PRODUCT BROCHURE

Hydrofluoric acid Vapor Phase Etcher – VPE

The idonus hydrofluoric (HF) acid Vapor Phase Etching (VPE) system is a cleanroom microfabrication equipment. HF vapor enables stiction-free release of microelectromechanical systems (MEMS) by thermally-controlled etching of the silicon dioxide layer.

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idonus offers a range of hydrofluoric (HF) acid Vapor Phase Etching (VPE) products. HF VPE, hereafter VPE, are based on the chemistry of HF acid which selectively etches silicon dioxide (SiO_2) while silicon (Si) remains intact. The standard VPE are available for different diameters: 100 mm, 150 mm and 200 mm wafers.

Contents

1. Product overview

The idonus hydrofluoric acid Vapor Phase Etching (VPE) apparatus is used in cleanroom microfabrication facilities for stiction-free[1] etching of silicon dioxide (SiO_2). The VPE product is available for 100 mm, 150 mm and 200 mm wafers. Clamping solutions are also available for processing on smaller wafers or discrete chips.

The VPE meets the need for safe release of microstructured devices with tiny gaps or fragile suspended beams (*e.g.*, comb-drive, AFM probe). Such structures are often encountered in microelectromechanical systems (MEMS). Working with liquid HF acid is precluded because the cohesion forces of liquid destroy the tiny structures or make them stick permanently. Instead, stiction-free release of these structures is possible with the VPE since the etching is completed with HF acid in vapor phase.

Benefits

- Safe HF acid handling
- Re-usable HF acid
- Easy wafer clamping mechanism
- Ideal for all wafer sizes
- No additional installation required: apparatus is used in an acid wet bench
- Upside down etching of wafers
- Back-side protection
- Low running costs

2. Use of HF in vapor phase

HF acid is routinely used for selective etching of SiO_2 in MEMS devices. Typically, the SiO_2 layer found in Silicon-On-Insulator (SOI) wafers is an electrically insulating layer that is also used as a sacrificial layer for the release of MEMS microstructures.

Etching in an HF acid vapor atmosphere is a quasi-dry process. By controlled heating of the substrate, the amount of vapor on the wafer – and thus the etching rate of SiO_2 – can be adjusted in a reproducible means. Since the wafer is never in contact with any liquid, stiction-free MEMS release can be achieved with a high yield. Typical etch rates of SiO_2 achievable with HF in vapor phase are in the range of 4 – 10 µm/hour.

2.1. Chemical reaction

The etching of SiO_2 consumes fluoride (F^-) ions via the chemical reaction:

$$SiO_2 + 4\ HF \rightarrow SiF_4 + 2\ H_2O$$

SiO_2 reacts with HF acid to form SiF_4 (gas) and H_2O (water) by intermediate formation of silanol groups. The chemical equation, although much simplified, indicates that water vapor comes into play in the etching rate of silicon dioxide.

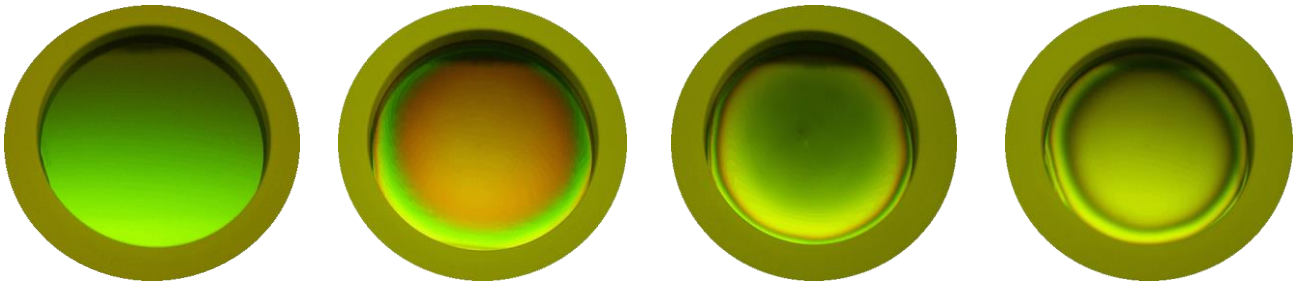
[1] Stiction is a portmanteau word constructed from the contraction of the words "sticking" and "friction."

Warning: The chemistry implies the use of hydrofluoric (HF) acid. HF is an extremely dangerous chemical. The VPE equipment must therefore be installed in facilities that safely handle the treatment of HF vapor, *i.e.* the VPE must be used inside an acid wet bench station. Proper care must be taken when using this system.
idonus can provide information regarding installation, operation and maintenance of the vapor etcher. idonus will not assume responsibility for misuse of this system or for any harm or damage caused by using this product.

Note: User is responsible for adherence to local policies and procedures as well as all applicable federal, state, and local regulations and public health guidelines.

