TECHNICAL SPECIFICATIONS

FOR THE SUPPLY OF
A ‘DEEP RIE ETCHING SYSTEM’
FOR
SCUOLA SUPERIORE SANT’ANNA

PROGETTO FELIX

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INTRODUCTION

This document summarizes the technical characteristics of a Deep RIE – etching system to be installed in the area of InPhoTec (TeCIP Institute) – Sant'Anna School.
The purpose of this system is to carry out etching of silicon and dielectrics through reactive ions excited in a plasma. The system will use a radiofrequency (RF) excitation to generate a plasma inside a vacuum processing chamber. The wafer will be located in the processing chamber on a specific support (chuck). The control of the processing parameters (gas flow, chamber pressure, chuck temperature, RF power) enables to set the amount of radical ions inside the chamber which, reacting with the surface, achieve the removal of the target material, i.e. the dry etching process. The plasma will be generated from processing gases, which will be at least: SF_6 (1), O_2 (2), C_4F_8 (3), one among He or Ar (4), CHF_3 (5). Other possible gases may be available according to the choice of the supplier. Each gas line should be configurable for its processing gas. The flow of the gases will be regulated on each line by high-precision Mass Flow Controller (MFC). Optional inlets will be configured for Cl_2. Cl_2 installation will not be required, but the possibility of an upgrade is mandatory. Additionally, the system should be capable of fast switching the reacting gas injected in the chamber. This feature is required in order to achieve etching of high-aspect ratio trenches, in a process called "Bosch" or "Bosch-like". This kind of process is made of two different sub-steps, quickly alternated: a passivation (protection) step and an etching (removal) step. The quick alternation between these two steps allows etching deep trenches.
A load-lock system will be included in the system, in order to carry the process wafer from ambient pressure to the processing chamber. The system will be configured for 6" wafers, but should be upgradeable to 8" wafer size or, as an alternative, configured for 8" and adapted to process 6" wafers.
In the processing chamber the wafer shall be held onto the processing chuck either by electrostatic or mechanical clamping, and thermalized with backside He flow. The processing chuck should be cooled by a cooling system (included with the system). The temperature operating range should be from -150° C to 40°C. Cryogenic temperature may be reached through the use of liquid nitrogen, available at the facility. For this purpose, a compatible dewar container will be necessary. The supplier must provide one of the two following systems in order to achieve chuck cooling: a – Closed loop recirculator (chiller); b – Dewar and connection piping for liquid nitrogen (LN2) cooling.
The machine should be able to achieve high aspect-ratio etching. The evaluation of the machine capabilities as well as the acceptance tests will be based upon the processes defined in Sec. 3.2.

1. Technical specifications: minimum requirements

1.1 Configuration

- The system is configured for 6'' Silicon SEMI M1 wafers
- Upgradable to 8'' (200mm) wafers
- Loading of the 6" wafer must be possible without venting the main processing chamber. A load lock system must be present. Loading from ambient pressure to the processing pressure inside the chamber must be carried out in less than 10 minutes.
- Mechanical or electrostatic clamping of wafer
- The load-lock and the chamber should meet the following requirements:

1.	Chamber processing vacuum:	≤ 1 mTorr
2.	Loading time from load-lock to process chamber	≤ 10 min
3.	Chamber pumpdown time from vented to ≤ 0.1 mTorr	≤ 60 min

- Dry pumping technology

- The system should be configured with at least five processing gas lines with the following configuration:
  1. SF_6
  2. O_2
  3. C_4F_8
  4. Ar or He
  5. CHF_3
- Each gas line must be equipped with Mass Flow Controller with an error $\leq 5\%$
- One additional gas line providing He for “back side cooling” of the process wafers
- Expandable to min. 8 processing gas
- Support for the addition of Cl_2 processing gas
- Fast switching of gases necessary for Bosch-like processing
- Through-wall installation
- Footprint (maximum): grey area 3m x 2.6m; white area: 3 m x 1.6 m
- Capacitively-coupled plasma (CCP) RF Generator 13.56 MHz, min. 300W with automatic matching unit
- Inductively coupled plasma generator (ICP) RF Generator Power 1 kW or higher with automatic matching unit
- Cooling system for the chuck, supplier choice among these two:
  a. Closed-loop circulator chiller for non-cryogenic temperatures ($-20°C \leq T \leq 40°C$)
  b. Cryogenic cooling of the chuck down to -150°C

