Plasma assisted SiO_2 FOR TC-SAW DEVICES

Evatec's Process Engineer **Hokwon Kim**, Scientist **Edmund Schuengel** and Product Marketing Manager **Carlo Tosi** explain the importance of temperature compensation for TC-SAW devices and how plasma enhanced reactive magnetron sputter deposition on CLUSTERLINE® provides a cost effective manufacturing solution.

Temperature compensation layers are key

Fast and efficient communication for the new 5G world has driven the rapid advancement of radio-frequency (RF) filters technology for numerous communication devices. One of the most successful types of commercial RF filter devices are surface acoustic wave (SAW) filters. These utilize an interdigitated transducer (IDT) electrode configuration on piezoelectric substrates to couple the surface acoustic waves with the electric signal around a resonant frequency typically in the range from 10 MHz to 3 GHz. A high quality temperature-compensating layer, usually SiO_2, that encapsulates the IDT structure of the TC-SAW device is essential to ensure high performance. Figure 1 illustrates the typical structures required.

Challenges in SiO_2 deposition for RF filters

The unique, thermo-elastic properties of SiO_2 are ideally suited to ensure the required low temperature sensitivity but its manufacture poses challenges for materials deposition technology in RF filter applications. Particular difficulties arise in relation to achieving good planarization, high density, and conformal coverage over the IDT structure electrodes. Not only are these becoming more complex and technically demanding in terms of aspect ratios and miniaturization, but also more challenging through ever more demanding throughput targets and lower manufacturing costs.

Technologies such as plasma enhanced atomic layer deposition (PEALD) or pulsed laser deposition (PLD) can certainly accomplish excellent conformal coatings, but reactive magnetron sputtering deposition (RMSD) offers the potential for much higher deposition rates and improved scalability for the lowest manufacturing costs providing the problem of achieving the required gap filling performance on "non planar substrate topologies" can be solved.

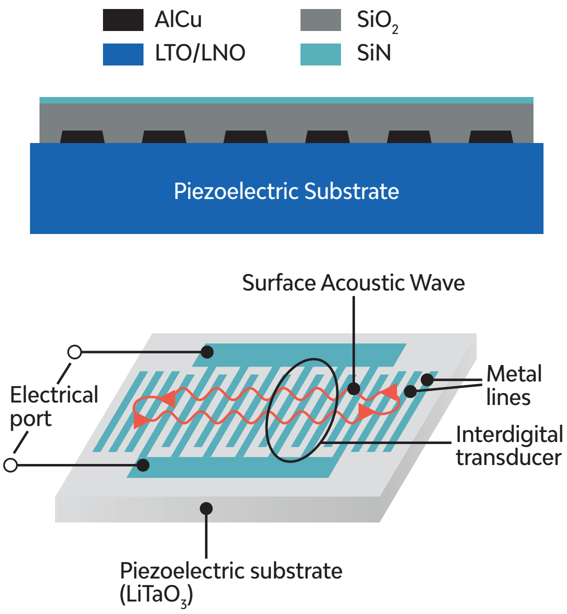

Figure 1. IDT structure

Cost effective mass production platform

Efficient mass-production can be achieved in Evatec's fully automated CLUSTERLINE® 200 cassette-to-cassette production tool equipped with Batch Process Module (BPM) technology. The BPM at its heart comprises a vacuum chamber equipped with a large turntable with multiple individual rotating chucks. Single wafers up to 8 inch, or carriers for mini batches of smaller wafers are placed at each chuck on the table by the vacuum handler attached to the BPM. Multiple sputter sources for RMSD can be installed according to process requirements together with a plasma source. Tool architecture highlighting options for turntable and source configuration is shown in figure 2.

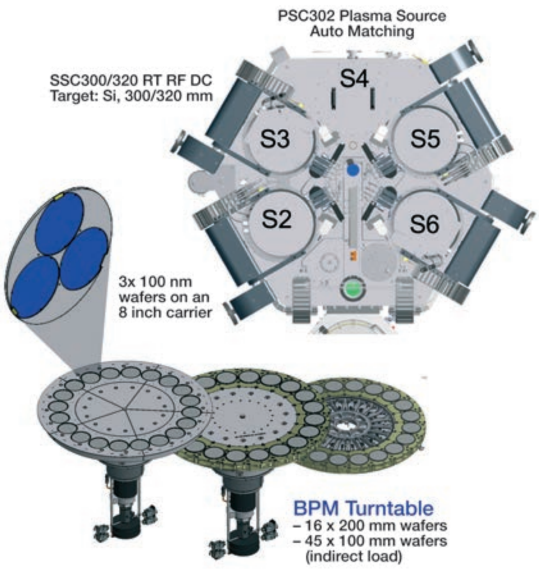

Figure 2. BPM tool architecture

The system is designed not only for high throughput deposition of dielectric materials such as SiO_2 and SiN or metallic layers such as Al, W, Hf, Ti, and Nb, but also for integration of a wide range of in-situ treatment and process monitoring technologies of the films during the deposition process, tailored to the specific requirements of the solution provided..

A sputter based solution has been found

Combining RMSD with additional plasma treatment of the growing film has now been shown to be an effective manufacturing approach. An additional plasma is generated through a magnetized capacitively coupled radio-frequency plasma source (PSC). A section of the source is shown in figure 3. A quasi-neutral beam of electrons and ions flows out of the source and onto the substrates. In addition to the physical effect of the ions, chemically reactive radicals can be added by mixing a reactive gas into the process gas flow of the plasma source. While the total ion flux density onto the substrate is simply controlled by the RF power, adjusting process parameters such as the magnetic field distribution allows precise control of the DC self-bias voltage and thereby ion energy at the substrate. A wide range of ion energies between 50 eV and 1000 eV is achievable. This independent control of the dominant energy and the total flux distribution of the ions is key to achieving optimum performance of the plasma enhanced RMSD process. Our process achieves efficient back etch and consequently the required surface conformality of the coating whilst still maintaining the advantages of rate and scalability associated with sputtering.

