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Mechanics of plasma exposed spin-on-glass (SOG) and polydimethyl siloxane (PDMS) surfaces and their impact on bond strength

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Abstract

Silicone polymer (PDMS), widely used for micro-fluidic and biosensor applications, possesses an extremely dynamic surface after it is subjected to an oxygen plasma treatment process. The surface becomes extremely hydrophilic immediately after oxygen plasma exposure by developing silanol bond (Si–OH), which promotes its adhesion to some other surfaces like, silicon, silicon dioxide, glass, etc. Such a surface, if left in ambient dry air, shows a gradual recovery of hydrophobicity. We have found an identical behavior to occur to surfaces coated with a thin continuous film of SOG (methyl silsesquioxane). The chemistry induced by oxygen plasma treatment of a spin-on-glass (SOG) coated surface provides a much higher density of surface silanol groups in comparison to precleaned glass, silicon or silicon dioxide substrates thus providing a higher bond strength with polydimethyl siloxane (PDMS). The bonding protocol developed by using the spin coated and cured SOG intermediate layer provides an universal regime of multi level wafer bonding of PDMS to a variety of substrates. The paper describes a contact angle based estimation of bond strength for SOG and PDMS surfaces exposed to various combinations of plasma parameters. We have found that the highest bond strength condition is achieved if the contact angle on the SOG surface is less than 10°.

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Keywords: PDMS; SOG; Plasma; ATR-FTIR; Contact angle; Bond strength

1. Introduction

An important need of the biosensor and micro-fluidic industry is its successful integration to micro-electronics. Some of the widely used materials amenable to micro-fabrication processes are glass, silicon, polymethyl methacrylate (PMMA), polydimethyl siloxane (PDMS), etc. [1]. Silicon, being the most widely used material for micro-electronic applications, may be thought of as a natural choice for such an integration. However, for defining flow paths fabrication of micron-scale features in silicon, expensive deep reactive ion etching (DRIE) processes or extensive use of wet chemical processes is needed. This generates large amounts of environmentally unfriendly waste [2,3]. Replica molded silicone rubber, PDMS, has often been suggested as an alternate route and has been successfully used in diverse applications ranging from micro-fluidics [4], genomics [5], proteomics [6], metabolomics [7], etc., though its integration with different substrates can be a challenge. A variety of processes are currently used to promote adhesion between PDMS and substrates like glass, silicon, silicon dioxide, etc. This includes spun on liquid PDMS acting as adhesion intermediate layer [8], surface activation by using high pressure, low power gas plasmas [9], chemical treatment of surfaces [10] thus developing weak van der Waals forces of attraction between the various layers, etc. Among all these techniques, the use of oxygen plasma produces the strongest SOG–PDMS bonds which are irreversible in nature [9]. The changes in surface texture and chemistry happening in post exposed PDMS surface have been widely studied by many researchers using a variety of techniques like attenuated total

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