VAPORIZERS AND GAS FILTERS DEVELOP THE NEXT BREAKTHROUGH

Learn more at mspcorp.com
MSP
TURBO-VAPORIZERS™
PRECISION, CONTROL, STABILITY, UNIFORMITY

Vapor Solutions by MSP
MSP, a division of TSI, offers a complete line of vaporization products for liquid source vaporization in gas-phase processing like Chemical Vapor Deposition (CVD) and Atomic Layer Deposition (ALD) used in semiconductor device fabrication and industrial coating applications. MSP’s line of Turbo-Vaporizers use a droplet vaporization, direct liquid injection (DLI) technique designed to meet modern demanding vaporization needs.

The Turbo-Vaporizer Difference
MSP’s exclusive technology offers a broad range of advantages over older, more conventional techniques. The Turbo-Vaporizer applies advanced technology from aerosol science and thermo-dynamics to create a more refined solution to vaporization. In thin film applications, the stable and uniform vapor leads to a higher quality thin film and higher wafer yields. The precision and control of the vaporizer makes it possible to vaporize difficult precursors, which were not usable before, opening up new areas for process development. The unique design provides longer, stable operation resulting in less down time and more money saved for users.

This market-proven technology provides faster response time, precision flow control, and options for high temperature operation. Other benefits include:
+ Extremely stable concentration output
+ Active heat exchanger for complete vaporization
+ Low temperature vaporization/reduced risk of thermal decomposition
+ Longer Mean Time Between Repair (MTBR)
+ Ability to vaporize difficult precursors
+ Direct liquid injection (DLI) - liquid on demand
+ Higher vapor concentration potential
Applications

The complete line of Turbo-Vaporizers are used in a variety of applications including most types of CVD and ALD processes and some types of etch/ashing processes. For the complete model line, please refer to the table on page B.

The vaporizers are ideal for applications that require a high quality, stable vapor, some of which include:

- Semiconductor Microelectronics
- LEDs Optoelectronics
- Protective Coatings
- Nanoparticle Synthesis
- Energy Production/Storage
- Powder/Fiber Processing
- Solar Photovoltaic
- Medical Device
- Bio Assays
**BETTER VAPORIZATION**

**MORE PROCESS OPTIONS**

**Industry Leading Technology**
State-of-the-art vaporization from MSP stands apart from other techniques. These older technologies, including valve/injection, bubbler, and flash vaporization, are commonly used today, however they provide moderate or poor performance. See below how MSP's vaporization technique stands up to the other vaporization techniques.

<table>
<thead>
<tr>
<th></th>
<th>MSP Turbo-Vaporizer</th>
<th>Valve/Injection</th>
<th>Bubbler</th>
<th>Flash Vaporization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Precision Flow Control</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Complete Vaporization</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>No Thermal Decomposition</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Low Liquid Flow Rates</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>High Vapor Concentrations</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Longer MTBR</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Carrier Gas</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Fast Response Time</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

H = Superior; M = Moderate; L = Poor
Full Range of Precursors

A wide array of liquids can be vaporized with the Turbo-Vaporizer, including new precursors for high dielectric (K), low dielectric, and gap-fill processes. The flexibility and precision of the vaporizer enables the vaporization of difficult precursors which may have a tight window between thermal decomposition and vaporization or have low vapor pressures. A partial list of liquid precursors which have been used in the Turbo-Vaporizer is listed below:

+ TEOS  + TMA  + GeCl4  + HCD  + Acetic Acid
+ TEMAHf  + TMB  + TIPClA  + HDFDA  + H2O2
+ TEMAZr  + TMOS  + TCA  + HDSO  + Water
+ THF  + TMCTS  + TCS  + HMDS  + Alcohol
+ TDEAT  + TMQGe  + DEZ  + TaEOt  + Benzene
+ TDMAT  + MTS  + DMS  + GaFMD  + Octane
+ TTIP  + TDMAS  + DMZ  + OMCTS  + Cyclo-Hexane
+ TPT  + TPMPS  + DPMS  + PMCH  + Toluene
+ TEB  + SiCl4  + BDEAS  + PFOSF  + ACL
+ TEPO  + TiCl4  + BTBAS  + SAM24
THE DIFFERENCE
IS IN THE DESIGN

