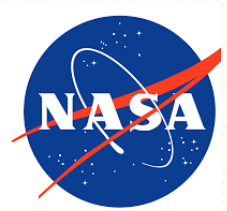
Tergeo plasma cleaners

Versatile tabletop plasma cleaner for R&D and low-volume production

Customers around the world













Australia

Germany

United Kingdom

France

China

Israel

Saudi Arabia

Brazil

South Korea

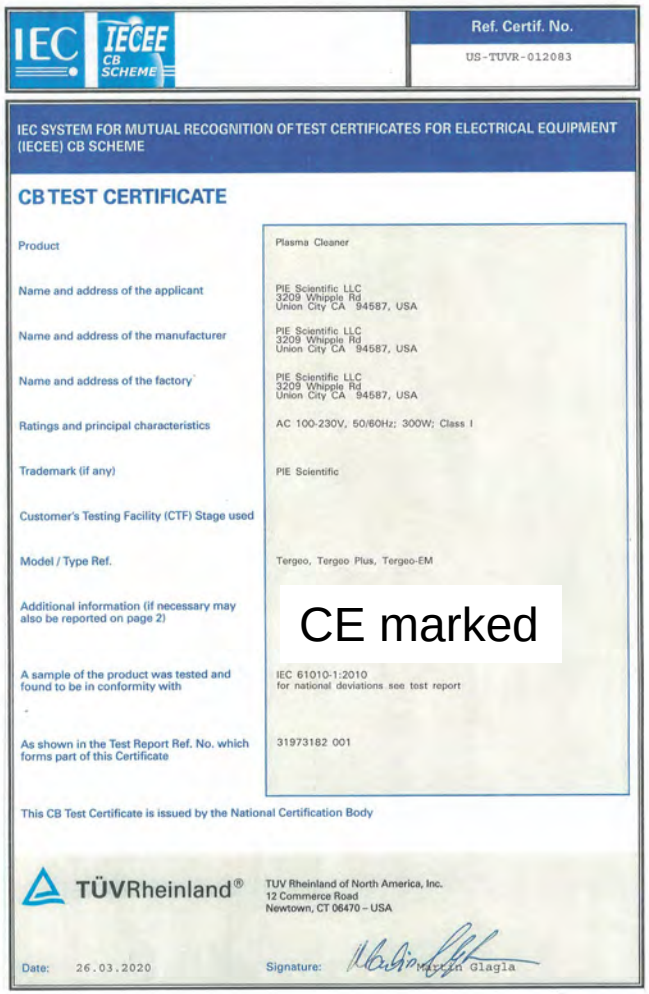
Japan

Certified by TÜV Rheinland and UL Japan

IEC 61010-1:2010 certificate for European countries

UL CAN/CSA 61010-1:2012 certificate for North America

Rf emission conformity certificate from UL Japan Inc.



