Conax TECHNOLOGIES
Ideas. Solutions. Success.

EtchDefender™ TECHNOLOGY

WHITE PAPER

Technology that extends the life of quartz thermocouple sheaths in ASM EPSILON® reactors up to three times longer

Lana M. Custard, Ph.D., Conax Technologies Design Engineer
2300 Walden Avenue, Buffalo, New York 14225 USA
Mike.Ferraro@ConaxTechnologies.com
+1 **716 684 4500** | **+1 800 223 2389**

In many epitaxial processes, deterioration and failure of the quartz sheath protecting thermocouples (TCs) is the limiting factor when determining maintenance schedules. Premature TC sheath failure costs the Fab valuable production time and increases the maintenance budget. In the interest of providing the semiconductor industry with a solution that could drastically increase the usage/lifetime of these TCs and significantly reduce premature failures, Conax Technologies began an 8-year venture to develop an advanced quartz TC sheath.

Conax Technologies partnered with a University renowned for its specialty in Glass and Ceramic Engineering. With the goal of improving quartz resistance to the harsh epitaxial process, Conax Technologies and the University systematically evaluated a series of potential solutions. After years of work, a coating engineered specifically for semiconductor quality quartz sheaths, compatible with the epitaxial process, and exceeding expectations for service life was achieved. As a result, Conax Technologies filed with the US Patent Office, and EtchDefender™ is a Patent Pending design.

Due to the complexity of the epitaxial processes relative to temperatures, gas compositions, gas flow rates, and thermal cycling conditions, simplistic simulation was deemed inadequate. Therefore, the final qualification phase involved use of functional EtchDefender™ TCs in a real production environment. Qualification was performed over an extensive period at a major Fab producing epitaxial wafers on multiple ASM® EPSILON® reactors. The Fab ran both uncoated and EtchDefender™ center TCs on reactors using the same recipe. All wafers produced were closely monitored using surface photovoltage (SPV) and secondary ion mass spectrometry (SIMS) technology to inspect and detect any potential contaminants due to the EtchDefender™ coating. The Fab did not experience any changes in wafer quality or contamination while running the EtchDefender™ TCs.

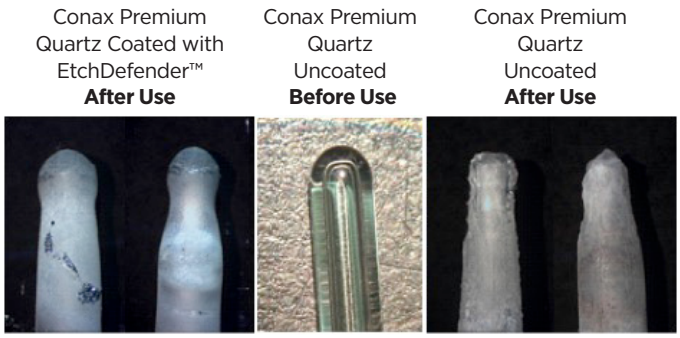

Figure 1. (left) Image of 2 EtchDefender™ TCs run at a Fab in an ASM® EPSILON® Reactor. (center) Example of the Conax uncoated premium quartz sheath before population with the thermoelements and prior to running in the reactor. (right) Image of 2 uncoated TCs run at the same Fab to failure under identical process parameters.

EtchDefender™ TCs were removed during planned maintenance after processing 11,200 wafers and were still functioning at the time of removal. Images of both the EtchDefender™ and uncoated TCs are shown in Figure 1.

Uncoated Sheath Deterioration

Quartz sheaths function to protect the thermoelements during wafer processing, however, frequent and continued thermal cycling at typical operating temperatures causes devitrification and structural damage. The density change (up to 20%) associated with devitrification (quartz to cristobalite phase transition) causes stresses to build in the sheath and microcracks to form. This accelerates the ablation rate of the sheath by high velocity process gasses and presents as severe pitting of the sheath. Pitting leads to holes in the sheath that transverse the quartz providing a pathway between the chamber environment and the interior of the quartz sheath.