Precision flow control directly upstream of the vaporization zone results in extremely fast response times. Annular gas entry creates axially homogenous vapor concentrations. Pair these features with active heating downstream of the liquid breakup zone and the result is the most stable and uniform vapor delivery system available. Carrier gas type, carrier gas flow rate, liquid flow rate, and temperature can all be easily adjusted providing more process flexibility.

**Operating Principle**
+ Carrier gas at a high pressure passes through a small orifice to produce a high velocity gas jet
+ Liquid is introduced into this high velocity gas jet to form extremely small droplets
+ Generally, the higher the gas velocity, the smaller the droplet diameter
+ Carrier gas to liquid mass flow rates, and orifice sizes can be optimized to ensure 100% vaporization

**Ultra-fast, Low Heat**
By breaking the liquid flow into ultra-fine droplets, the surface area of the liquid is increased >10^4, creating almost instantaneous vaporization at the lowest possible heat load.

**Performance Enhanced Turbo-Vaporizer™**
The Performance Enhanced (PE) Turbo-Vaporizers are designed to handle demanding applications in ALD and CVD. These vaporizers include on-board precision liquid flow control, and are designed to generate extremely small droplets and to minimize dead volume. These features result in superior concentration stability, the ability to eliminate thermal decomposition, and extremely fast response times. Benefits include:
+ Precision liquid control / vapor concentration
+ Fast response time/ minimal dead volume
+ Smaller droplet diameters
+ No contamination particles generated due to thermal decomposition elimination
+ Uniform axial droplet/vapor concentration
+ Liquid bubble elimination / suppression
+ Factory adjustable gas orifice
Heat Exchanger Design
+ 2-stage heating process ensures complete droplet vaporization
+ The high velocity atomizing gas jet establishes a recirculating gas flow in the first stage to heat the gas uniformly to the vaporizer temperature
+ Vaporization then occurs by mixing the droplet aerosol with the recirculating hot gas flow
+ Low maintenance: clean carrier gas sheathes the liquid droplets preventing deposition inside the vaporizer which can lead to clogging.

Excellent for Thermally Sensitive Liquids
+ Heat transfer occurs indirectly through the gas to the suspended droplets
+ Carrier gas flow surrounds droplets, largely eliminating direct liquid-to-hot metal contact
+ Droplet temperature remains low due to evaporative cooling
+ Thermal decomposition is largely eliminated or greatly reduced
## MEETS YOUR APPLICATION NEEDS

**ONE SIZE DOESN’T FIT ALL...**

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Flow Rate</th>
<th>Features</th>
</tr>
</thead>
</table>
| Model 2840PE | Extremely stable output, perfect for ALD     | Low Flow   | + Compact design  
+ Excellent for low flow applications  
+ Ultra-fast response time         |
| Model 2820  | Classic system, great for easy to vaporize precursors | Medium Flow | + Wide internal orifices for minimized clogging  
+ Compact design  
+ Great for high vapor pressure precursors |
| Model 2820D | Dual liquid inlet                           | Medium Flow | + Wide internal orifices for minimized clogging  
+ Compact design  
+ Great for R&D applications         |
| Model 2800PE | Ultra-fast vaporization, good for thermolabile liquids | Medium Flow | + Fast vaporization  
+ Excellent for thermally sensitive liquids  
+ Dual pass heat exchanger           |
| Model 2800  | High temperature vaporization               | Medium Flow | + <300ºC operating temperature  
+ Ultra-fast vaporization  
+ Excellent for thermally sensitive liquids |
| Model 2801PE | High flow, good for expansive vapors       | High Flow   | + Long heat exchanger residence time  
+ Wide internal pathways allow room for expansion |
| Model 2841PE | High flow, perfect for water vapor          | High Flow   | + Dual heaters  
+ 500W heater power  
+ Generates up to 5000 sccm of water vapor |
| Model 2821  | Stable vaporization at very high flow       | Very High Flow | + 3600W heater  
+ Up to 6000g/hr (TEOS equivalent)  
+ Three controlled heated zones |
| Model 2860PE | Drop-in replacement for direct injection valve | Medium Flow | + Compact design  
+ Air cool option  
+ Extremely stable output |