IEC IECEE CB SCHEME

Ref. Certif. No.
US-TUVR-012083

IEC SYSTEM FOR MUTUAL RECOGNITION OF TEST CERTIFICATES FOR ELECTRICAL EQUIPMENT (IECEE) CB SCHEME

CB TEST CERTIFICATE

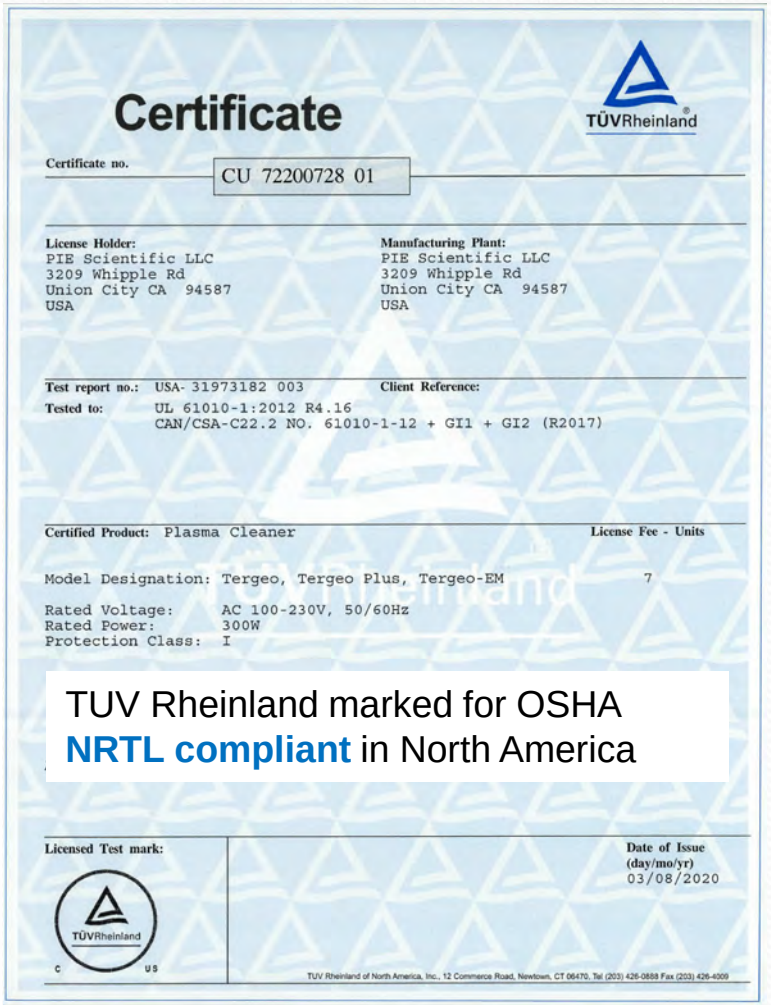
Product	Plasma Cleaner
Name and address of the applicant	PIE Scientific LLC 3209 Whipple Rd Union City CA 94587, USA
Name and address of the manufacturer	PIE Scientific LLC 3209 Whipple Rd Union City CA 94587, USA
Name and address of the factory	PIE Scientific LLC 3209 Whipple Rd Union City CA 94587, USA
Ratings and principal characteristics	AC 100-230V, 50/60Hz; 300W; Class I
Trademark (if any)	PIE Scientific
Customer's Testing Facility (CTF) Stage used	
Model / Type Ref.	Tergeo, Tergeo Plus, Tergeo-EM
Additional information (if necessary may also be reported on page 2)	
A sample of the product was tested and found to be in conformity with	IEC 61010-1:2010 for national deviations see test report
As shown in the Test Report Ref. No. which forms part of this Certificate	31973182 001

This CB Test Certificate is issued by the National Certification Body

TÜVRheinland®
TUV Rheinland of North America, Inc.
12 Commerce Road
Newtown, CT 06470 - USA

Date: 26.03.2020 Signature: Martin Glagla

CE marked



Certificate

TÜVRheinland

Certificate no. CU 72200728 01

License Holder:
PIE Scientific LLC
3209 Whipple Rd
Union City CA 94587
USA

Manufacturing Plant:
PIE Scientific LLC
3209 Whipple Rd
Union City CA 94587
USA

Test report no.: USA- 31973182 003 Client Reference:
Tested to: UL 61010-1:2012 R4.16
CAN/CSA-C22.2 NO. 61010-1-12 + GI1 + GI2 (R2017)

Certified Product: Plasma Cleaner License Fee - Units

Model Designation: Tergeo, Tergeo Plus, Tergeo-EM 7

Rated Voltage: AC 100-230V, 50/60Hz
Rated Power: 300W
Protection Class: I

TUV Rheinland marked for OSHA
NRTL compliant in North America

Licensed Test mark:

Date of Issue (day/mo/yr)
03/08/2020

TUV Rheinland of North America, Inc., 12 Commerce Road, Newtown, CT 06470, Tel (203) 426-0888 Fax (203) 426-4009