  Regardless of which system is included, it must be possible to connect and perform operation with both cooling systems.
- At least one see-through window on the main process chamber to allow the installation of an interferometric end-point system
- End-point detection system able to monitor the cleaning of the chamber (e.g. optical emission detection)
- Anti-corrosion treatment in order to preserve the chamber surfaces
- Heated chamber walls in order to reduce chamber contamination
- Isolation valve between the processing chamber and the high-vacuum pump (turbo-molecular or other technology) pumping on the chamber.
- Clearly documented capability of achieving the processed described in section 3.2
- Automatic operation by computer software

1.2 Terms and conditions

- Conformity to EC standard and certification
- Availability of spare parts guaranteed for minimum 10 years
- Warranty: 1 year
- Shipment and installation included to:

  Scuola Superiore Sant’Anna (TeciP Institute)
  Via G. Moruzzi 1
  56127 Pisa (Italy)

2. Technical specifications: evaluable features

2.1 Configuration

- Types of end-point system available and/or included
- Accuracy and type of the endpoint system supplied
- Accuracy of processing temperature control

- Evaluation of the performance in the processes described in Sec. 3.2 according to the documentation provided by the supplier
- Cost and availability of spare parts/consumables
- Software and hardware maturity and engineering
- System engineering, quality and durability of the parts supplied
- Dewar for liquid nitrogen or closed-loop recirculator
- Inclusion of a scrubber system for exhaust gases

2.2 Terms and conditions

- System lifetime: number of years of available support
- Consumable spare parts kit for yearly ordinary maintenance
- One extra year warranty

3. Installation, acceptance, documents, training

3.1 Installation

The supplier is in charge of the move-in operations: moving the crate from the truck to the site, opening the package, positioning the tool in the working area.

Scuola Superiore Sant'Anna, by following the supplier directions, is in charge for: connecting all the necessary facilities to the tool.

Supplier must check for the correct placement and connections, facilities presence, gas flows and pressure values. Execute the acceptance procedures and functionality tests.

3.2 Process definition

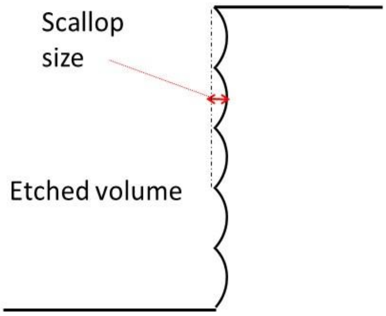
This paragraph details the processes that should be feasible with the machine in order to meet the minimum requirements for the machine performance. The same processes will need to be demonstrated on-site after installation in order to meet the acceptance criteria (see 3.3).

Tools used for metrology:

Tescan SEM Microscope, Nikon Optical Microscope, Tencor step profiler, Filmtek 4000 thin film measurement tool. (available at InPhoTec/Sant'Anna School)

Process verification methods:

- Scallop size definition:



- Sidewall angle (α) defined as:

- Morphology/angles measured through cross-sectional SEM micrographs carried out at InPhoTec/Sant'Anna
- Depth and layer thicknesses will be measured by step profiler and ellipsometry/ refractometry measurements with technical tools at InPhoTec / Sant'Anna
- Optical inspections
- In-wafer etch-depth uniformity will be evaluated as $U = \frac{(dmax - dmin)}{2x\,(davg)}\, x\, 100$, where *dmax*, *dmin* and *davg* are the maximum, minimum and average etch depths, respectively. A minimum of 18 points will be measured for each evaluation. Outliers may be discarded if they lie at more than 2σ of the average measurement, where σ is the standard deviation calculated from the results.
- All the parameters will be evaluated in the central part of the wafer (1 cm edge exclusion)

3.2.1 Bosch-like process

A Bosch-like process will be carried out with the system, employing C_4F_8 and SF_6 and/or Ar/O_2.

The process will be carried out on a 6" silicon wafer with a SiO_2 pattern (1) and with a resist pattern (2). The wafers will be prepared by InPhoTec/Sant'Anna, from standard Silicon <100> SEMI M1 wafers.

(1) Will have 3 micron of SiO_2 etched down to the silicon wafer with a sidewall slope of about 87-88°
(2) Will have a layer of 10 um of AZ 9260 photoresist (PR), with sidewall angle 88/89°

The exposed area (to be etched) of each wafer will be ~18% on wafer level.

Features of sizes from 2 to 50 μm wide, and several 100 μm-long, will be present in the mask layout.

The etch process result will be evaluated on a wafer-scale, with an edge exclusion of 1 cm.

