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Batch fabrication of RF-MEMS switches and problems encountered

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Abstract: Simulation of micro electro mechanical system (MEMS) is well established and largely developed. But implementation or fabrication is quite difficult. The bridge of MEMS switch is very much soft but it does not touch the signal line. So there is an important factor of increasing tress. For low power consumption and high signal transfer micro machined structure is introduced. But opening of window or back side micro machining is challenging because here two wafers are taken for making the device. Different types of fabrication related problems described in this paper.

Keywords: Micro electro mechanical system (MEMS), Switch, Micro machined structure, Electroplating.

I. INTRODUCTION

RF- MEMS has wide area application in industry like antenna, filter, phase shifter for cost, frequency, gain, large-scale integration, lifetime, linearity, noise figure, packaging, power handling, power consumption, reliability, ruggedness, size, supply voltage, switching time and weight [1]. In design of devices like planar and non-planar antenna, filters, power dividers, switches and passive elements, MEMS technology is employed for its high quality factor, wide tuning range, low phase noise and small chip size [2]. MEMS makes it possible to realize not only low insertion loss and bias power consumption but also single chip package which is impossible with standard semiconductor process [3 – 7]. It can define MEMS capacitive-type sensor is basically an electrostatic transducer that depends on electrical energy in terms of constant voltage (voltage drive) or constant charge storage (current drive) to facilitate monitoring of capacitance change due to an external mechanical excitation, such as force, acoustical pressure or acceleration [8]. MEMS switches reliability that seems to be related to the dielectric charging happening as the device is operated for a large number of cycles [9, 10]. The dielectric charging seems to be dependent on the sign and magnitude of the electric field applied to the device when the switch is in the drive or hold modes [11–13]. Different types of modeling and simulation technique is used for realization of RF MEMS. Analytical models using various modeling techniques are available for fixed-fixed beams [14–18]. Various designs of capacitive RF MEMS switches fabricated using different metal substrate like nickel [19], aluminum [20,21] and gold [22] have so far been reported in literature.

In RF MEMS technology [23] identified film stress as an important factor influencing switch performance. Also different research has indicated that choices in device materials affect the profile of released microstructures [24–26].

The fabrication or implementation of RF MEMS device is critical time consumed process. In this paper the simplest fabrication of two moveable plate RF MEMS switch is described. Here it is discussed the different faced problem and the optimized solutions.

II. FABRICATION OF RF-MEMS SWITCH

Two high resistivity silicon wafer of 5-10 KΩ-cm is taken for making RF-MEMS switch. Standard cleaning I and standard cleaning II is done to remove wax, grease, unwanted particles, inorganic impurities from the surface of the silicon wafer. Now the two wafers treated in different way. One micrometer silicon dioxide is grown by simple pyrogenic wet oxidation technique on the both side of the Wafer I. High quality gold is required for making the bridge of MEMS switch so, chromium and gold is deposited by using rf sputter technique where the target of gold is highly purified. Sputtered chromium and gold thickness is near about 120 nm. For making the gold thickness up to one micrometer electroplating method is used. Four level photolithography steps are done for the total fabrication process.

To make the coplanar waveguide (CPW) structure first level photo lithography is done and for the second level lithography double side alignment technique is used to open the back side window.

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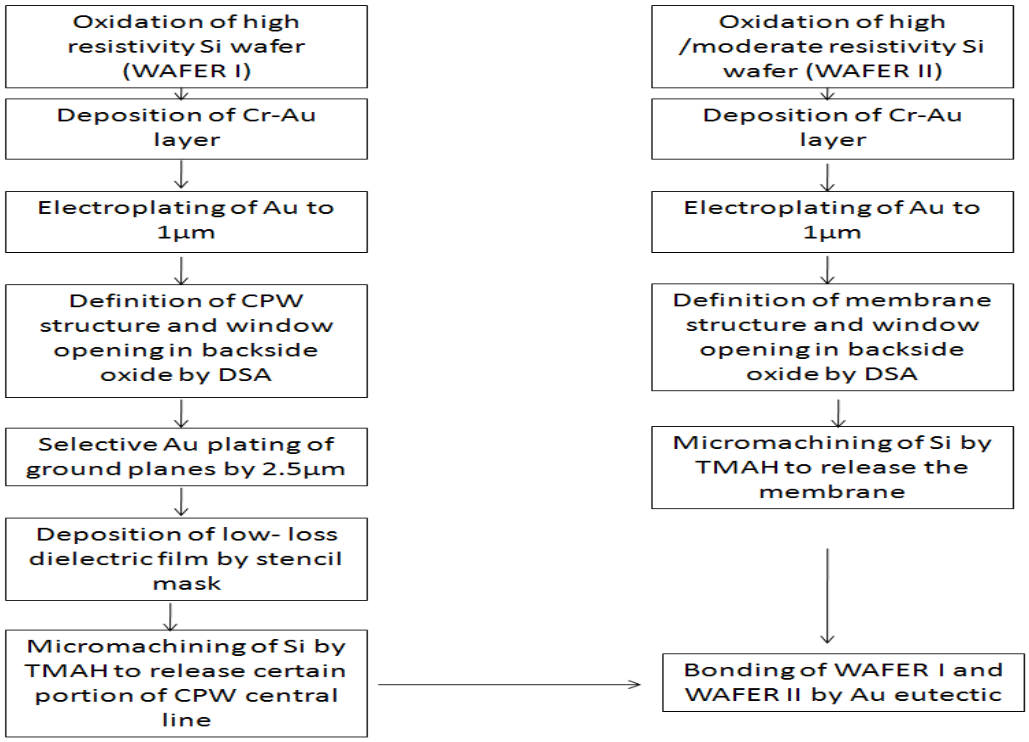