Test report No. : 12402432S-B
Page : 1 of 18
Issued date : August 28, 2018

RADIO TEST REPORT

Test Report No.: 12402432S-B

Applicant	:	PIE Scientific LLC
Type of Equipment	:	Plasma cleaner
Model No.	:	Tergeo-EM
Test standard	:	Rules for Regulating Radio Equipment, Article 65-3 (1) Public Notice of Ministry of Internal Affairs and Communications, No. 207
Test result	:	Complied

1. This test report shall not be reproduced in full or partial, without the written approval of UL Japan, Inc.
2. The results in this report apply only to the sample tested.
3. This sample tested is in compliance with the limits of the above standard.
4. The test results in this test report are traceable to the national or international standards.
5. This test report covers Radio technical requirements.
   It does not cover administrative issues such as Manual or non-Radio test related Requirements. (if applicable)
6. The all test items in this test report are conducted by UL Japan, Inc. Shonan EMC Lab.

Date of test: December 4, 2017 and August 10, 2018

Representative test engineer
Akihiro Oda
Engineer
Consumer Technology Division

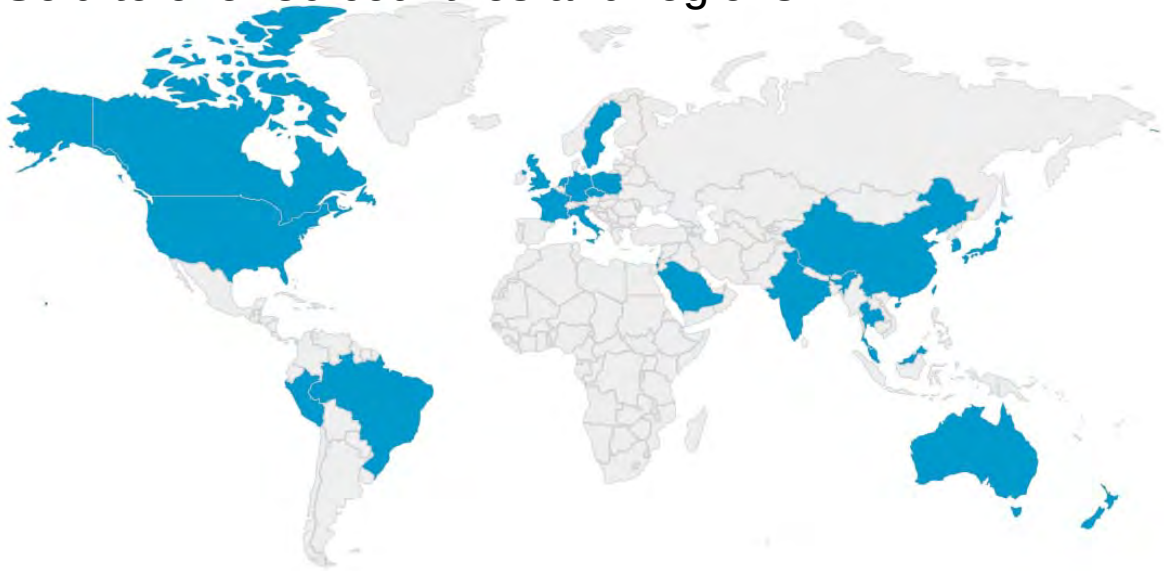
Approved by :
Toyokazu Imamura
Leader
Consumer Technology Division

UL Japan, Inc.
Shonan EMC Lab.
1-22-3 Megumigaoka, Hiratsuka-shi, Kanagawa-ken, 259-1220 JAPAN
Telephone : +81 463 50 6400
Facsimile : +81 463 50 6401

Global sales coverage

Made in San Francisco Bay Area in U.S.A.