The process should be able to achieve simultaneously:

- 100-micron deep etch of trenches on 5-micron wide openings
- Aspect-ratio dependent etch rate variation from 50 μm to 5 μm < 40%
- Etch rate of silicon at least 2 μm/min
- Selectivity > 150:1 (SiO_2 to Si – case (1)); > 50:1 (PR to Si – case (2));
- Flat bottom on Features > 25 μm, i.e., no "grass" present on all 5 μm and larger openings (small pillar-like etch leftovers, higher than 0.5% of the etch depth)
- Sidewall scallop size < 100 nm
- Sidewall angle with respect to the substrate surface 91° > α > 89°
- No black silicon formation outside the edge exclusion

- In-wafer uniformity on 50-µm-wide identical openings: < 3% (from a minimum of 18-point measurement performed at InPhoTec with step profiler)

3.2.2 Shallow silicon etching process

InPhoTec will provide (a) SOI wafer patterned with our proprietary layout (b) one or more Si wafer coated with 220 nm of SiO_2 patterned with the same layout.

The SOI wafer composition will be as follow:

220 nm SiO2 (patterned mask layer),

215-220 nm Si (guiding layer to be etched),

3050 nm SiO2 (buried oxide layer, BOX).

The 220 nm SiO2 mask will be patterned by InPhoTec via a previous EBL exposure (both for (a) and (b)). The overetch amounts to 10-15 nm below the Si surface. The slope of the SiO_2 profile is 87-88°. The hard mask pattern contains 500-nm wide lines, with minimum distance between guides as close as 150 nm. It is therefore relevant that the critical dimensions (CD) will be kept when transferring the pattern from the SiO2 mask to the Si layer. In particular, loading effects in the small gaps should be contained. The pattern contains structures that can be cleaved through in order to inspect the cross-section.

The process, carried out at cryogenic temperatures (T < - 80°C, if available), should achieve:

- Non-switching process (continuous gas flow, no chopping)
- Silicon should be etched down to 220 nm depth (Si wafer) or to the buried oxide layer (SOI wafer) everywhere outside a 1 cm exclusion edge from the border.
- Si etching sidewalls must be as smooth as possible (no scalloping)
- Sidewall angle with respect to the substrate surface $91° > \alpha > 89°$.
- No notching at the Si/SiO_2 interface.
- Deviation from the patterned sizes on the SiO_2 mask (measured in top-view): < 5 nm
- Depth variation in openings from 150 nm to 15 um: < 13 nm
- Etch rate of silicon between 20 and 150 nm/min
- Etch depth accuracy on a given feature size: ±10 nm
- In-wafer etch-depth uniformity < 5% (from a minimum of 18-point measurement performed at InPhoTec with step profiler)

3.2.3 SiO_2 and SiN etching

The system should be able to achieve shallow etching of SiO_2 and SiN with photoresist mask.

1 – SiO_2 on Silicon
With a photoresist mask thickness of 650 nm or thicker, the process, using gases chosen according to the supplier's choice should be able to achieve:

- Etch of 220 nm of SiO_2 on a bulk Si substrate and on a SOI wafer
- No notching at the SiO_2-Si interface

- In-wafer etch-depth uniformity < 5% (from a minimum of 18-point measurement performed at InPhoTec with step profiler)
- Sidewall angle with respect to the substrate surface 92° > α > 85°
- Etch rate between 20 and 150 nm/min
- Etch depth accuracy: ±10 nm

2 – SiN on SiO_2/Silicon
With a photoresist mask thickness of 650 nm or higher, the process, using gases chosen according to the supplier's choice should be able to achieve:

- Etch of 250 nm of LPCVD SiN deposited on PECVD SiO_2 layer (>500 nm) deposited on bulk Si wafer
- No notching at the SiN-SiO_2 interface
- In-wafer etch-depth uniformity < 5% (from a 18-point measurement performed at InPhoTec with step profiler)
- Sidewall angle with respect to the substrate surface 91° > α > 85°
- Etch rate between 20 and 150 nm/min
- Etch depth accuracy: ±10 nm

3.3 Acceptance

Installation and commissioning, followed by process start-up with demonstration of the defined processes must be performed on site by the supplier.
For system acceptance, after the installation is complete, the system should demonstrate on site the processes defined in 3.2, as well as the complete functionality of all the hardware provided.

3.4 Documents

Supplier must:

1. Detail the configuration of the equipment and the list of parts and components
2. Deliver layout of installation and a list of the facilities required for a proper functioning of the tool
3. Deliver process data and an overview of the attainable performance
4. Deliver procedures for standard operation and maintenance
5. Deliver safety instructions
6. Provide EC conformity declaration
7. Describe after sales service and support solution.

