Improving frequency Control of Temperature Compensated Surface Acoustic Wave Devices

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***Abstract*—In this paper, we demonstrated improvement of frequency uniformity and stability for Temperature Compensated Surface Acoustic Wave (SAW) devices. SiO_2 has been used to obtain low Temperature Coefficient (TempCo) in SAW devices for more than three decades [1]. One of the big issues is that SAW devices have to be processed at temperatures below 300C. When low temperature SiO_2 is exposed to the ambient environment, it interacts with ambient humidity [2], [3], [5], [6]. Such interactions can change frequency of the SAW devices and can make frequency trimming with a focused Ion Beam [7], [8] extremely challenging. UV and steam treatment of SiO_2 improved trimming rate stability on the first trimming [4] and [9], but was not sufficient to provide tight frequency control required for SAW devices after the second trimming. Using silicon nitride (Si_3N_4) capping layer on top of SiO_2 showed some improvement in frequency control after trimming process. Most improvement was obtained using aluminum nitride (AlN) capping layer on top of SiO_2 followed by two trimming steps.**

Keywords-SAW, Temperature, coefficient, trimming. frequency

I. INTRODUCTION

Controlling frequency of temperature compensated devices is critical in obtaining high yielding production process. The use of SiO2 films has been recently used to improve behavior of SAW filters over the required temperature range. Unfortunately, the diffusion of the moisture into SiO2 film during exposure of the wafers to the ambient environment causes the reaction of H20 with strained Si-O bonds and formation of silanol (Si-OH). This has a great effect on the local intrinsic SiO2 film stress and leads to the reduction of compressive residual stress and progressive increase of the tensile residual film stress.

With above mentioned effect, it is impossible to obtain yield above 90% without use of frequency trimming. In this paper we address the issues with obtaining best results through a judicious use of both deposition and trimming techniques.

II. EQUIPMENT

In this research, we used Advanced Modular Systems' (AMSystems) three chamber cluster tool pictured in Figure 1 for deposition of all layers as well as frequency trimming.

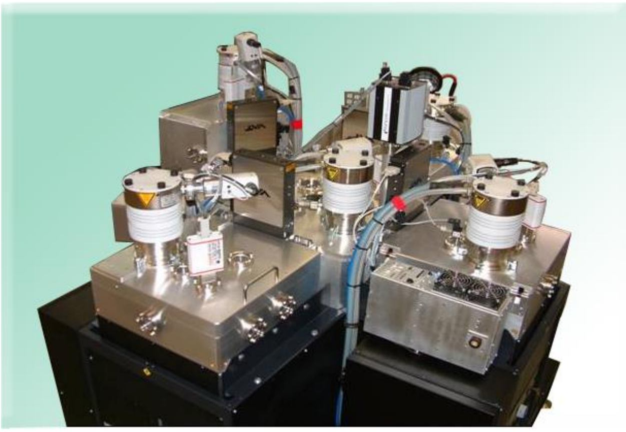
SiO2 was deposited using RF diode mode from SiO2 target. We used 12" target at 1kW of RF power and frequency 13.56 MHz. Only Ar process gas had been added during SiO2 deposition.

Si3N4 film was deposited by dual AC magnetron from highly doped - highly conductive Si target. 40kHz AC power at 1kW had been applied between two Si targets. Ar and N2 were added as process gases during deposition. Deposition was done in poisoned nitride mode to get a stable and stoichiometric Si3N4 film.

Standard process for AlN deposition was used with dual AC magnetron. AC power applied between targets in a reactive deposition mode.

Standard Trimming process was performed on the deposited films. Process is established by removing film thickness of the top layer, based on frequency maps using an adjustable focused DC ion source and scanning wafer mechanism. Trimming process was used to get high yield of devices from wafer.

Figure 1: AMSystems Cluster Tool



III. METHODS FOR IMPROVING TEMPCO CONTROL

For several decades SAW device manufacturers attempted to utilize SiO2. Unfortunately, low temperature oxide depositions necessary for the SAW applications, combined with a need for low cost equipment, limited options available to the SAW manufacturers. Over decades many methods have been tried in order to reduce variation of frequency due to the inherent oxide interactions with ambient moisture. In this paper we have compared few methods of protection and surface modification of the silicon dioxide films in order to prevent the physical adsorption of water vapor molecules on the surface of silicon dioxide film and reaction between Si-O bonds with H2O molecules with Si-OH formation.

To prevent physical adsorption of water vapor on Silicon dioxide film we used two different cap layers: AlN and Si3N4 films. Both films have good passivation properties, stable and have high grain density. 500A of Si3N4 or AlN films were deposited on top of SiO2 films without vacuum break. 500A was chosen to make sure that after trimming process at least 200A of the film is still remaining.