Sold to over 30 countries and regions

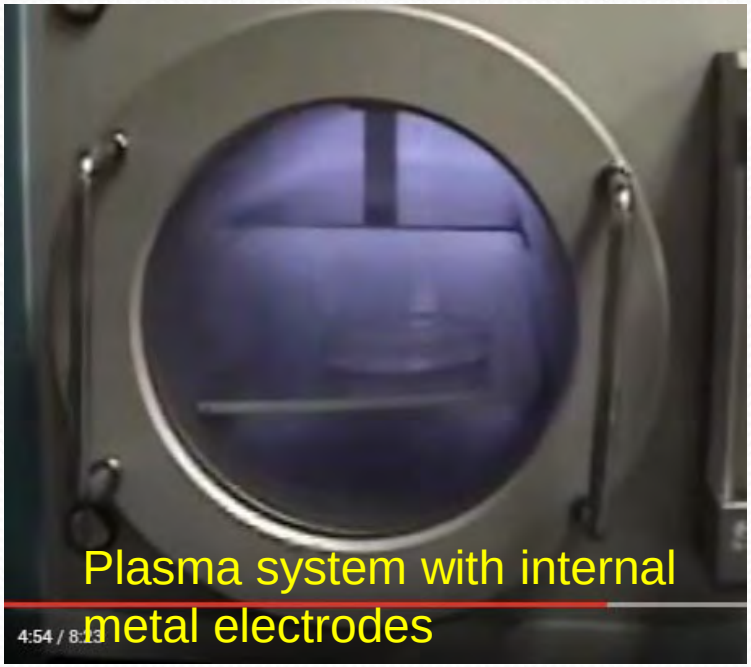


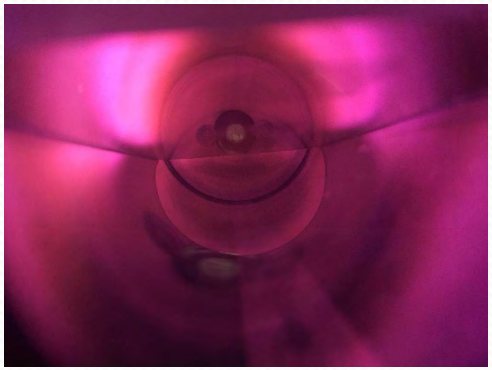
North America: The United States, and Canada
Europe: United Kingdom, Germany, France, Italy, Netherlands, Austria, Sweden, Switzerland, Luxembourg, Czech Republic, Poland, Hungary, Croatia, and Monaco
Asia: Japan, S. Korea, China, Hong Kong, Taiwan, Singapore, Malaysia, India, and Thailand
Middle East: Israel and Saudi Arabia
Oceania: Australia, and New Zealand
South America: Brazil, and Peru

Key Spec

Items	Feature and Spec
RF power supply	75-watt or 150-watt for Tergeo; 150-Watt or 500-Watt for Tergeo-plus; can be adjusted at 1-watt interval; 13.56MHz high frequency RF power supply; automatic impedance matching; **Continuous and pulsed plasma (pulse ratio 100% to <1%).**
Sample chamber	Cylindrical quartz chamber (ID:110mm, OD:120mm, Depth 280mm for basic Tergeo; ID160mm, OD170mm, Depth 280mm for Tergeo plus). One rectangular quartz shelf included.
Plasma discharge mode	Capacitively coupled discharge for the direct plasma source. Inductively coupled plasma source as the remote plasma source.
Electrode placement	External rf electrode design to reduce ion sputtering on the metal electrodes.
Source design	**Dual plasma sources in one system**. Both the traditional direct mode plasma processing and the gentle downstream mode plasma processing in one system
Plasma diagnostics	**Realtime plasma intensity sensor** for quantitative plasma status monitoring
Gas delivery	One solenoid valve controlled gas input port for chamber venting/purging purpose; two or three additional MFC regulated gas input ports for process gas delivery. All the gas input ports use the standard 1/4" Swagelok tube compression fitting.
Pressure sensor	Premium full range **corrosion resistant (platinum filament)** pressure sensor.
Pump	Basic oxygen service oil pump (ultimate pressure <10mTorr) or oil-free dry pump from Edwards Vacuum LLC. Pump can be controlled by the plasma system.
System control	7 inch LCD touchscreen. 20-recipe library. Fully automatic operation. 3-recipe job sequence mode.
Enclosure dimension	W450mm X H250mm X D430mm for basic Tergeo, W500mm X H300mm X D430mm for Tergeo-plus
AC input	Universal 100V~230V AC input 50/60Hz

Better uniformity and lower contamination





Inductive coil antenna design in some lo-cost plasma cleaner results in bad uniformity

Better uniformity. Plasma discharge technology in Tergeo plasma cleaner originates from the research carried out in the Plasma & Ion Source Technology at the Lawrence Berkeley National Laboratory. The difference in plasma color is because of the different process gas. Tergeo plasma cleaner clearly has much better uniformity. Bad uniformity means bad process control. Tergeo system also have larger usable volume for the same chamber diameter.