2.2. Etching process

As an illustrative example, we show in Figure 1 the HF etching process completed with the VPE on a 100 mm blank silicon wafer that was pre-treated with a 1 µm-thick layer of thermal oxide.



Before etching:
100 mm silicon wafer with 1 µm thermal oxide.

After 25 minutes:
The inner part having the same color indicates homogeneous etching.

After 30 minutes:
Some oxide is left.

After 35 minutes:
All oxide is removed on 80% of the wafer diameter.

Figure 1: *Homogeneity of the HF etching observed during the process.*

The photograph in Figure 2 shows an example of one of our products – the idonus VPE 100 for 100 mm wafers (4-inch) – configured with:

- the reaction chamber with reservoir (polymer material),
- the clamping mechanism with its optional electrostatic chuck, and
- a control unit with power supply for thermal and electrostatic control.

Closed-loop temperature control is performed with a proportional-integral-derivative (PID) controller.

Figure 2: *The idonus hydrofluoric acid Vapor Phase Etcher system (VPE). The lid and purge system (not shown in the photograph) are included in the basic equipment.*

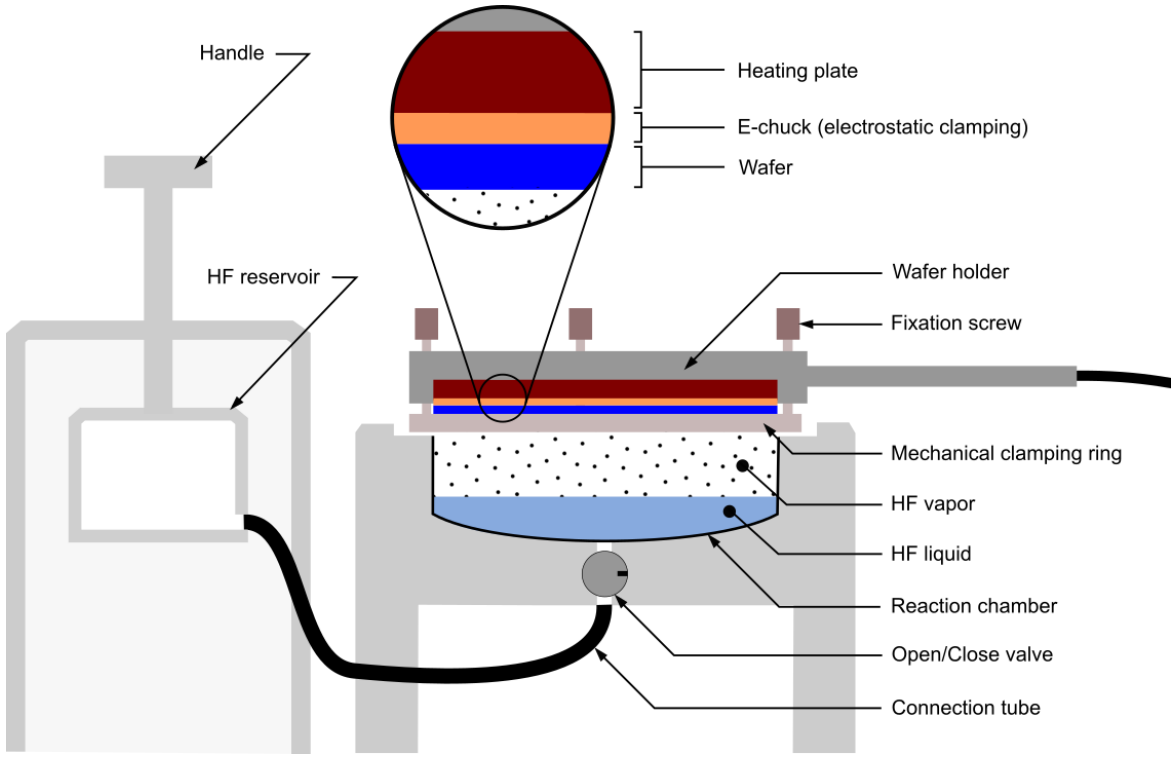


Figure 3: *Simplified schematic cross-section view of a VPE (gas exhaust circuit not shown). The technical terms highlighted in Section 3 refer to this illustration. In this schematic, the reaction chamber is filled with HF acid, the valve is closed and the HF reservoir is in high position.*

3. Product description

The VPE consists of a reaction chamber and a wafer holder (see Figure 2 and Figure 3). A heating element is integrated in the wafer holder. It controls the temperature of the substrate to be etched. Wafer clamping can be achieved in two ways: either mechanically or electrostatically. In both cases, the hidden side of the substrate is protected from etching.

- Wafers can be **clamped mechanically** using the clamping ring. Bolt on fastening is done from the backside of the wafer holder, which is never in direct contact with the HF vapor. The three large polymer screws are easy to handle with protective gloves.
- idonus offers an **optional electrostatic clamping** mechanism (see Section 4). Single chips (at least 5 mm-wide) as well as full wafers can be clamped to the heating element. This solution has the advantage of eliminating the stress concentration of mechanical clamping.

