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Investigation of ProTEX® PSB Thin Film as Photosensitive Layer for MEMS capacitive pressure sensor diaphragm based Si/SiC Wafer

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A B S T R A C T

Characterization of ProTEX® PSB thin films of newly developed photosensitive layer as alternative replacement for silicon nitride or silicon oxide wet etch masks. ProTEX® PSB thin films have been deposited on Si/SiC wafer for bulk micromachining technology in MEMS capacitive pressure sensor diaphragm to obtain a new recipe process flow of various factor. In this paper, we will discuss the process flow for ProTEX® PSB deposition to estimate the final film thickness that is defined by the spin-coating rotational speed, final cure temperature and hard bake time of ProTEX® PSB coatings. ProTEX® PSB thin films have been preliminary characterized by infinite focus microscopy (IFM) and scanning electron microscopy (SEM) to examine the substrate surface conditions and the effects of undercut edges structure. Based on these results, it was determined the optimum thickness of ProTEX® PSB is 2.133 µm with the spin speed of 3000 rpm. The recommended for the first bake temperature of 110 °C in 120 seconds and for the second bake temperature of 240 °C in 60 seconds. ProTEX® PSB can withstand the etch mask with etch rate of 1.28 µm/min for 8 hours and gives good quality effect of undercut edge on Si/SiC wafer.

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INTRODUCTION

The most widely etching method applicable to a micro-electro-mechanical systems (MEMS) process including steps of: (a) forming an etching mask on a wafer such as silicon nitride and silicon oxide, (b) forming a plurality of patterns in the etching mask corresponding a depths of the plurality of trenches, (c) etching the wafer using the etching mask that having the plurality of patterns formed, (d) eliminate an alignment in photolithography that allow to form a accurate structure, simply fabrication process and reduce a fabrication cost (Dalvi-Malhotra, J., *et al*., 2008). Basically, silicon nitride and silicon oxide materials are usually is used as the etch masks in the KOH etching due to high selectivity of the etchant towards both materials. For the purpose of silicon bulk micromachining, the silicon oxide cannot withstand the layer of etch mask for a long hours in etching process due to the etch rate is relatively higher compare to the silicon nitride with (~30-70nm/min) for thermal oxide (Rosminaziun, A.R., *et al*., 2013). Silicon nitride has a better stability in wet etch due to its lower etch rate compare to silicon oxide and the possibility of the presence of pinholes in the mask layer but the main issue in terms of high cost involved deposition of the silicon nitride etch mask via Low Pressure Chemical Vapor Deposition (LPCVD) process contributes to an additional process step in the overall fabrication process flow (Tomokazu, T., *et al*, 2010). The newly developed ProTEX® PSB as photosensitive etches protection materials have key advantages over standard photoresists typically used in today's MEMS application. This new technology will enhance throughput by reducing the number of process steps and simplify the flow with minimal impact on overall undercut performance.

The ProTEX® PSB polymeric coating serves as s silicon nitride mask replacement for etching silicon substrate in alkaline anistropic etching of silicon keeps gaining special interest even though it is one of the oldest techniques in bulk micromachining structure. This is due to its low cost and simple implementation (Dalvi-Malhotra, J., *et al*., 2007].

Fabrication process:

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The fabrication process flow for the MEMS capacitive pressure sensor diaphragm is depicted in Fig. 1. The Si/SiC wafer is used in the fabrication as shown in Fig. 1(a). The backside of SiC was polished to remove another side SiC layer on surfaces until the thickness of silicon is about 300 µm (Fig.1b). Then, the first layer, ProTEX PS primer coating are deposited on the silicon substrate with spin-coat speed at 1000 rpm for 60 seconds (Fig.1c).