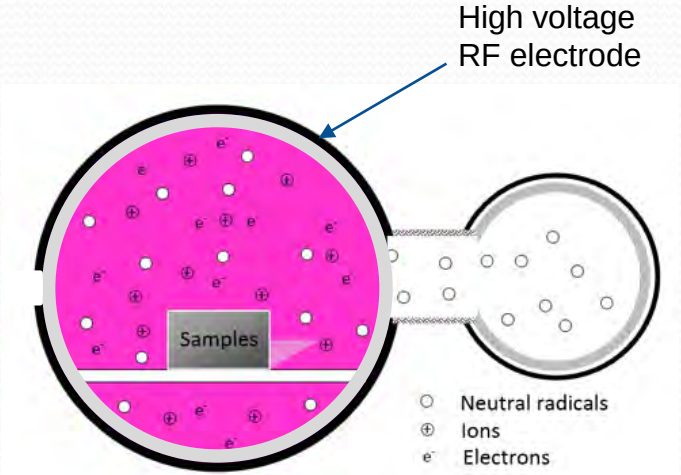
Lower contamination: Electrodes are placed outside of the quartz tube in Tergeo plasma cleaner. Ions can't reach the metal electrodes. If high voltage metal electrode is placed inside the plasma chamber, ions will be accelerated to high energy and sputter metal out of the electrodes. Metal will then deposit onto the samples and cause metal contamination issue. Metal sputtering contamination issue is especially severe if KHz rf power supply is used to generate the plasma because ions can be accelerated by KHz electric field.

Tergeo vs other plasma cleaners

High voltage rf electrodes are placed outside the plasma chamber in Tergeo system. It results in better plasma uniformity, less contamination and more usable space

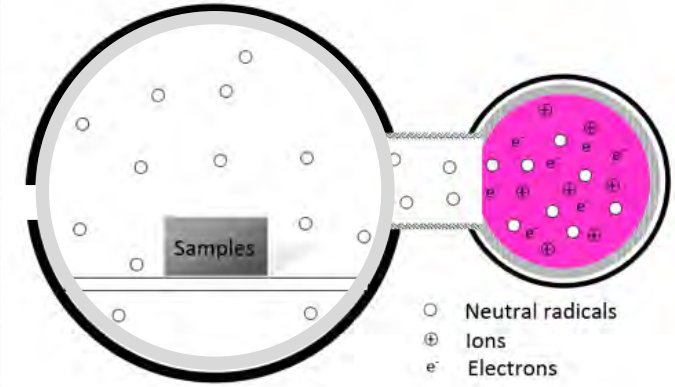
Tergeo

Direct mode



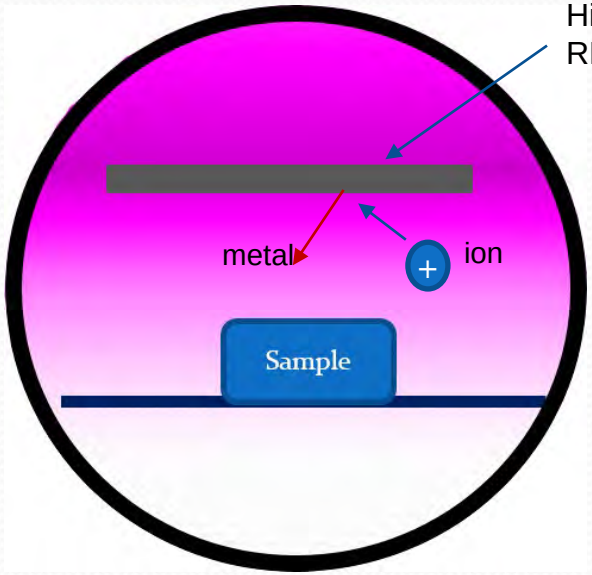
Better uniformity, no metal contamination