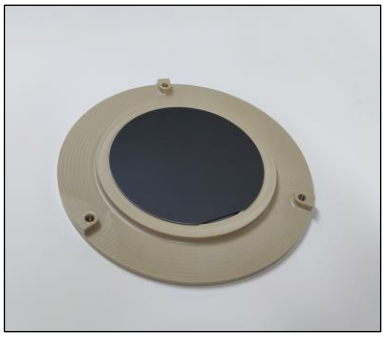
Features of the idonus VPE

- Easy to setup
- Easy wafer clamping mechanism
- Safe HF acid handling
- Re-usable HF acid
- Ideal for all wafer sizes
- Back-side protection

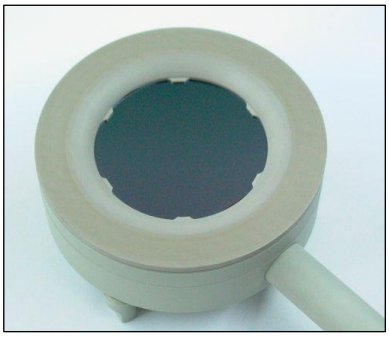
Once the substrate is clamped on the **wafer holder**, the reaction chamber can be filled with liquid HF. The **reaction chamber** is then closed with the **wafer holder**. HF evaporates at room temperature and the etching process starts spontaneously. The etch rate is adjusted by temperature control of the wafer, which can be adjusted from 35°C to 60°C. Figure 4 illustrates these operation steps.

The HF acid can be re-used for multiple etchings. For this purpose, the **HF reservoir** is used for temporary storage of the **HF liquid** during substrate exchange: After processing a **wafer**, the acid present in the **reaction chamber** can be flown in the sealable **HF reservoir**. **HF liquid** transfer is simply done by lowering the **HF reservoir** with the **handle**. By communicating vessels, the acid flows into the **HF reservoir** which can be closed by the manual **valve**. Refilling the **reaction chamber** with acid is done by turning the **valve** and lifting the **handle**: the acid flows back into the **reaction chamber**.

The VPE system has a small footprint and can easily be integrated into an existing flow box.



Mechanical clamping ring.
A 100 mm wafer is ready for mechanical clamping.



Wafer holder with a mechanically clamped 100 mm wafer.
The wafer is held by 6 clips to increase the etchable area.

Hydrofluoric acid Vapor Phase Etching system ready to use.
The reaction chamber is closed by the wafer holder and the HF vapor remains in the reaction chamber.

Figure 4: *Operation steps for mechanical clamping of a wafer. In the example shown, a 100 mm wafer (4-inch) is being prepared for HF vapor etching with the VPE 100.*

4. Available options

As mentioned above, the VPE product is available with serval options. Note that we offer many specialties that are not listed here. For more details, please inquire with the idonus sales team.

4.1. Electrostatic chuck for multiple chip clamping

The electrostatic chuck is able to clamp multiple chips, as well as parts of a wafer, to the wafer holder by means of electrostatic force. This device is extremely useful for R&D prototyping where working on complete wafers is not always possible. The electrostatic clamping of chips allows to perform the harsh dicing process of MEMS wafers before the HF vapor release. By modifying the classical fabrication sequence, it becomes possible to produce MEMS devices with extremely soft suspensions.

The usage of the electrostatic chuck is very simple. The chips are placed on the wafer holder (see Figure 5) and the electrostatic force is turned ON with a switch located on the control unit. The electrostatic force can be adjusted.

4.2. Safety mesh and adaptor rings for wafer holder

The safety mesh is a HF resistant mesh that is placed into the reaction chamber (see Figure 6). Its purpose is to catch released parts that are not attached to the handle wafer. HF condenses on the mesh. Therefore, the mesh must not be manipulated without protective gloves. Adaptor rings to smaller wafer sizes are available for 150 mm and 200 mm wafer holders.

Figure 5*: Electrostatic chuck with multiple chips.*

4.3. Reaction Chamber Temperature Control

The etch rate of silicon dioxide varies with the temperature of the liquid HF in the reaction chamber. The temperature of the HF depends on the ambient temperature of the cleanroom. Additionally, the HF heats during long etching processes (exothermic reaction), which results in an increasing etch rate from wafer to wafer until the system has stabilized.