* Since absolute flow ranges are dependent on liquid and carrier gas types, flow ranges are meant to be comparative across models.
### Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Flow Rate</th>
<th>Description</th>
<th>ALD</th>
<th>CVD</th>
<th>Etch/ Water Vapor</th>
<th>R&amp;D</th>
<th>Industrial</th>
<th>Thermolabile Liquids</th>
<th>High Temp</th>
<th>Liquid Injection Valve Replacement</th>
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<tbody>
<tr>
<td>2840PE</td>
<td>Very Low</td>
<td>Extremely Stable Output</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>2820</td>
<td>Medium</td>
<td>Easy to Use Precursors</td>
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<td>2820D</td>
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<td>Dual Liquid Inlet</td>
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<tr>
<td>2800PE</td>
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<td>Thermolabile Liquids</td>
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<td></td>
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<td>Medium</td>
<td>High Temperature</td>
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<td>2841PE</td>
<td>High</td>
<td>High Heat</td>
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<tr>
<td>2801PE</td>
<td>High</td>
<td>Expansive Vapors</td>
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<td></td>
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<td></td>
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<tr>
<td>2821</td>
<td>Very High</td>
<td>High Output</td>
<td></td>
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<tr>
<td>2860PE</td>
<td>Medium</td>
<td>Injection Valve Replacement</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

### Perform Enhanced (PE) Design
- **2840PE**: Y
- **2820**: N
- **2820D**: N
- **2800PE**: Y
- **2800**: N
- **2801PE**: Y
- **2841PE**: N
- **2821**: N
- **2860PE**: Y

### Max. Liquid Flow* DI Water (g/hr)
- **2840PE**: 60
- **2820**: 90
- **2820D**: 90
- **2800PE**: 90
- **2800**: 90
- **2801PE**: 120
- **2841PE**: 300
- **2821**: 600
- **2860PE**: 60

### Max. Flow Flow* TEOS equivalent (g/hr)
- **2840PE**: 720
- **2820**: 900
- **2820D**: 900
- **2800PE**: 900
- **2800**: 900
- **2801PE**: 1200
- **2841PE**: 3000
- **2821**: 6000
- **2860PE**: 720

### Gas Flow Range* N₂ (SLPM)
- **2840PE**: 0.25-15
- **2820**: 0.5-20
- **2820D**: 0.5-20
- **2800PE**: 0.25-15
- **2800**: 0.5-15
- **2801PE**: 0.25-15
- **2841PE**: 1-100
- **2821**: 0.25-15
- **2860PE**: 0.25-15

### Temperature Range* (ºC)
- **2840PE**: 40-200
- **2820**: 40-300
- **2820D**: 40-300
- **2800PE**: 40-200
- **2800**: 40-200
- **2801PE**: 40-200
- **2841PE**: 40-200
- **2821**: 40-200
- **2860PE**: 40-200

### Typical Power (W)
- **2840PE**: 300
- **2820**: 300
- **2820D**: 300
- **2800PE**: 300
- **2800**: 300
- **2801PE**: 300
- **2841PE**: 300
- **2821**: 300
- **2860PE**: 300

### Dimensions HxWxD (cm)
- **2840PE**: 29x8x11
- **2820**: 22x18x14
- **2820D**: 22x14x18
- **2800PE**: 29x17x12
- **2800**: 31x12x17
- **2801PE**: 30x12x12
- **2841PE**: 42x14x18
- **2821**: 24x8x9
- **2860PE**: 30x8x12