Fig.1. Flowchart of RF-MEMS switch fabrication

To increase the two ground line 1.5 micrometer more than the signal line selective electroplating process is done. After that 2.5 micrometer height of ground line is obtained. Gold-gold germanium- gold eutectic is deposited on the top of the ground substrate by using e-beam evaporation technique through tensile mask for getting better adhesion with other prepared wafer. For the second wafer first oxidised by pyrogenic wet oxidation of one micrometer thickness is obtained. Deposition of chromium-gold layer is done by same sputtering technique. Third level photolithography is done to design the bridge and fourth level photolithography is done for defining the window. Wafer I and wafer II are then bonded by wafer bonder using eutectic. Teflon tape is raped the bonded wafers except the window. Window is opened by using TMAH solution.

III. FABRICATION PROBLEMS ENCOUNTERED

If the plating solution is freshly prepared then it is seen that there is faster deposition at the time of electroplating process which causes nonuniform deposition of gold material. So there is needed to optimizing the current density again for smooth electroplated layers. The solution is observed that it may prepare bulks of solution at one go to avoid the encountered difficulty. During etch- back of Silicon dioxide the PPR was coming off as the wafers had to be kept in Buffered HF Oxide Etch (BOE) for a long time due to thick oxide layers. The thick oxide layer is essential for optimum performance of the RF MEMS switch. As the positive photo resist (PPR) was coming off the window for micromachining was not properly opened resulting in larger opened window dimensions and curved window edges as shown in Fig 2.

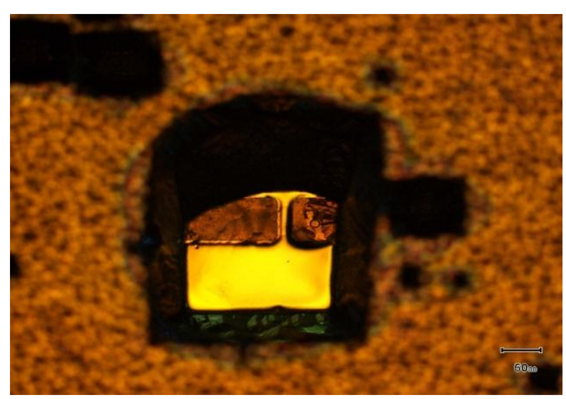

Fig.2 Problem in larger opened window

To overcome this problem the PPR thickness is increased and baking time (both PRE- and POST-) of PPR increased. As the wafer taken is single side polished (SSP) proper backside alignment could not be achieved which resulted in unaligned devices (Refer Fig 1: The CPW central line is not below the released shunt membrane). As a solution is taken both sides of the wafer were sputtered with Cr- Au for proper visibility of the alignment marks. This also solved problem the Oxide layer is now protected with a Cr- Au layer. The other problem is that the swelling of the released membranes (both SHUNT and CPW) occurred as shown in Figure 3 and figure 4.