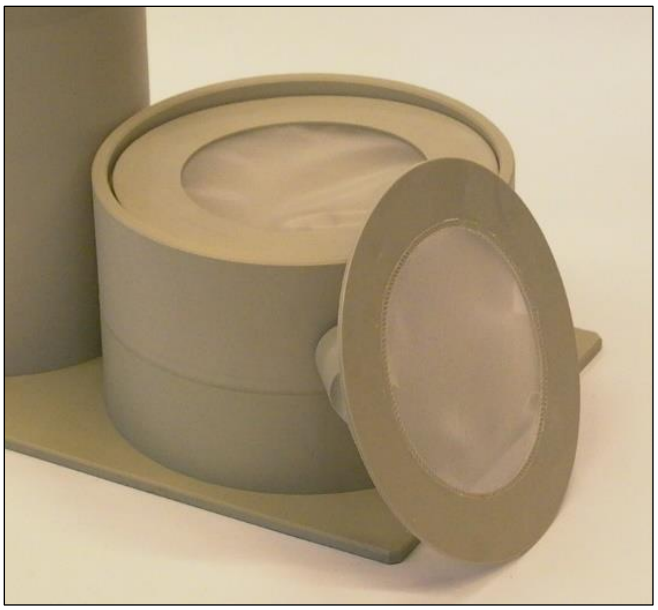


***Figure 6**: VPE optional accessories (left: Safety mesh, right: Adaptor ring for smaller wafer size). Other options are available such as e.g., quarter wafer clamping.*

To stabilize the etch rate, we have developed a reaction chamber with temperature-controlled HF in the container (VPE TRC, see Figure 7). The temperature of the HF can be adjusted with an additional controller. A heater below the reaction chamber pre-heats the acid so that during the process the acid temperature stays stable.

5. Technical specifications

The specifications of our standard VPE products are listed in Table 1 (VPE 100), Table 2 (VPE 150) and Table 3 (VPE 200). Please contact us for further details on our standard products or for your specific needs.

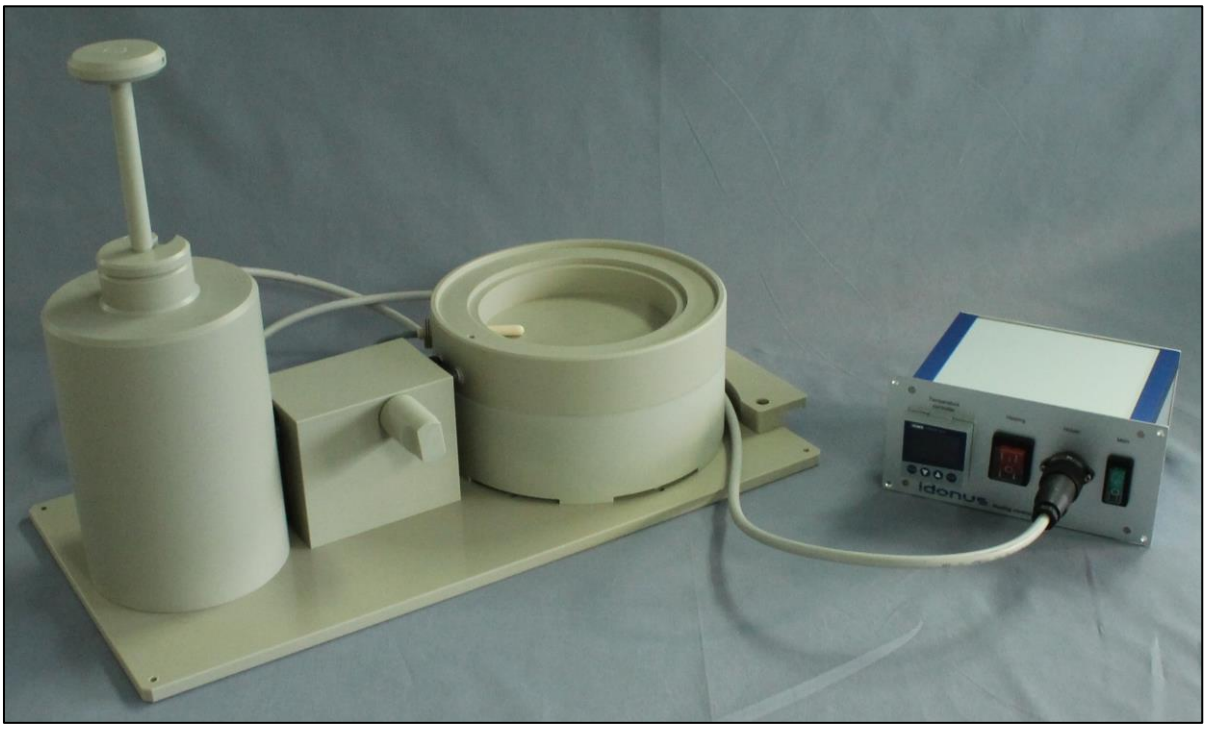


***Figure 7:** VPE with Temperature controlled Reaction Chamber (VPE-TRC model).*

6. Applications

The idonus VPE have been installed in many cleanrooms of universities, public research institutes as well as companies with small-volume production. You will therefore find interesting examples of applications in the scientific literature. In this section, we provide an illustrated view of some potential applications.