The first baking at a temperature of 120°C for 60 seconds and the second baking at a temperature of 240°C in 60 seconds to harden the primer coating. The second layer, ProTEX® PSB coating was applied on the silicon substrate with spin-coat speed at 3000 rpm for 60 seconds. The ProTEX® PSB was baked at temperature of 120 °C in 60 seconds (Fig.1d). Subsequently, the photosensitive coating layer is exposed using a photolithography process to pattern for approximately 300 seconds through a photomask (Fig.1e). The ethyl lactate (EL) is used to develop the ProTEX® PSB mask by immersed into the bath for 30 seconds until geometric pattern from a photomask will be appeared on the Si/SiC substrate. The MEMS capacitive pressure sensor diaphragm has been etched in Potassium Hydroxide (KOH) with concentration of 55%wt at 80°C temperatures.

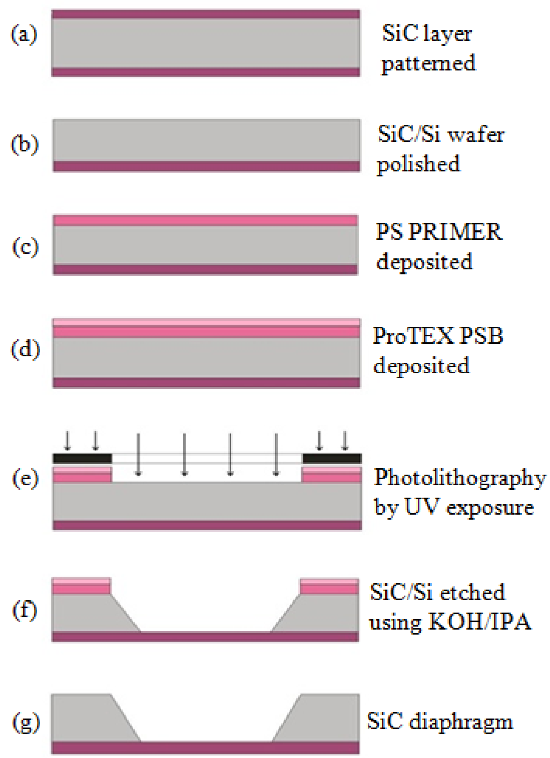

Fig. 1: Process flow for the fabrication of MEMS capacitive pressure sensor diaphragm

RESULTS AND DISCUSSION

(a) Thickness versus spin speed of ProTEX PS Primer and ProTEX® PSB:

The most common method of photosensitive application is spin coating process. A determined amount of ProTEX® PSB is dispensed either on the static or slowly rotating on Si/SiC wafer. The Si/SiC wafer is rapidly speeding up to a speed ranging between 500 – 3000 rpm. The acceleration stage is critical to obtain good uniformity due to the ProTEX® PSB begin evaporating immediately after dispensing. When the spinning time is 30 second, less than 1% of the originally dispensed amount of the ProTEX® PSB remains on the Si/SiC wafer since the ProTEX® PSB rest flies off during spinning.

Considering in Fig. 2, the requirement that the thickness of second layer, ProTEX® PSB thin film is greater than first layer, ProTEX PS Primer thin film in the spin-coating process in the same spin speed at 3000 rpm due to the ProTEX® PSB has higher viscosity properties. The higher viscosity affects the slower rate in spin coating process that offers the compensation of increased film thickness uniformity (Alvankarian, J., *et al*., 2011). The maximum allowable thickness of the first layer, ProTEX PS Primer approximately range from 1.10-1.15 µm while for the second layer, ProTEX® PSB is about range from 2.10-2.15 µm.