Downstream mode



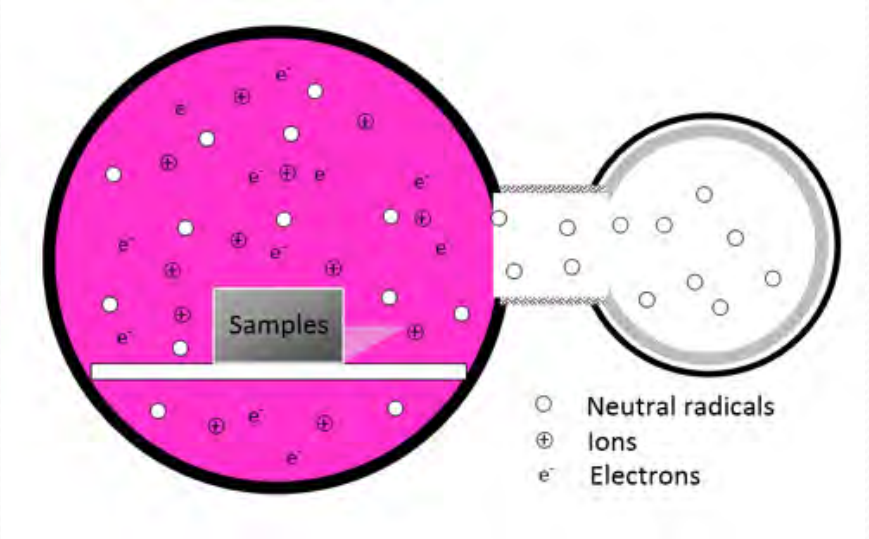
Gentle ion-free chemical reaction

Competitors

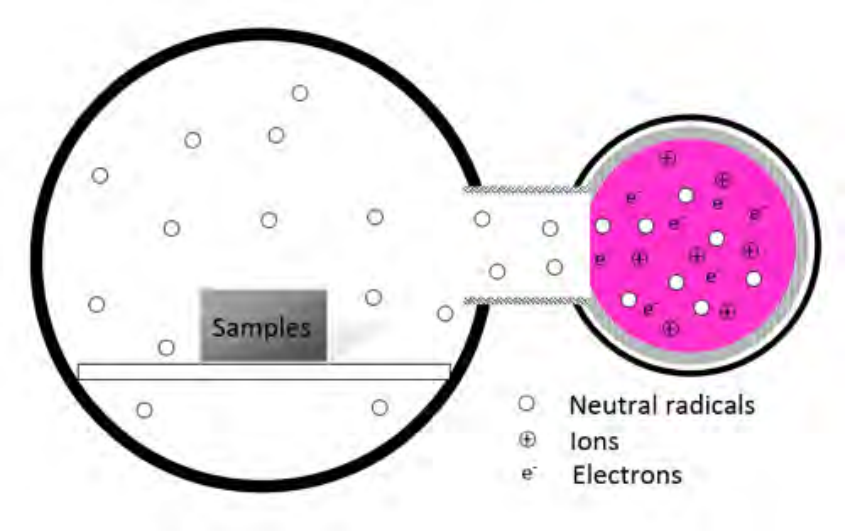


High voltage rf electrode in the plasma attracts high energy ions and cause metal sputtering contamination on the samples