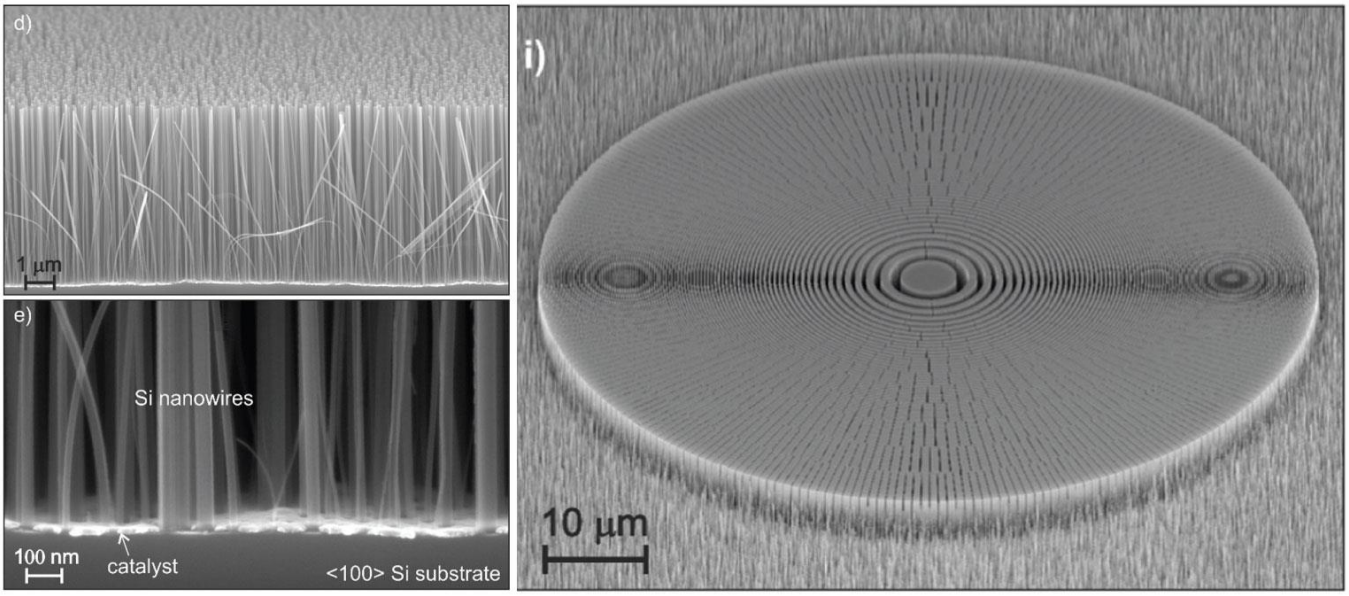


Figure 8: *Very high aspect ratio structures etched in silicon by means of metal assisted chemical etching in hydrofluoric (HF) acid vapor phase. Source: Nanoscale Horizons, Vol. 5, pp. 869-879, 2020. Digital object identifier (doi): 10.1039/C9NH00709A.*

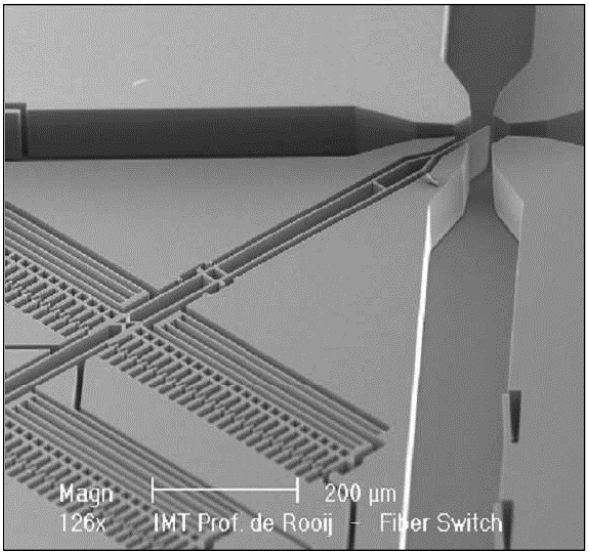


Figure 9: *SEM image of a 2x2 optical cross connect commercialized by Sercalo Microtechnology Ltd. Source: IMT University of Neuchâtel / Sercalo Microtechnology Ltd.*