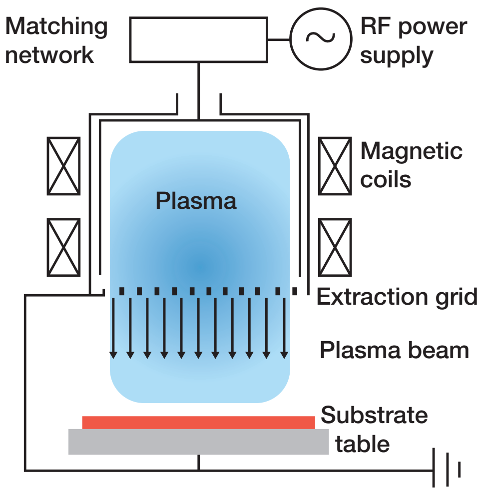

Figure 3. PSC plasma source

Switching gears for optimum film properties for TC-SAW filter applications

Due to the high rotation speed of the turntable, each substrate receives a layer of less than 1 nm of SiO_2 as it passes underneath a sputter source. This ultrathin fraction of the total layer is then treated by the PSC process, etching and planarizing the topmost few atomic layers. This cycle is repeated with each rotation of the table until the desired total thickness of the SiO_2 layer is reached. Real time monitoring of the growing layer by the GSM optical monitoring system ensures precise end point termination of the process at the required layer thickness, yielding excellent run to run repeatability for each batch.

This unique setup enables large windows of process operation. The degree of planarization and side-wall conformality can be controlled by independently varying the sputtering and PSC parameters with a high degree of uniformity and reproducibility while minimizing any sacrifice in throughput.

Take a look at the results

Results in production can be seen in figure 4 which shows AFM height topography images. (Top) AFM image of SiO_2 surface after deposition of 1 µm SiO_2 with PSC on a single crystal Si wafer. (Bottom) Three-dimensional height images of the SAW IDT device structure surface before and after SiO_2 deposition. Note the planarization effect of our SiO_2 film.

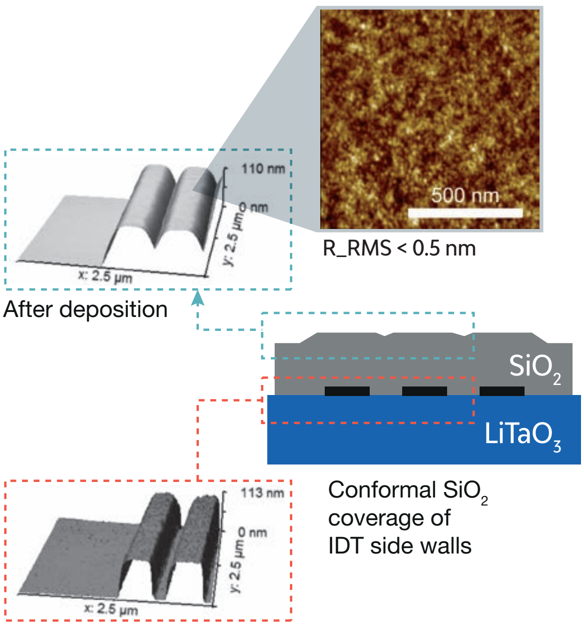

Figure 4. AFM planarization results

Figure 5. SEM Cross-section of TCSAW IDT

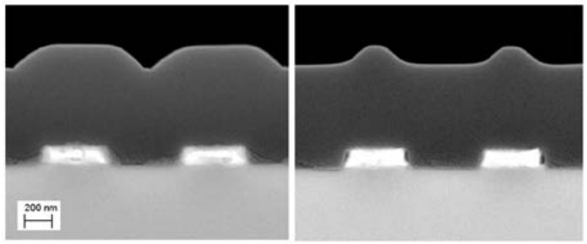

Figure 5 shows Scanning Electron Microscopy images of TC-SAW IDT cross-sections with SiO_2 coverage. Different surface planarization profiles over the IDT structure can be achieved by varying the process conditions. For example, the cross-sectional profile of the right image is more preferred for planarization and gap-free SiO_2 than the surface profile of the left one.

Leveraging know-how for other processes

The benefits of plasma enhanced RMSD processes can also be enjoyed for other types of coatings too. The technology can equally be applied to smoothen layers and reduce interface losses in optical coating stacks. Additional advanced process control (APC) features such as plasma emission monitoring (PEM), and rotating target technology deliver the high process rates and excellent layer uniformities essential for high performance optical layers. Typical characteristics for SiO_2 layers are shown in figure 6 below. You can read more about the capabilities of CLUSTERLINE® 200 equipped with BPM technology in the Photonics chapter of this edition of LAYERS.

Basic SiO_2 deposition process	
Substrate	**Film Parameter**
Wafer diameter	8 inch (direct loading)
Typical deposition rate	From 2 to 5 nm/s
Film thickness / temperature	1000nm/ 280°C
Thickness uniformity (within wafer) 1 sigma	<0.3%
Thickness uniformity (wafer to wafer) 1 sigma	<0.2%
Thickness uniformity (run to run) 1 sigma	< 0.5% when GSM is used
Refractive index @633nm wavelength	> 1.46
Average film stress range	-300 Mpa
Film stress range (within wafer)	±50 MPa
Surface roughness	<1.0 nm (RMS)
Crystallinity	Amorphous
Density	2.3 g/cm³

Figure 6. SiO_2 deposition