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D 5.5
Final PZT in-situ sputtering tool: Application note

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential , only for members of the consortium (including the Commission Services)	

Deliverable number:	D 5.5
Deliverable name:	Final PZT in-situ sputtering tool: Application note
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Lead contractor:	OER

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Abstract

The Oerlikon cluster tool CLUSTERLINE 200 (CLN200) is widely used in the semiconductor industry and therefore proven as a very reliable sputter equipment. Up to 6 single modules can be attached to the central robot handling and the tool can be optionally configured with 3 auxiliary stations (degasser, cooler and aligner).
Fully equipped the sputter tool allows to fabricate complete PZT film stacks including bottom and top electrodes on either 6" or 8" substrates in one run. Alternatively if a substrate already coated with a bottom electrode is loaded into the tool it can be equipped with more than one PZT modules which will increase the wafer throughput.
For the PZT film deposition a single ceramic target is sputtered by RF magnetron technology onto a very hot substrate. The actual deposition equipment is able provide a sufficiently high substrate temperature to allow the direct growth of the piezoelectric perovskite phase of PZT. With the present in-situ growth of the correct crystalline structure the disadvantages of a subsequent post annealing step can be avoided.

High quality PZT films can be produced at deposition temperatures of about 600°C, with a (100) or (111) orientation as a function of the substrate and optional seed layer.
Applying an optimized poling procedure highest piezoelectric coefficients $-e_{31,f}$ of 20 C/m^2 can be achieved. This transversal response is the key property for most applications, but values up to 150 pm/V are also achievable for the longitudinal response $d_{33,f}$ of the PZT films.
With respect to the dielectric and ferroelectric properties the films show a high performance as well, both a permittivity of 1300 and a remanent polarization of 20 µC/cm^2 are excellent values.

The actual throughput at high film quality is about 2.7 wafers/h at 1 µm film thickness with the potential of more than 3.6 wafers/h at further process optimization. Typically the thickness of the films is between 1 and 2 µm but if required films with a thickness up to several microns are achievable. The characteristical target lifetime for a 4 mm target is more than 1000 kWh which enables the production of more than 1300 wafers at 1µm thickness.

Public introduction[1]

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[1] According to Deliverables list in Annex I, all restricted (RE) deliverables will contain an introduction that will be made public through the project WEBsite

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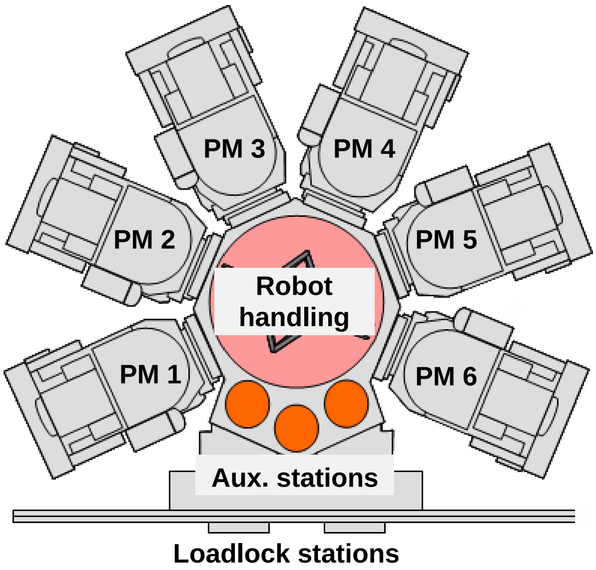
1 HARDWARE SETUP FOR PZT SPUTTERING

1.1 Deposition tool architecture

1.1.1 General

The Oerlikon cluster tool CLUSTERLINE 200 (CLN200) is widely used in the semiconductor industry and therefore proven as a very reliable sputter equipment (fig.1). It consists of 2 load locks wafer loading, a central robot for wafer handling and the sputter or etch modules for the depositions or the etching, respectively. Up to 6 single modules can be attached to the central robot handling and the tool can be optionally configured with 3 auxiliary stations (degasser, cooler and aligner) located close to the load locks.



