Microelectronic Engineering 133 (2015) 51–58

Contents lists available at ScienceDirect

Microelectronic Engineering

journal homepage: www.elsevier.com/locate/mee

A plasma processing combined with trench isolation technology for large opening of parylene based high-aspect-ratio microstructures

Wen-Cheng Kuo *, Chih-Ming Liu

Department of Mechanical and Automation Engineering, National Kaohsiung First University of Science and Technology, No. 2 Jhuoyue Rd., Nanzih, Kaohsiung, Taiwan, ROC

A R T I C L E I N F O

Article history:
Received 26 March 2014
Received in revised form 20 September 2014
Accepted 14 November 2014
Available online 23 November 2014

Keywords:
Bulk micromachining
Comb-drive actuators
Deep reactive ion etching (DRIE)
High aspect ratio structure (HARS)
Inductively coupled plasma (ICP)

A B S T R A C T

This paper presents a parylene-based trench isolation method with which to create high-aspect-ratio microelectromechanical system structures. The silicon-based structures were electrically isolated by supported parylene beams, and the movements of suspended silicon structures used to sense or actuate were not confined by trench openings. The proposed process is a simple, low-temperature, and dry-etching fabrication process for structure releasing and electrical isolation, and does not involve the LPCVD, PECVD, ion implantation, sputtering processes, or sandwiched oxide/polysilicon/metal isolation traditional methods require. The parylene-based electrical isolated beams can be created through multiple steps of parylene deposition/remove inside a silicon mold. By enhancing the microtrenching effect, the suspended structure does not thoroughly remove the floor polymer inside the trenches when the trench aspect ratio is relatively small. The steps of trench etching, sidewall protection, structure release, and photoresist stripping can be finished by modifying the etching or passivation steps in the BOSCH process, and it can be integrated as the macro commands of ICP etcher. The single-run of the ICP-RIE process can automatically finish the suspended silicon structure creation. By using the proposed process, a test device 50 μm thick and with a maximal trench aspect ratio of 10 and a maximal suspended structure width of 40 μm was created. The proposed process can be used to fabricate devices for large in-plane displacement, increasing the sensitivity of the sensors and actuators.

1. Introduction

Bulk silicon micromachining is an crucial technology applied in microelectromechanical systems (MEMS) that requires a considerable sensor or actuator device thickness to enhance sensitivity and performance. To fulfill these requirements, creating a suspended high-aspect-ratio structure (HARS) that features electrical isolation is essential. Three concerns should be discussed before creating the suspended HARS: deep trench etching, structure release, and electrical isolation.

The deep trench etching is performed to define structural depth. The inductively coupled plasma (ICP) sources with the BOSCH process [1] can effectively balance the two steps of etching and passivation to achieve the high etching rate and vertical trench shape that is used widely for HARS trench etching.

Regarding structure release, numerous methods can be employed to create HARS, such as single-crystal reactive etching and metallization [2], the black silicon method (BSM) [3], the silicon-on-insulator (SOI) process [4], surface–bulk micromachining [5], the dissolved wafer process (DWP) [6], the boron etch-stop assisted lateral silicon etching process (BELST) [7], the aluminum interconnect process for air-gap-insulated microstructures [8], the polymer sidewall protection process for trench isolation technology [9], and the polymer sidewall protection with a trench isolation process [10]. The BSM [3] and SOI [4] processes are simple processes used for structure release, and are easily controlled by using the buried oxide layer as the sacrificial layer for wet release. However, these two wafers are too expensive compared with standard silicon wafers. The DWP process [6] involves high doping concentrations and produces inferior mechanical properties. In the processes proposed in [2,5–10], extra fabrication steps, such as plasma-enhanced chemical vapor deposition (PECVD), ion implantation, or sputtering, are required for structure release.

Regarding electrical isolation, compared to the complex steps involved in the electrical insulation layer creation [2,5,7,10]. Air gap insulation [8] and trench isolation [9] isolate the suspended silicon structures and substrates, and thus, are two methods suitable for electrical isolation. However, the small gap limits the displacement of the suspended movable structure, thereby reducing performance. Furthermore, expending the gap to increase performance by using the air gap insulation [8] and trench isolation [9]

* Corresponding author.
E-mail address: rkuo@nkfust.edu.tw (W.-C. Kuo).

