

TiAl₃ for W CVD chamber temperature measurement

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Since the critical dimension of integrated circuits has shrunk, tungsten CVD deposition, thanks to its better step coverage with respect to Aluminium PVD one, has become the metallization technology of choice for filling of contacts and vias. [1]

This technique is based on the chemical reduction of tungsten hexafluoride. The deposition process consists of two main steps: nucleation, with silane and hydrogen as reducing agents, and bulk deposition, with H₂ as the only participant, basing on formulas (Eq.1) [2].

Among the various process parameters that are involved in the reaction, pressure, gas flows and temperature play a key role in the process control.

While for pressure and gas flow there are several methods to measure and control in real time their values, such as manometers and flowmeters, regarding temperature the only way we have to control it is based on a thermocouple reading below the heater which has main drawback the fact that it can not measure the real temperature on the wafer.

The aim of this work is to provide a quick, simple and consistent method to control temperature at wafer level.

In the kinetic limited regime, the deposition rate (R) is independent from WF₆ flow, but it is a primarily a function of the wafer surface temperature and hydrogen partial pressure as expressed in the Arrhenius equation (Eq.2) [3].

Being deposition rate dependent on temperature, with the shrink of critical dimensions and the increase of aspect ratio severities, it has become critical to fine control the temperature in order to guarantee an optimal structure filling without the formation of any voids. (Fig.1)

TiAl₃ temperature control method is based on kinetic of TiAl₃ formation, starting from Ti and Al reagents (Eq.3).

A wafer with a layer of Ti and a layer of AlCu(0.5%) is introduced in a hot chamber for a fixed time. At the chamber process temperatures (above 400°C) TiAl₃ formation begins, causing a resistance sheet increase [4].

By measuring the difference between resistance sheet before and after heating the wafer, we can indirectly obtain the temperature of the process chamber (Eq.4).

This work focuses on building a new calibration curve to better fit and adapt the method to MCVD Centura WxZ chambers and statistically verifying new method consistency and accuracy.

The new calibration curve was obtained by using a thermocouple (TC) wafer as reference. Thermocouple wafer is an alternative method to measure process chamber temperature, it is very precise and reliable, however it requires long chamber downtime thus impacting manufacturability. Heater temperature was measured by TC at four different setpoints and the new calibration curve coefficients were extrapolated (Fig.2).

Once the curve was built, reproducibility and repeatability were confirmed by means of GaugeR&R method on five different process chambers.

Linear regression curve was used to verify the consistency between computed temperatures and deposition rate of chambers (Fig.3).

Finally, method resolution was confirmed by forcing a 5°C and 10°C shift setpoint and by demonstrating the results were statistically distinguishable through Anova methodology (Fig.4).

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References

1. ULSI technology, C.Y.Chang (1996);
2. A high throughput blanket tungsten process based on H₂/WF₆ chemistry, J.E.J.Schmitz et al, Applied Surface Science **38**, (1989);
3. Flow and reaction simulation of a tungsten CVD reactor, J.I.Ulacia F. et al, Applied Surface Science **38**, (1989);
4. TiAl₃ formation kinetic in sputtered Ti/Alcu0.5% thin film, C.Bresolin et al, Microelectronic Engineering **64**, (2002)

Equations

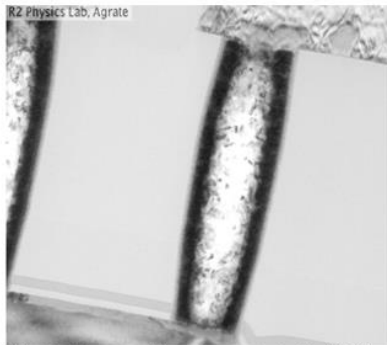
1. $3 H_2 + WF_6 \rightarrow W + 6 HF$
 $3 SiH_4 + 4 WF_6 \rightarrow 4 W + 3 SiF_4 + 12 HF$

2.
$$R = K \sqrt{P_{H_2}} e^{\frac{-Ea}{RT}}$$

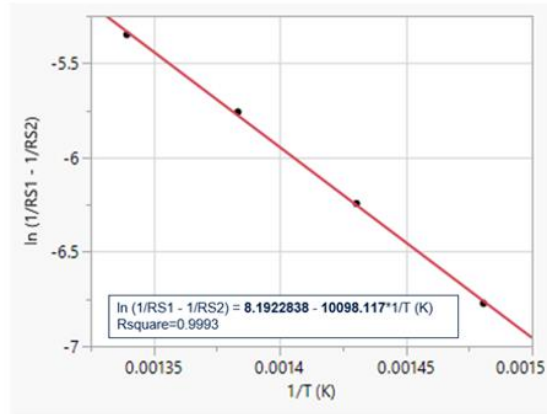
3. $Ti + 3 Al \rightarrow TiAl_3$

4.
$$\frac{1}{T} = \frac{\ln\left(\frac{1}{RS_{pre}} - \frac{1}{RS_{post}}\right) - \beta}{\alpha}$$

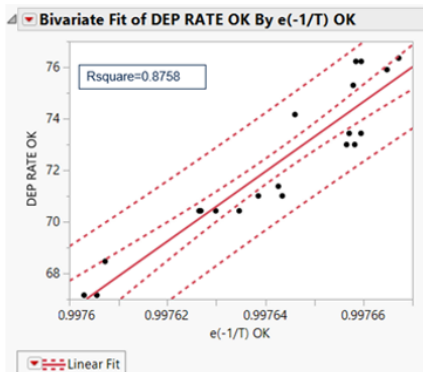
Figures



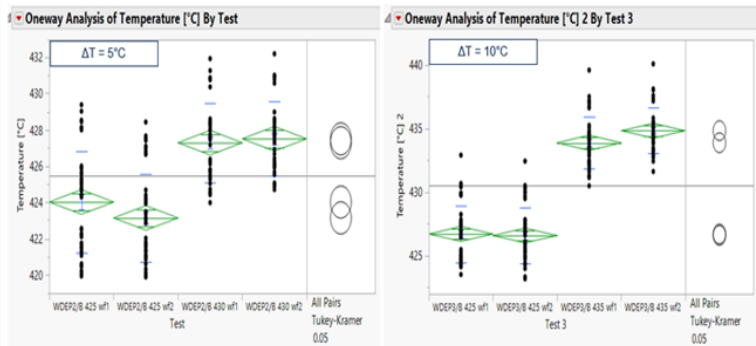
(Fig.1): Cross section of a contact with W filling problem.



(Fig.2): calibration curve with extrapolation of new calibration coefficients



(Fig.3): linear regression of deposition rate as a function of temperature



(Fig.4): Anova analysis for 5°C and 10°C differences