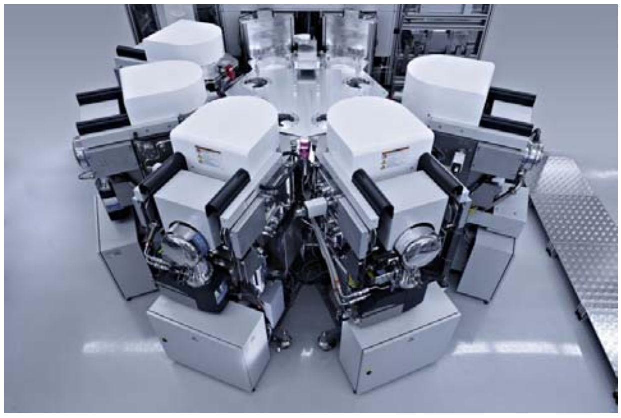


Figure 1: Oerlikon cluster tool CLN200

With this configuration complete PZT film stacks including bottom and top electrodes can be fabricated on 6" or 8" substrates in one run. Table 1 shows exemplary a configuration for such a process chain with Ti/TiO2/Pt bottom and CrAu top electrode, a typical layer stack which is used during the piezoVolume project. Alternatively if a substrate coated with a bottom electrode is loaded into the tool it can be equipped with more than one PZT modules. With a typical thickness of 2 µm and a deposition rate of about 1nm/s the PZT depositon is the slowest process step and therefore this will increase the wafer throughput.

	Auxiliary	*PM 1*	*PM 2*	*PM 3*	*PM 4*	*PM 5*	*PM 6*
PZT including Pt bottom and CrAu top electrode	Cooler Degasser Aligner	Etch	Ti TiO2	Pt	PZT	Cr	Au

Table 1: Typical cluster tool configuration for a complete PZT layer stack including electrodes

1.1.2 Process modules

For a process with bottom and top electrode according to table 1 the sputter modules will be typically equipped as shown in table 2.

	Etch	*Ti / TiO2*	*Pt*	*PZT*	*Cr*	*Au*
PVD mode	ICP etch	DC / Reactive DC	DC	RF	DC	DC
Max. heater temperature	No	500°C	500°C	800°C	500°C	500°C
Gas supply	Ar	Ar O2	Ar	Ar O2	Ar	Ar

Table 2: Typical configuration of etch / sputter modules

The metal and dielectric films are sputtered by a DC magnetron or a reactive pulsed DC magnetron process, repectively. The PZT films are deposited from a single oxide target and due to its non-conductivity a RF magnetron sputter process has to be established
To achieve the optimum film structure the sputter stations for the metals and dielectrics are equipped with a heated substrate holder (chuck) for temperatures up to 500°C and equipped optionally with a RF bias capability.

1.1.3 PZT deposition module

The module dedicated to the PZT process is equipped with a RF cathode and autotuning matching network capable for a RF load power up to 5 kW.
To reach the very high deposition temperature required for an in-situ PZT deposition process a so called Very Hot Chuck was developed for temperatures up to 800°C. (fig.2)
Further on the special design of the anode allows a very homogeneous gas distribution and finally the installed RF bias capability enables to tune the film properties in a wide range.

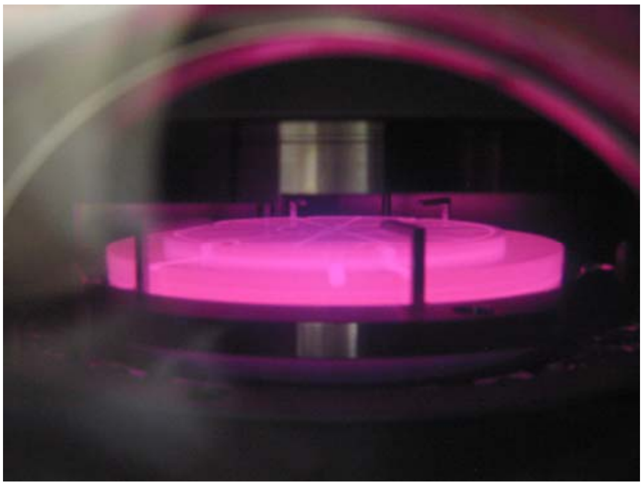


Fig. 2: Very hot chuck for 6” wafer.