Direct vs downstream cleaning modes



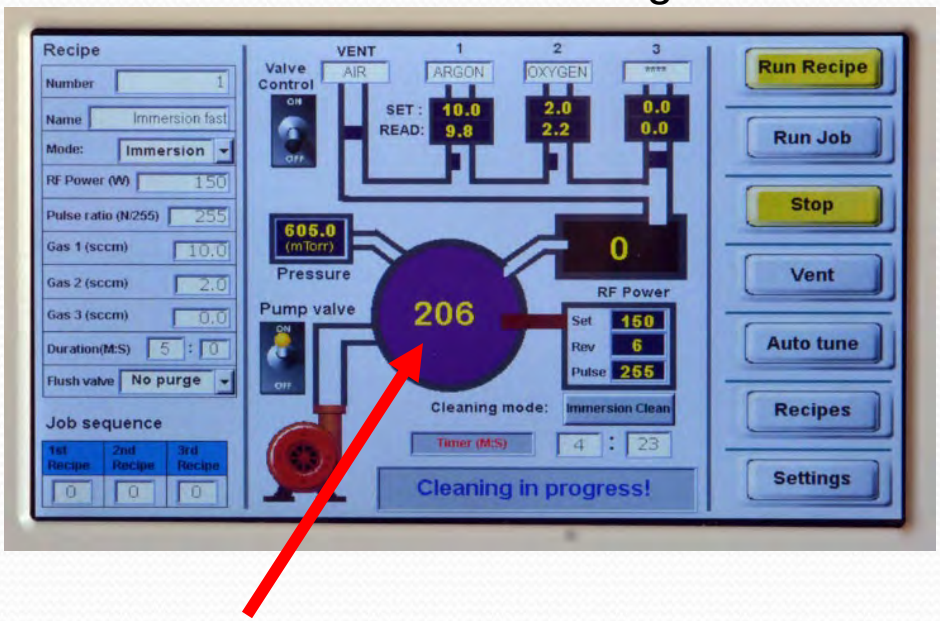
Direct/immersion mode plasma cleaning
Plasma is generated in sample chamber
Samples are immersed in plasma
Samples are subject to chemical reaction with radicals and energetic ion sputtering



Remote/downstream mode plasma cleaning
Plasma is generated outside sample chamber.
Samples are not immersed in energetic plasma
Only gentle chemical reaction takes place on sample surface.
No energetic ion sputtering. No sample damage due to excessive heating, charging and ion bombardment.

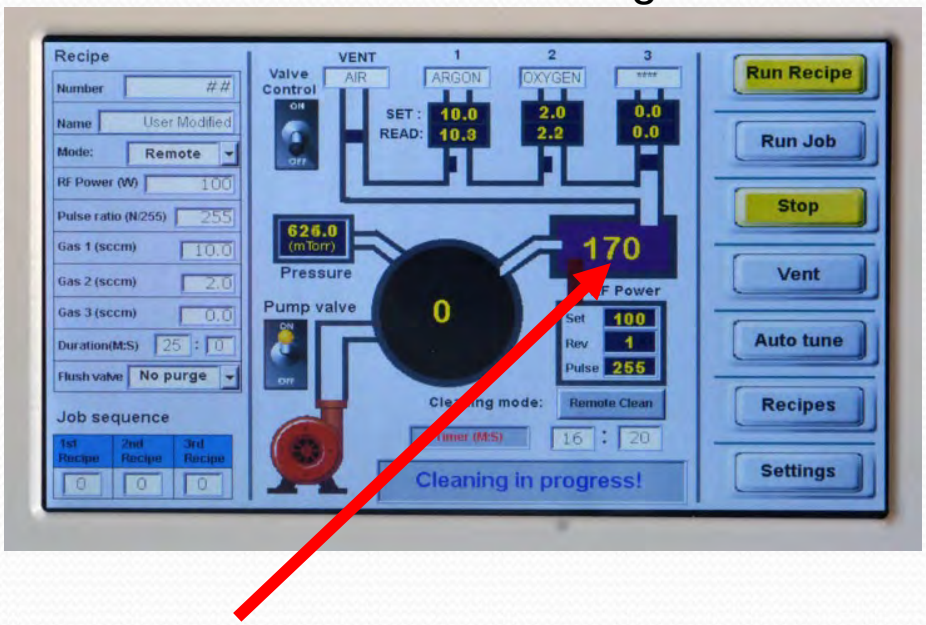
Proprietary plasma sensor technology, quantitative data for repeatable process