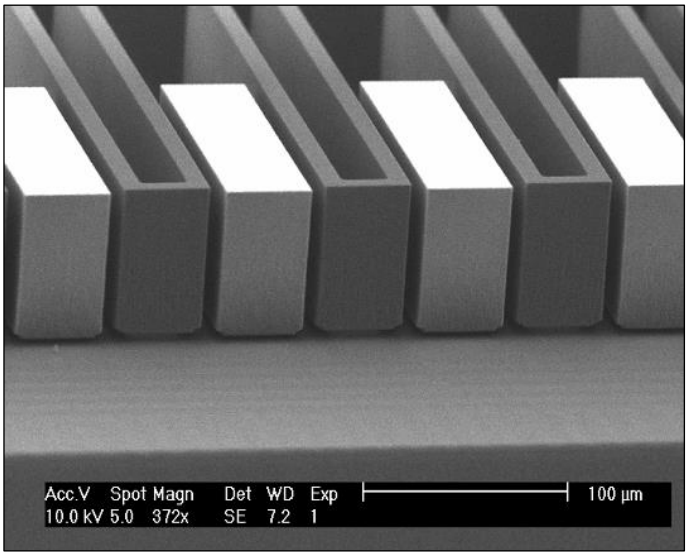


Figure 10: *Silicon isle structures on an SOI substrate. The undercut of the SiO_2 is accurately controlled.*
Source: IMT University of Neuchâtel, Switzerland.

Applications

- Stiction-free release of MEMS devices
- Single side SiO_2 etching (hidden side protected during process)
- Dicing-free release of structures on SOI substrates
- Structure thinning
- Etch rate adjustable from 0 to typ. 10 µm/h (low etch rate ensure stiction-free processing)

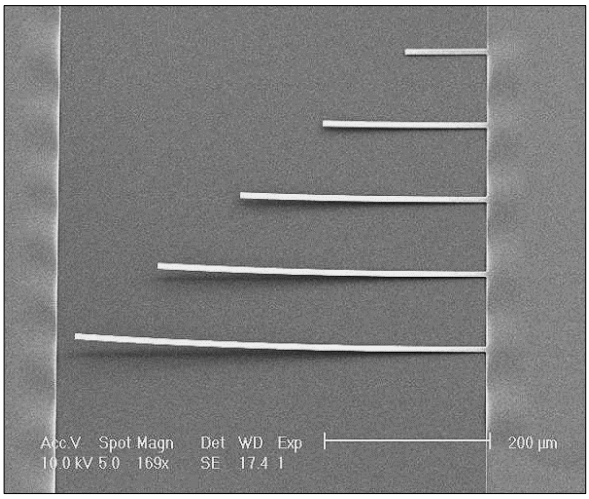


***Figure 11**: Thin Film Application. 0.5 µm-thick polysilicon beams released on 1 µm thermal SiO_2. The beams are 10 µm wide, and have a length between 100 µm and 500 µm.*

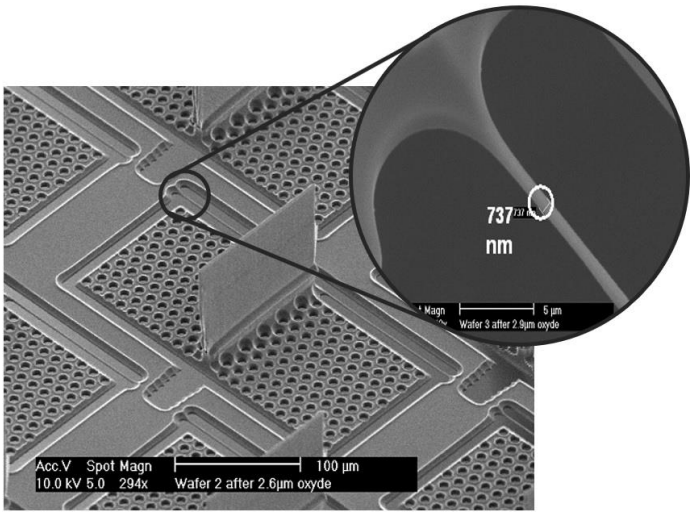


***Figure 12:** Microfabricated silicon actuator. Consecutive oxidation and HF vapor etching enables fabrication of silicon beams thinned to sub-micron width supporting a platform with vertical mirror.*
Source: IMT University of Neuchâtel, Switzerland.