Thermoelement Deterioation

Once the sheath degradation occurs as described above, Cl in the deposition gasses, HCl used during cleaning cycles and H_2 molecules will diffuse through the sheath. These molecules cause reactions within the microcracks leading to disassociation of the quartz into H_2O and free Si. The Si is then free to react with the platinum thermoelement forming platinum silicide (PtSi). The formation of PtSi will: 1) cause calibration drift in the thermoelements; 2) cause embrittlement of the thermoelements at the grain boundaries; and 3) cause a lower melting point in the negative leg of the TC, all facilitating an eventual open circuit condition.

Conax TECHNOLOGIES
Ideas. Solutions. Success.

EtchDefender™ TECHNOLOGY

WHITE PAPER | Extending the life of quartz thermocouple sheaths in ASM EPSILON® reactors

EtchDefender™ Sheath Deterioration

When first introduced to an epitaxial process the EtchDefender™ coating will appear darkened as shown in Figure 2; it is an inherent result of the initial exposure of the coating to process gasses. Darkening of the coating does not change TC function or pose any risk of contamination. As the TC continues to run in the process, the darkened region will gradually diminish. Within the epitaxial process EtchDefender™ impedes the destructive chemical attack that accelerates ablation of the quartz and eventual TC failure. The reduced ablation rate achieved with the EtchDefender™ coating is clear in Figure 1. Instead of pitting, a smooth surface results from the ablation process and quartz loss is a fraction of that seen from uncoated quartz sheaths. As a result, EtchDefender™ center TCs were run in a trichlorosilane (TCS) epitaxial process up to 3X longer than uncoated TCs.

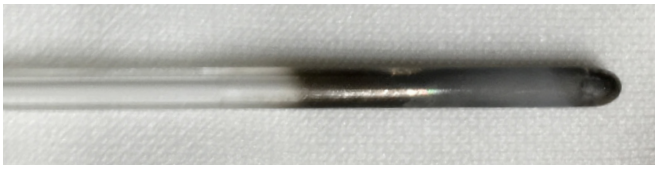

Figure 2. Example of coating appearance after process exposure (~10 runs).

Relative to Process Contamination

FactSage simulations to predict any potential decomposition of the EtchDefender™ coating was completed using the following criteria:

Chemical species:	processing gasses including: H_2, HCl, Cl_2, $SiHCl_3$, SiH_2Cl_2, SiH_4 solids including: Si, SiC, SiO_2, Ta_xO_x
System pressure:	1 ATM
HCl partial pressure:	10-100%
Temperature:	800-1200°C
Refractory oxide content:	0-100%
Results:	The total amount of decomposition did not depend on refractory oxide content therefore, results are shown using 100%. The worst-case decomposition corresponded to 100% HCl at 1 ATM; simulation results using these parameters are listed: 5% decomposition @ 800°C 0.3% decomposition @ 1200°C
Possible ablated species:	Si, SiC, SiO_2, SiO, Ta_xO_x, Ta_xSi_x, $Ta_xSi_xO_x$, compounds of the coated quartz and processing gas components

With the introduction of new material into a complex system, especially at high temperatures, thermodynamic anomalies are possible and, as the simulations suggest, there may be minimal decomposition of the coating. These decomposition products and any ablated species are effectively removed through the exhaust management system. Of the multiple Fabs that have used EtchDefender™ TCs, not a single one has detected process deviations or wafer contamination. Additionally, there is the concern of contamination resulting from an overtemp situation; and therefore, a Fab chose to run evaluations at 1450°C. Even during testing at 1450°C, no metal-organic contamination could be detected. All preliminary laboratory testing and Fab generated data proves there is no increased risk of contamination with the use of EtchDefender™ TCs.

2300 Walden Avenue, Buffalo, New York 14225 US | **+1 716 684 4500** | **conaxtechnologies/etchdefender.com**