For SiO2 surface modification we used two methods:

1. High power density UV radiation
2. Annealing of SiO2 film in high humidity environment

High power density UV radiation was done by scanning wafer under excimer laser radiation. XeCl excimer laser with wavelength 308nm and power density greater than 10MW/cm2 per pulse was used for SiO2 surface modification. Surface densification under this process conditions prevented diffusion of moisture into SiO2 grain bonds.

Annealing of SiO2 film in high humidity was done at the temperatures between 250…300C in water stem with post annealing and then, drying. This process allows saturating all available Si-O bonds and eliminating further changes under exposure to the ambient.

Figures 2 and 3 show improvements obtained using different methods commonly used to improve frequency control in temperature compensated SAW devices.

Figure 2: Average Frequency as a function of time exposure to atmosphere for different methods of SiO_2 treatments and capping processes

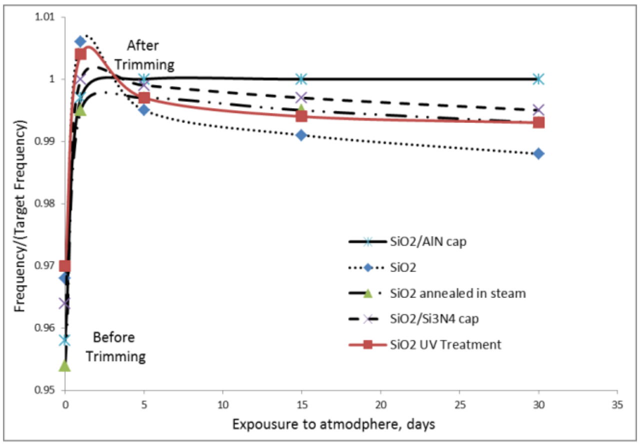
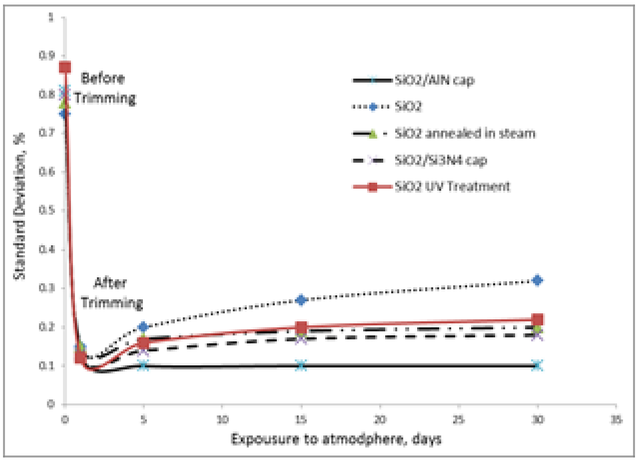
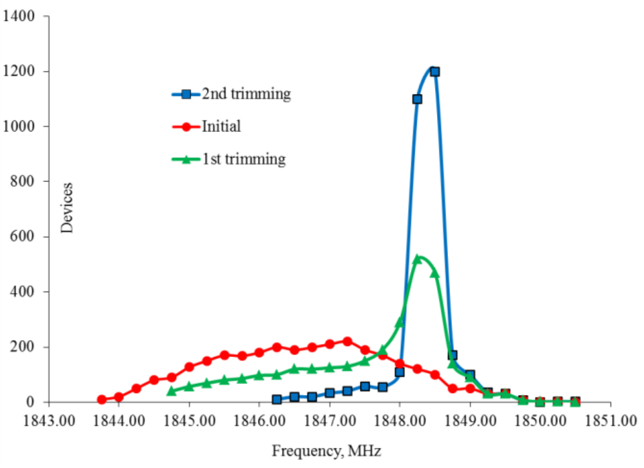


Figure 3: Cross wafer Frequency variation as a function of time exposure to atmosphere for different methods of SiO_2 treatments and capping processes



The most successful method as we observed is to cap SiO2 with AlN without air exposure and trim it with focused ion beam. Even though this technique is adequate for a lot of devices, there is a further benefit in performing a second trim. Figure 4 shows the benefits of the two steps trimming vs. one step trimming.

Figure 4: Two step trimming on an AlN capped temperature compensated SAW device



Depending on the initial frequency distribution, the first trim can have 5X improvement. Second trim provides another 4X improvement over the first trim. As the result the total frequency improvement can be as big as 20 times.

IV. SUMMARY

Capping SiO2 temperature compensated layer with AlN film and using two steps trimming can provide high yielding SAW devices for the tough requirements for today's RF filter needs.

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