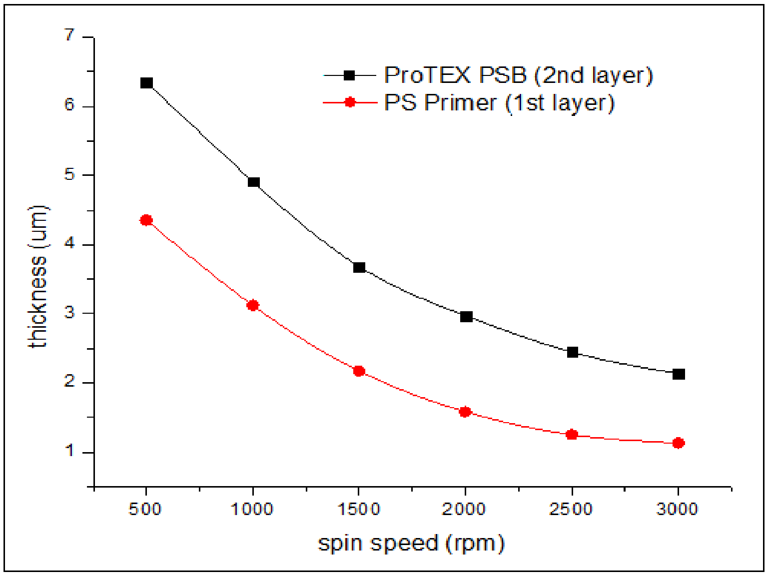

Fig. 2: Thickness versus spin speed of ProTEX PS Primer and ProTEX® PSB

(b) Thickness versus time with different temperature of ProTEX PS Primer and ProTEX® PSB:

The first layer, ProTEX PS Primer is deposited on the Si/SiC wafer. Then, ProTEX PS Primer soft-bake at different temperature 90 °C, 100 °C, 110 °C and 120 °C to define the characteristics of minimum thickness that has good surface tension when combination with ProTEX® PSB layer. Thinner films around 0.525 µm were achieved corresponding to the ProTEX PS Primer when harden at high temperature, 120°C due to the lower viscosity properties when compare to ProTEX® PSB as shown in Fig. 3.

In the final ProTEX® PSB the dissolution rate in the developer, ethyl lactate (EL) is highly depend on the solvent concentration. Fig. 4 shows the different temperature of soft-bake process of ProTEX® PSB which is 90 °C, 100 °C, 110 °C and 120 °C. From the results, the higher temperature for soft-bake can reduce the thickness of photosensitive is about 2.15 µm. ProTEX® PSB thin film can be achieved by hardening the ProTEX® PSB with subsequently for the final parameters at 110 °C in 120 seconds.

After coating, the Si/SiC wafer must undergo a soft-bake. A method for hardening a ProTEX PS Primer and ProTEX® PSB thin film formed on a Si/SiC wafer, it is usually subjected to a soft-bake or pre-bake step. A soft-bake is often required to harden both ProTEX PS Primer and ProTEX® PSB to increase the adhesion to the Si/SiC wafer and to establish the exposure characteristic.