http://dx.doi.org/10.1016/j.mee.2014.11.012
0167-9317/

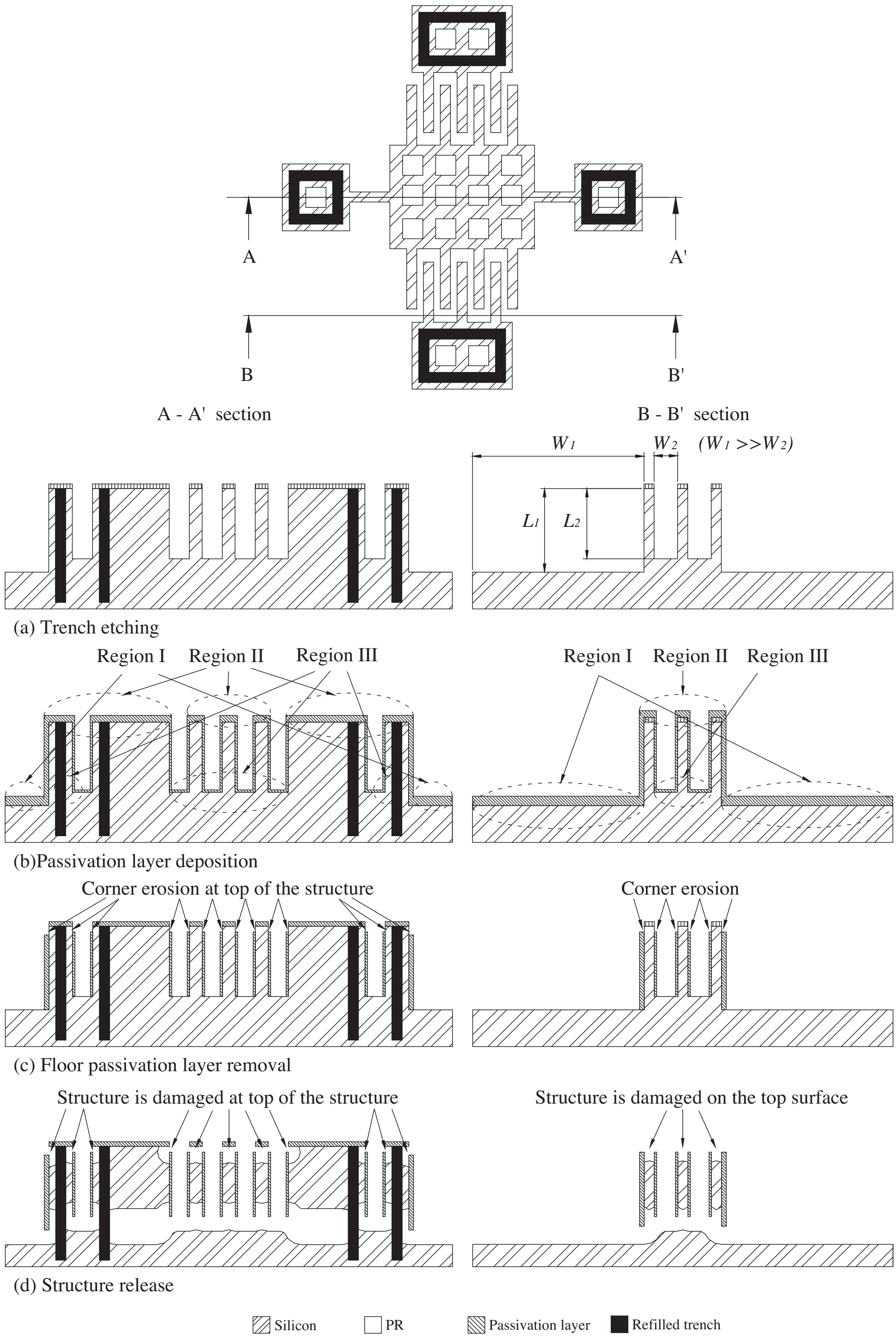

Fig. 1. Schematic of the mechanism of corner erosion occurring at the top of the structure.

methods is difficult. The weaker stiffness of the longer thin aluminum interconnect [8] cannot support the suspended structure. When the gap is increased by employing the trench isolation method [9], erosion constantly occurs on the top side of the structures. Fig. 1 depicts the mechanism of corrosion during the process. Step (a) is the trench etching, and L_1 is deeper than L_2 because the aspect ratio (W_1) is smaller than (W_2) by aspect-ratio-dependent etching (ARDE) [11]. In Step (b), because W_1 is much larger than W_2, the trench aspect ratio in Region I is much smaller than that in Region III. Therefore, the deposition rate in Region I is higher than that in Region III, a phenomenon that is attributable to the conductance effect [11,12] and the reactant transport effect [13].