### Dimensions HxWxD (in)
- **2840PE**: 11.4x3.3x4.3
- **2820**: 8.8x7.2x5.5
- **2820D**: 8.6x5.5x7.2
- **2800PE**: 11.6x6.8x4.8
- **2800**: 12.2x4.7x6.8
- **2801PE**: 11.7x4.7x4.8
- **2841PE**: 16.4x5.5x7.2
- **2821**: 9.3x3.2x3.5

### Line Voltage, Frequency
- **2840PE**: 120VAC, 60Hz
- **2820**: 220VAC, 50Hz
- **2820D**: 120VAC, 60Hz

* Liquid and gas flow ranges are effected by liquid and gas type; assuming medium vacuum or lower downstream of the vaporizer.

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**Solutions for Advanced Processing**
INNOVATION IN FILTER DESIGN

Extremely Low Pressure Drop
MSP's chemically and thermally resistant vapor/gas filters are specifically designed for low pressure and high temperature applications, providing reliable filtration even for chemically aggressive vapors/gases. The filters are designed to have extremely low pressure drops, making it easier to work in an ultra-low pressure environment. Pump down is faster, and lower pressures are possible.

Nano-Filtration Media
The Nano-Filtration Media used in the VPG-A6 is comprised of sintered stainless steel fibers of a homogenous construction with efficiency and pressure drop capabilities not previously attainable by a conventional sintered metal filter media construction.

Cross Flow Filter Design
The cross flow filter design provides high efficiency, low pressure drop filtration with an easy to install form factor.
+ The flow is diverted to pass through the filter media perpendicular to the gas entry
+ As face velocity decreases, pressure drop across the filter decreases and efficiency increases
+ The cross flow design reduces the face velocity in a tube type filter, which leads to decreased pressure drop and increased filtration efficiency

Flow Path

VAPOR PROCESS GAS (VPG™) FILTERS - 316SS

<table>
<thead>
<tr>
<th>Model</th>
<th>VPG-A3</th>
<th>VPG-A6</th>
<th>VPG-C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Ultra-low pressure drop, high filtration efficiency</td>
<td>Ultra low pressure drop, ultra high efficiency</td>
<td>Large surface area, long life</td>
</tr>
<tr>
<td>Flow Range (SLM)</td>
<td>0-100</td>
<td>0-30</td>
<td>0-100</td>
</tr>
<tr>
<td>2.5nm Filter Efficiency @1 SLPM (%)</td>
<td>99.99999999 (nine 9s)</td>
<td>99.9999999999 (twelve 9s)</td>
<td>99.9999999999 (twelve 9s)</td>
</tr>
<tr>
<td>10nm Filter Efficiency @1 SLPM (%)</td>
<td>99.9999 (six 9s)</td>
<td>99.99999999 (ten 9s)</td>
<td>99.99999999 (nine 9s)</td>
</tr>
<tr>
<td>50nm Filter Efficiency @1 SLPM (%)</td>
<td>99.99 (four 9s)</td>
<td>99.99997 (five 9s)</td>
<td>99.9999 (six 9s)</td>
</tr>
<tr>
<td>Pressure drop</td>
<td>&lt;0.04 kPa@1 SLPM; kPa = 0.0439*Q(SLPM)-0.0516</td>
<td>&lt;0.04 kPa@1 SLPM; kPa = 0.0477*Q(SLPM)-0.066</td>
<td></td>
</tr>
<tr>
<td>Filter Media</td>
<td>Sintered 316SS powder</td>
<td>Sintered 316SS fiber</td>
<td>Sintered 316SS powder</td>
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<tr>
<td>Fittings</td>
<td>1/2” VCR</td>
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<tr>
<td>Wetted Materials</td>
<td>316 Stainless Steel</td>
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<tr>
<td>Temperature Range (°C)</td>
<td>&lt;300</td>
<td></td>
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</tr>
<tr>
<td>Length (”)</td>
<td>5</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>1</td>
<td>1</td>
<td>3</td>
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</table>
Flexible Solutions
Turbo-Vaporizer™ can be used with many commercially available control solutions, allowing you to standardize flow controllers, temperature controllers, and voltage controllers across your system.