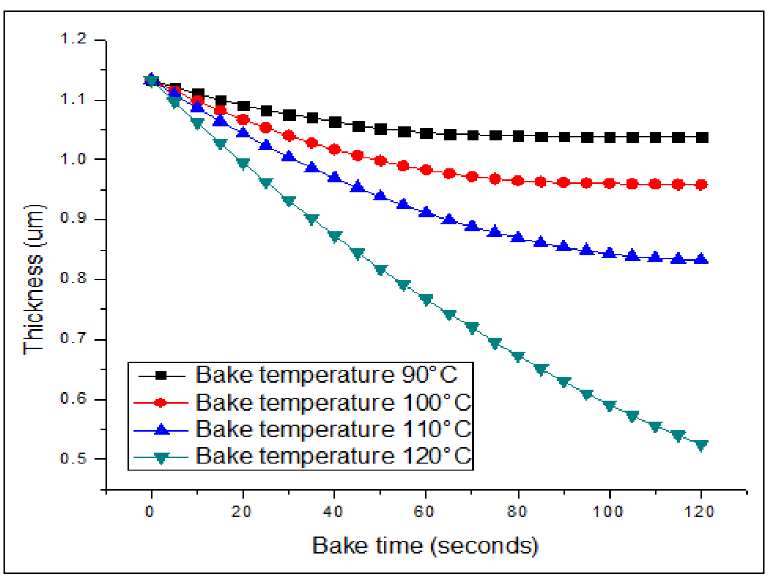

Fig. 3: Thickness versus time with different temperature of ProTEX PS Primer

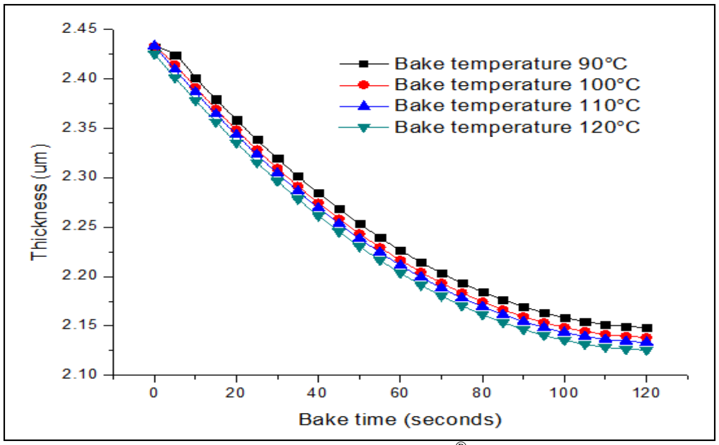

Fig. 4: Thickness versus time with different temperature of ProTEX® PSB

(c) Scanning electron microscope (SEM) of ProTEX® PSB deposition:

SEM image in Fig. 5. shows the cross-section ProTEX® PSB coating reveals good adhesion to Si/SiC substrate indicated the layer is partially locked each others.

Fig. 6. clearly shows a SEM image of the pattern of MEMS capacitive pressure sensor diaphragm structure by using ProTEX® PSB coating after exposed using Karl Suss mask aligner for 300 seconds and developed in ethyl lactate (EL) for 30 seconds.

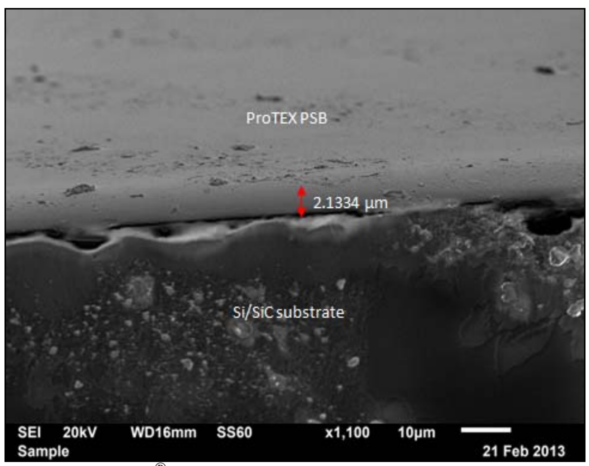

Fig. 5: SEM image of cross-section ProTEX® PSB layer on Si/SiC substrate

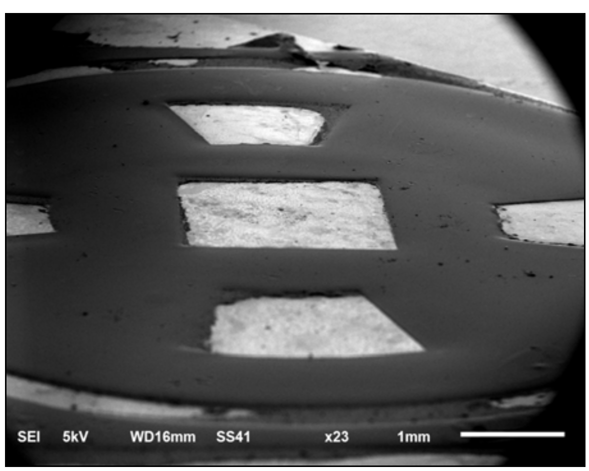

Fig. 6: SEM micrograph of ProTEX® PSB layer was exposed and developed in ethyl lactate (EL)

Fig. 7: ProTEX PS Primer and ProTEX® PSB layer is deposited for MEMS capacitive pressure sensor diaphragm

Summary:

We have demonstrated a novel fabrication process of photolithography technique to pattern Si/SiC substrate for MEMS capacitive pressure sensor of bulk micromachining process with controlled the temperature, thickness and spin speed coating of ProTEX® PSB layer that offer some possibility reduce processing time and reduce cost.

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