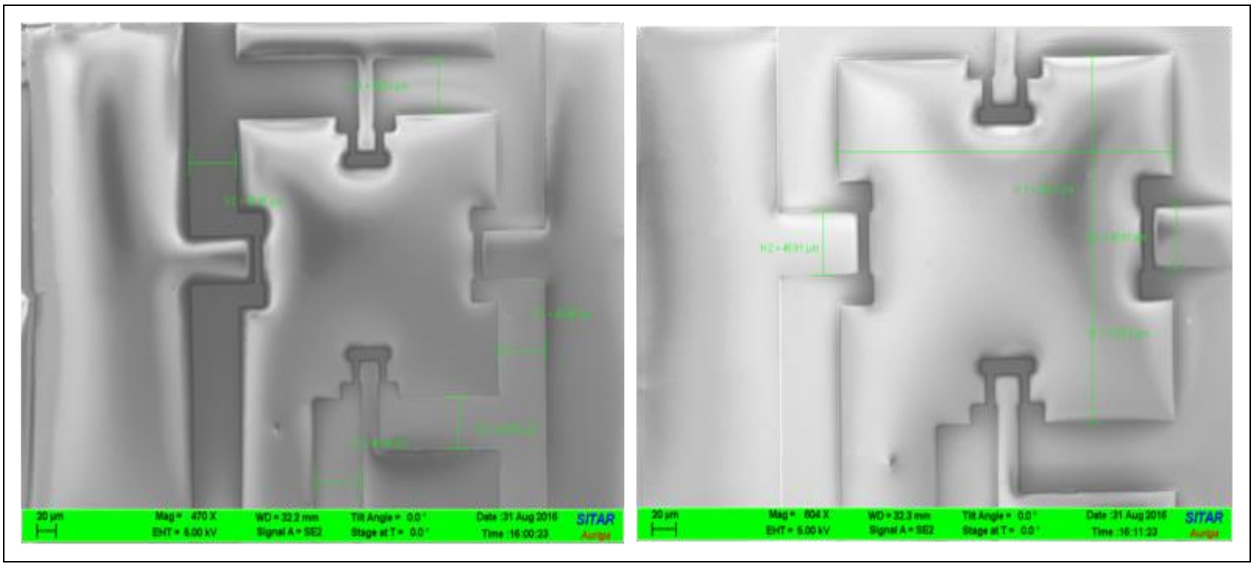

Fig. 5: SEM image of metal after lift-off process on a quartz wafer.

3. CONCLUSION

All the experiments were carried out successfully for both Si and Quartz wafers with different metal thicknesses and PECVD SiO_2 assisting layer. All the metal line dimensions were achieved with 3% tolerance. This investigation has shown an economical and easy lift-off process using PECVD SiO_2 assisting layer, and it can be used in various MEMS device fabrication, avoiding wet chemicals.

4. ACKNOWLEDGEMENT

We want to thank Dr. Indushekar for his guidance and support during the complete experiments.

We would also like to thank the metallization, characterization and wet etch and diffusion department for their process support.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Bharathi Sankar Ammaiyappan, Seyezhai Ramalingam and Mani Karthik, Piezoelectric-driven charging supercapacitors for bio-medical sensor applications, *J. Environ. Nanotechnol.*, 8(4), 26–32 (2019). https://dx.doi.org/10.13074/jent.2019.12.194388

Pandey, S., Bansal, D., Panwar, D., Shukla, N., Kumar, A., Kothari, P., Verma, S. and Rangra, K. J., Low cost lift-off process optimization for MEMS applications, *AIP Conference Proceedings*, 1724, 020105 (2016). https://dx.doi.org/10.1063/1.4645225

Slaughter, L. S., Cheung, K. M., Kaappa, S., Cao, H. H., Yang, Q., Young, T. D., Serino, A. C., Malola, S., Olson, J. M., Link, S., Häkkinen, H., Andrews, A. M. and Weiss, P. S., Patterning of supported gold monolayers via chemical lift-off lithography, *Beilstein J. Nanotechnol.*, 8, 2648–2661 (2017). https://dx.doi.org/10.3762/bjnano.8.265