2910 Multi-function Controller
This versatile precision controller can be used to control the on-board liquid controller in PE vaporizers, when paired with almost any commercially available liquid flow meter (LFM). It can be used to maintain a steady liquid flow, or to generate repeatable short duration vapor pulses for ALD applications.

2940 Liquid Flow Controller
This thermal LFC can be used to control the on-board Piezo valve in our PE Vaporizers. The 2940 features an all digital control system resulting in response times of <200ms making the 2940 a great choice for ALD applications. The 2940 supports zoned PID settings, and has a self-learning function to optimize control.

<table>
<thead>
<tr>
<th>Model</th>
<th>2940 Liquid Flow Controller</th>
<th>2910 Multi-Function Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Number</td>
<td>FC1 2940-01-1004</td>
<td>FC1 2940-01-5008</td>
</tr>
<tr>
<td></td>
<td>FC2 2940-01-1001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FC3 2940-01-1005</td>
<td></td>
</tr>
<tr>
<td>Full Scale DI Water (g/min)</td>
<td>0.08 1.0 5.0</td>
<td>Power @ 24V (W)</td>
</tr>
<tr>
<td>Full Scale TEOS Equiv (g/min)</td>
<td>0.58 6.4 32</td>
<td>Cycle Time (ms)</td>
</tr>
<tr>
<td>Overpressure Resistance (bar)</td>
<td>5 2 1</td>
<td>Input Signal (V)</td>
</tr>
<tr>
<td>Max Pressure Drop (mbar)</td>
<td>5 2 1</td>
<td>Input Impedance (kΩ)</td>
</tr>
<tr>
<td>Capillary Inner Diameter (mm)</td>
<td>0.48 1.0 1.8</td>
<td>Output Signal @ 0-24V (mA)</td>
</tr>
<tr>
<td>Port Connectors</td>
<td>1/8” Male VCR Fitting</td>
<td>Operating Temperature</td>
</tr>
<tr>
<td>Operating Temp (ºC)</td>
<td>0-50</td>
<td>Operating Humidity (%)</td>
</tr>
<tr>
<td>Operating Humidity</td>
<td>20-80 non-condensing</td>
<td>Dimensions (”)</td>
</tr>
<tr>
<td>Dimensions (”)</td>
<td>5x6x1</td>
<td>Weight (lb)</td>
</tr>
<tr>
<td>Weight (lb)</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>
Custom Solutions
Processes which require vapor created from a liquid cover an extremely wide spectrum of process conditions. Several important process parameters that affect vaporization include:
+ Liquid type and flow rate
+ Carrier gas type and flow rate
+ Process pressure and temperature
+ Ambient pressure and temperature
+ Distance between vaporizer and process zone

Designed for Your Application
MSP offers the widest range of standard vaporizer solutions commercially available. However, for many applications - particularly processes that will be rolled out to a large number of systems; a vaporizer solution specifically designed for your operating parameters may result in the highest quality, most stable and reliable vapor delivery solution. MSP routinely partners with industry leaders to co-develop and supply unique vaporization solutions for their leading edge technology process equipment.

The MSP Difference
MSP’s foundation was born out of academia, and the company is dedicated to partnering with leading technology research groups across the globe to bring cutting edge design to commercial applications.

Vaporization Experts
For over 30 years MSP has embraced and researched the science of vaporization becoming the foremost experts in this specialized field.

Commitment to Innovation
Every year our MSP vaporization experts continue to innovate and drive vaporization technology to new heights to meet the demands of progressively challenging process requirements. With 40+ active designs patents, MSP continues to lead the way in vapor delivery solutions.