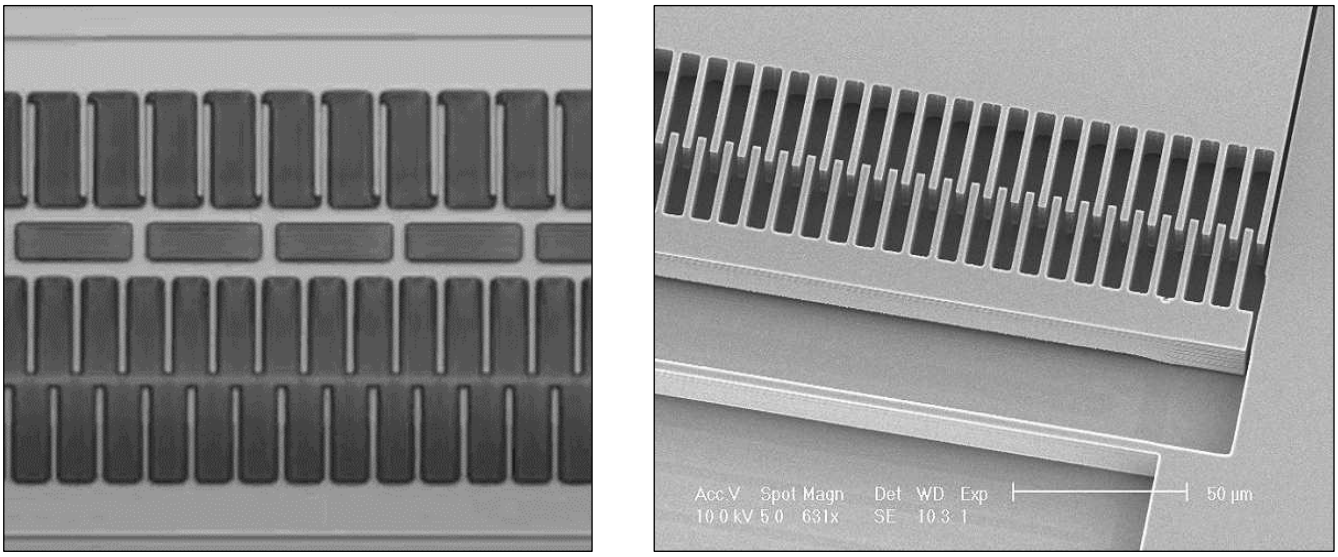


***Figure 13:** Stiction-free release of comb drives.*
Left: sticking. Right: stiction-free release of comb drives with 1 um gap between adjacent comb fingers.

Product code	VPE 100
Wafer sizes	100 mm or 4''
Etchant compatibility	HF 50%, mixtures of HF and organic solvents
Etching characteristics	
Etch rate	2 – 30 µm/h
Etching homogeneity	Typically 90% (on wafer surface); min. 50%
Backside protection	Typically 3 mm exclusion from the edge
Etching exclusion	5mm from the edge of the clamping ring
Etched materials	Silicon dioxide (SiO_2)
Resistant materials	Silicon, polysilicon, noble metals, aluminium
Wafer holder with heating plate	
Operating temperature	35°C to 60°C
Wafer clamping	
Mechanical clamping ring	For 100 mm wafers (other sizes optional)
Wafer contact	By 6 clips at Ø 94 mm
Mechanical clamping	Fixed by means of 3 large head screws from backside; screws are never in direct contact with HF acid vapor
Electrostatic clamping (optional)	For single chips (> 5 mm) as well as 100 mm wafers For all electrically conductive materials Bipolar electrostatic chuck
Reaction chamber & reservoir	Communicating vessels Safe acid handling system Re-use of HF acid
Etchant volume	100 mL (max. 160 mL)
Control Unit	Separate housing (rack mounting version)
Power supply	110 V AC 60 Hz or 230 V AC 50 Hz
Power consumption	200 VA
Front panel protection	IP65 (spraywater resistant)
Materials	All materials are HF resistant
Dimension (mm)	
Wafer holder	Ø 165 × 50 (with handle: 165 × 300 × 50)
Reaction chamber with reservoir	200 × 250 × 340 (W × H × L)
Control Unit	210 × 70 × 220 (W × H × L)
Installation Need of	Acid fume hood with air extraction Electrical power Water for rinsing

Table 1: *Technical specifications: 100 mm system (VPE 100)*

Warning: HF acid is an extremely dangerous chemical. Please refer to page 3 of this document for details.

Note: idonus reserves the right to change the specifications of its products without notice at any time (date of release of this document: February 2021). idonus fabricates the VPE for all wafer sizes. Please ask for specifications.

Product code	VPE 150
Wafer sizes	150 mm or 6''
Etchant compatibility	HF 50%, mixtures of HF and organic solvents
Etching characteristics	
Etch rate	2 – 30 µm/h
Etching homogeneity	Typically 90% (on wafer surface); min. 50%
Backside protection	Typically 3 mm exclusion from the edge
Etching exclusion	5mm from the edge of the clamping ring
Etched materials	Silicon dioxide (SiO_2)
Resistant materials	Silicon, polysilicon, noble metals, aluminium
Wafer holder with heating plate	
Operating temperature	35°C to 60°C
Wafer clamping	
Mechanical clamping ring	For 150 mm wafers (other sizes optional)
Wafer contact	By 8 clips at Ø 144 mm
Mechanical clamping	Fixed by means of 3 large head screws from backside; screws are never in direct contact with HF acid vapor
Electrostatic clamping (optional)	For single chips (> 5 mm) as well as 150 mm wafers For all electrically conductive materials Bipolar electrostatic chuck
Reaction chamber & reservoir	Communicating vessels Safe acid handling system Re-use of HF acid
Etchant volume	200 mL (max. 290 mL)
Control Unit	Separate housing (rack mounting version)
Power supply	110 V AC 60 Hz or 230 V AC 50 Hz
Power consumption	200 VA
Front panel protection	IP65 (spraywater resistant)
Materials	All materials are HF resistant
Dimension (mm)	
Wafer holder	Ø 210 × 50 (with handle: 210 × 340 × 50)
Reaction chamber with reservoir	245 × 250 × 400 (W × H × L)
Control Unit	200 × 70 × 200 for 230 V / 200 × 90 × 300 for 110 V
Installation Need of	Acid fume hood with air extraction Electrical power Water for rinsing