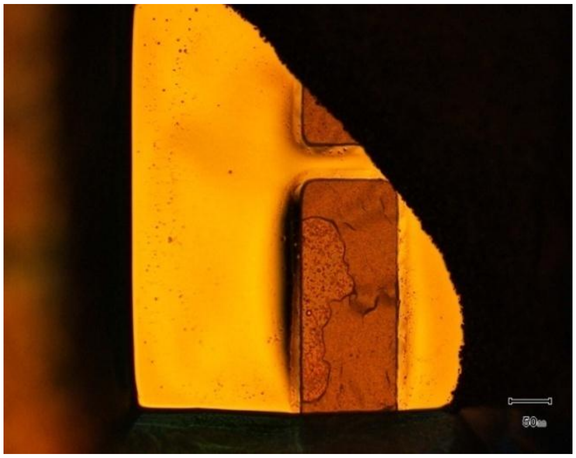

Fig.3 Problem in opening window

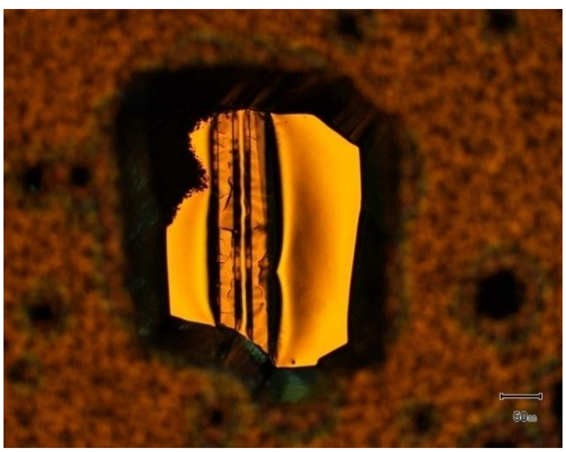

Fig.4 Another problem in opening window

Figure 5 is showed that bridge of the top wafer is cracked which give bad result and as well as it shorted with the signal line of the bottom wafer. To overcome this problem low temperature annealing after bonding is taken to reduce the problem associated with stress.

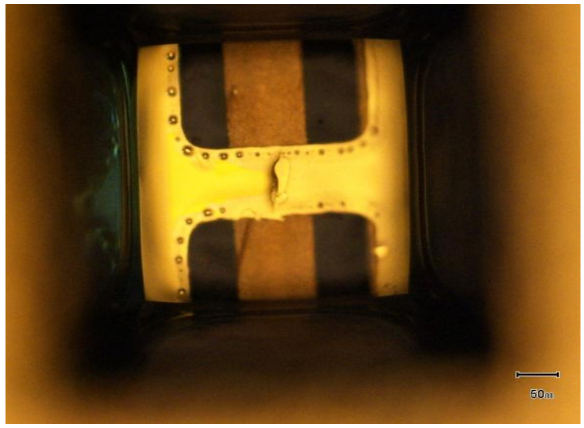

Fig.5 Tress problem of MEMS bridge

Although most of the Problems were solved there remained alignment issues as seen in Fig. 6 in some parts of the wafer where it is seen that the shunt and the signal line of the CPW is not properly aligned but the window opening is almost perfect.

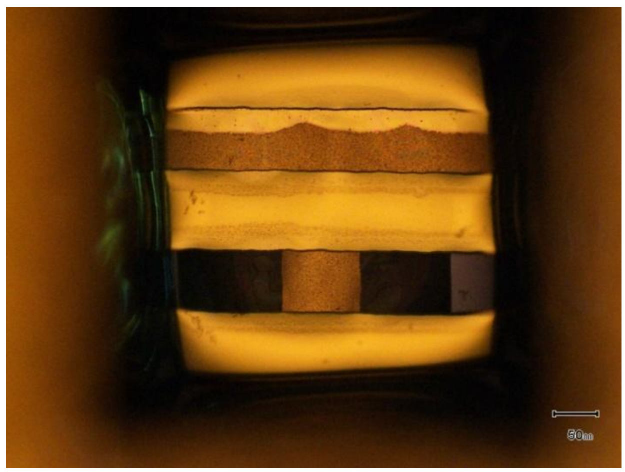

Fig.6 Alignments problem of two wafers

As a solution it is tried for better alignment in photolithography step at double side technique using the same mask but the wafers were damaged due to an accident in the laboratory as the device was over- etched. So the final solution is considered is that the use of both global and local alignment marks to completely do away with the alignment issues and the Masks are modified.

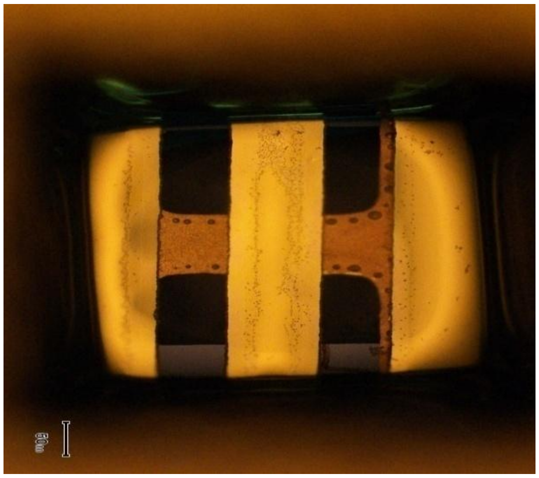

Fig.7 RF-MEMS based switch

IV CONCLUSIONS

This paper presents a methodology for the analysis of the fabrication process of RF MEMS switch by using two wafers. It is fabricated 15 switches as a batch fabrication in a single arrangement. Here it is tried to overcome the different fabrication problem of RF MEMS switch.

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