2 PERFORMANCE

2.1 Film quality

The high temperature RF magnetron sputter process enabled in-situ growth of the required perovskite PZT. High quality PZT films can be produced at deposition temperatures of about 600°C, with a (100) or (111) orientation as a function of the substrate and optional seed layer.

Applying an optimized poling procedure highest piezoelectric coefficients $-e_{31,f}$ of 20 C/m2 can be achieved. This transversal response is the key property for most applications, but values up to 150 pm/V are also achievable for the longitudinal response $d_{33,f}$ of the PZT films.

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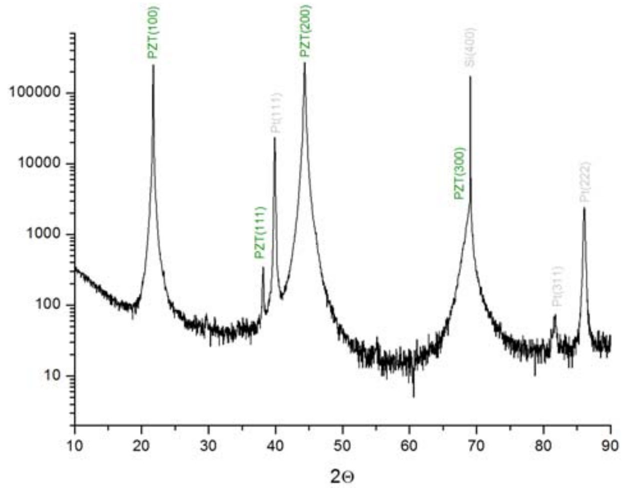

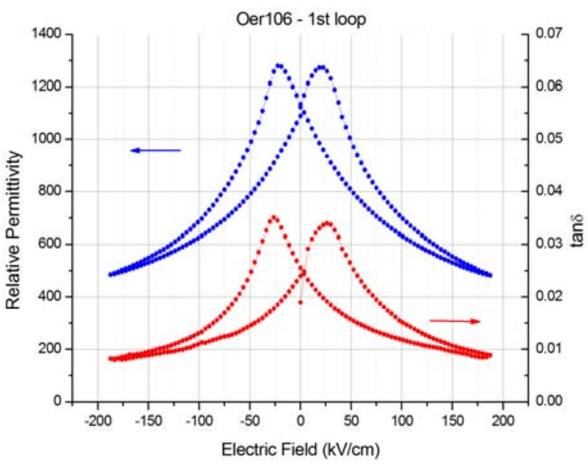

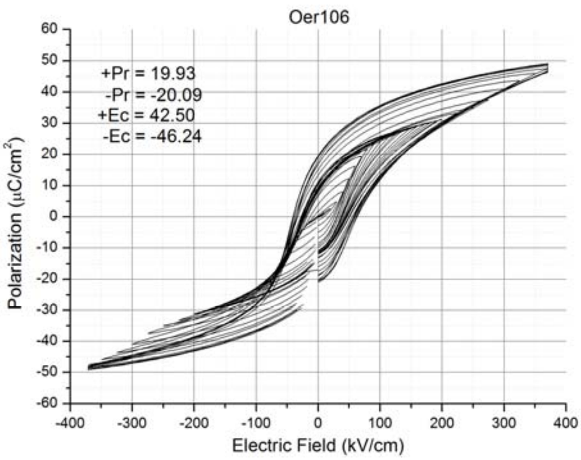

2.2 Productivity

The actual throughput at this high film quality is about 2.7 wafers/h at 1 µm film thickness with the potential of more than 3.6 wafers/h at further process optimization. The thickness of the films is usually between 1 and 2 µm but if required films with a thickness up to several microns are achievable. The typical target lifetime for a 4mm target is more than 1000 kWh which enables the production of more than 1300 wafers at 1µm thickness.