Table 2: *Technical specifications: 150 mm system (VPE 150)*

Warning: HF acid is an extremely dangerous chemical. Please refer to page 3 of this document for details.

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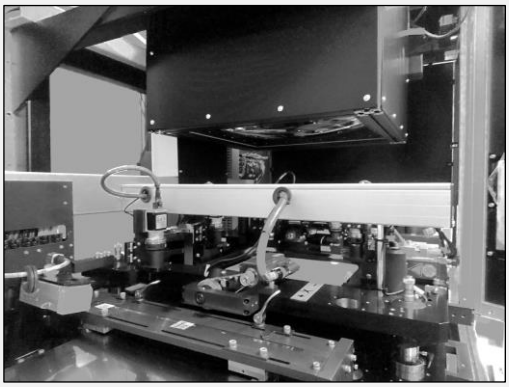
Product code	VPE 200
Wafer sizes	200 mm or 8''
Etchant compatibility	HF 50%, mixtures of HF and organic solvents
Etching characteristics	
Etch rate	2 – 30 µm/h
Etching homogeneity	Typically 90% (on wafer surface); min. 50%
Backside protection	Typically 3 mm exclusion from the edge
Etching exclusion	5mm from the edge of the clamping ring
Etched materials	Silicon dioxide (SiO_2)
Resistant materials	Silicon, polysilicon, noble metals, aluminium
Wafer holder with heating plate	
Operating temperature	35°C to 60°C
Wafer clamping	
Mechanical clamping ring	For 200 mm wafers (other sizes optional)
Wafer contact	By 8 clips at Ø 194 mm
Mechanical clamping	Fixed by means of 3 large head screws from backside; screws are never in direct contact with HF acid vapor
Electrostatic clamping (optional)	For single chips (> 5 mm) as well as 200 mm wafers For all electrically conductive materials Bipolar electrostatic chuck
Reaction chamber & reservoir	Communicating vessels Safe acid handling system Re-use of HF acid
Etchant volume	250 mL (max. 400 mL)
Control Unit	Separate housing (rack mounting version)
Power supply	110 V AC 60 Hz or 230 V AC 50 Hz
Power consumption	200 VA
Front panel protection	IP65 (spraywater resistant)
Materials	All materials are HF resistant
Dimension (mm)	
Wafer holder	Ø 260 × 50 (with handle: 260 × 390 × 50)
Reaction chamber with reservoir	295 × 250 × 455 (W × H × L)
Control Unit	200 × 70 × 200 for 230 V / 200 × 90 × 300 for 110 V
Installation Need of	Acid fume hood with air extraction Electrical power Water for rinsing

Table 3: *Technical specifications: 200 mm system (VPE 200)*

Warning: HF acid is an extremely dangerous chemical. Please refer to page 3 of this document for details.

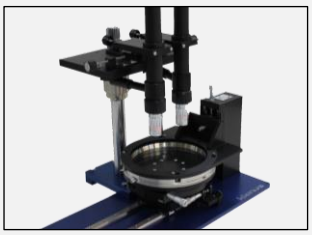
Note: idonus reserves the right to change the specifications of its products without notice at any time (date of release of this document: February 2021). idonus fabricates the VPE for all wafer sizes. Please ask for specifications.

Creative engineering and manufacturing • Our engineering team is accustomed to developing products according to client's needs. In-house machining and assembling facilities shorten the time from concept to finished products.

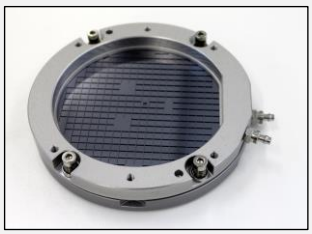


Customized UV-LED exposure system installed on a roll-to-roll machine

Visit our website to have an insight into our other products and activities. Contact us for further technical information and to obtain a quotation.



Double image microscope



A model of wafer chuck

About idonus

Founded in 2004, idonus is a Swiss company that develops and manufactures special equipment for the MEMS and watchmaking industries. Our product portfolio includes UV-LED exposure systems for photolithography, IR microscope for wafer inspection, vapor phase chemical etcher for silicon-based devices. Since 2016, we also provide ion implantation services and machines for the surface treatment of materials.

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