The compliance of the equipment to the minimum requirements and to the evaluable features must be evident in the documentation (1-7).
All the documentation must be compliant with all the tender forms and regulations.

4. Appendix

4.1 Summary table of minimum requirements

The compliance of the equipment to the minimum requirements must be evident in the documentation (see Sec. 1).

Summary Specifications

Parameter	Target Specs	Units	Notes
Footprint	Through-wall installation		
	Ideal footprint (less than): grey area 3m x 2.6m; white area: 3 m x 1.6 m		
Processing capabilities	5 different processing gases with MFC		Required gases: SF_6, O_2, C_4F_8, (Ar/He), CHF_3 MFC-equipped lines
	MFC error ≤ 5%		
	Expansion possible to min. 8 processing gases (including Cl_2)		
	Support for 6” SEMI M1 wafers and possibility of 8” upgrade		
	Processes described in 3.2 must be possible and clearly documented		
Chuck operating temperatures (LN2 Cooling must be supported)	≤ -150	°C	Minimum T
	≥ 40	°C	Maximum T
He back side cooling MFC controlled			
RF Generator 1 (capacitively-coupled)	≤ 30	W	Minimum stable operation power (at most)
	≥ 300	W	Maximum stable operation power (at least)
RF Generator 2 (inductively-coupled)	≤ 100	W	Minimum stable operation power
	≥ 1000	W	Maximum stable operation power
Impedance matching	Automatic impedance matching for both RF generators		Minimal reflected power
Stand-alone refrigeration system for chuck-cooling processing temperatures (closed-loop chiller or LN2 Dewar)	≤ -20	°C	Minimum operating temperature
	≥ 40	°C	Maximum operating temperature
Mechanical or electrostatic clamping of wafer			
Chamber processing vacuum	≤ 1	mTorr	
Vacuum gauges	Pressure monitoring for load-lock and chamber		
Loading time from load-lock to chuck	≤ 10	min	
Chamber pumpdown time from vented to ≤ 0.1 mTorr	≤ 60	min	
Endpoint system	Optical Emission Detection (OED or equivalent)		
Pumping system	Dry pumping		No emission of particles in the chamber
Isolation valve for high-vacuum pump isolation	Valve for isolation between the main chamber and the high-vacuum pump		

	(turbomolecular or equivalent)		
At least one see-through window to the processing chamber	Window for installation of interferometric endpoint system or equivalent		
Anti-corrosion treatment to improve chamber lifetime	According to supplier specifications		
Heated chamber walls	According to supplier specifications		To preserve chamber conditions
Automatic operation by computer software	Full automation		Manual operation also possible

4.2 Summary table of evaluable features

The compliance of the equipment to the technical specification assessable as improvements must be evident in the documentation (see Sec. 2).

4.2.1 Summary Evaluable Features (qualitative evaluation)			
Item	Parameter	Qualitative evaluation system	Max points
Configuration			
A.1	Ease of operation and maintenance	Accessibility of maintenance spaces; Software completion and stability; Completeness of available software options	6
A.2	Availability of spare parts Availability of on-site after-sale support	Costs of consumables, spare parts, availability of support	11
A.3	Performance of the system with respect to the processes described in Sec. 3.3	Accordance to the requirements in Sec. 3.3, according to the documentation provided by the supplier	12
A.4	Durability of the system	Periodic maintenance required	3
A.5	System stability, engineering	Overall quality of the machine engineering	4
		MAX TECHNICAL POINTS (qualitative part)	**36**

4.2.2 Summary Evaluable Features (quantitative evaluation)			
Item	Parameter	Quantitative evaluation System	Max points
Configuration			
A.7	Liquid nitrogen dewar and connecting piping included	If the parameter is absent = 0 If the parameter is present = max points	10
A.8	Additional Endpoint system	OED System included = 0 points OED + Interferometric system = max points	13

A.9	Scrubbing system included	Inclusion of air treatment system to remove by-products from pumps exhausts Parameter absent = 0 points Parameter included = max points	4
Conditions			
B.1	Consumable spare parts kit for yearly ordinary maintenance	If the parameter is absent = 0 If the parameter is present = max points	10
B.2	One extra year warranty	If the parameter is absent = 0 If the parameter is present = max points	12
		MAX TECHNICAL POINTS (quantitative part)	**49**
Price			
	System cost	Assigned according to the formula detailed in the official tender documents	15
	MAX PRICE POINTS		**15**
		MAX TOTAL POINTS	**100**