Direct/immersion cleaning mode



Plasma generated in the sample chamber. Plasma intensity reading is 206

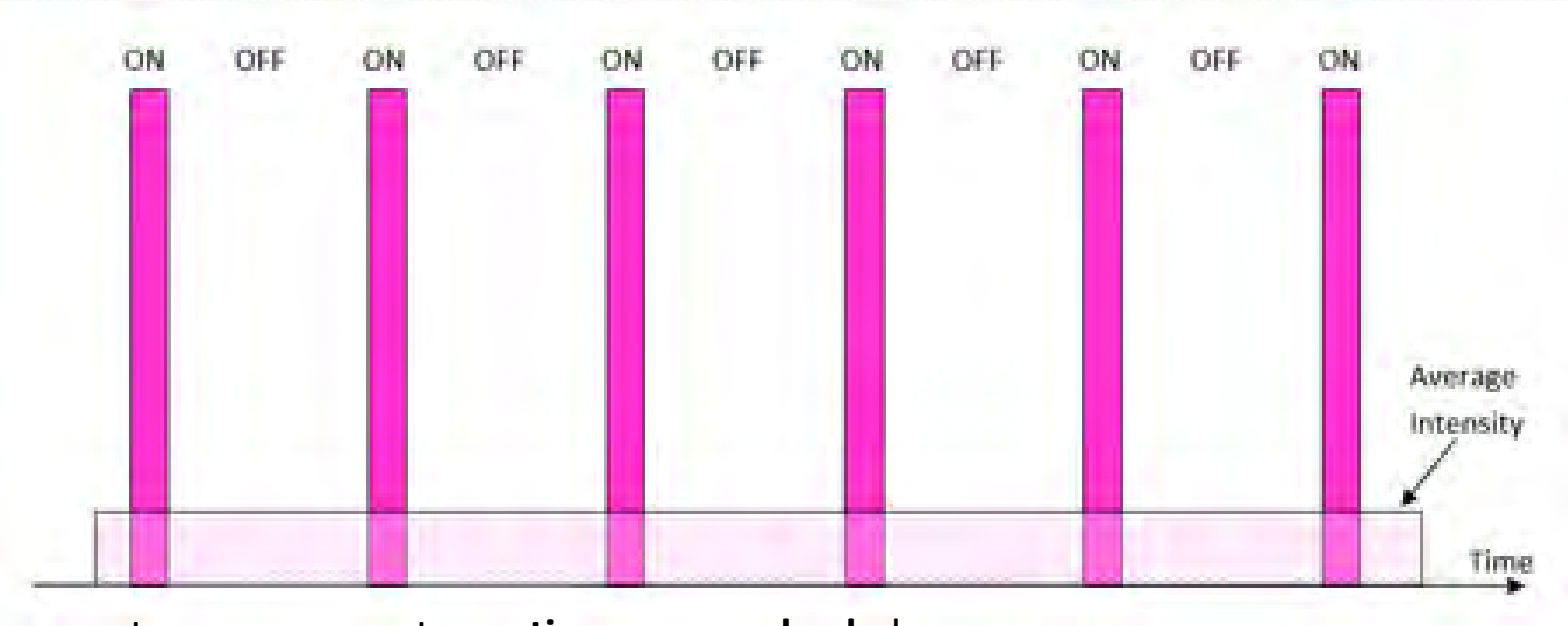
Remote/downstream cleaning mode



Plasma generated in the remote plasma source. Plasma intensity reading is 170

Take the guesswork out of plasma cleaning. Plasma sensor tells the user exactly how strong the plasma is. User can use the quantitative plasma intensity measurement as feedback to adjust gas flow rate and rf power for desired cleaning speed. User doesn't need to be plasma expert to set up right cleaning recipe for different samples.

Continuous and pulsed plasma



Tergeo plasma system can generate **continuous** or **pulsed** plasma.

Tergeo plasma system not only adjusts rf power but also adjusts the pulse duty ratio. Pulse mode further extends the dynamic range of the plasma intensity. The pulse duty ratio can be adjusted from 100% (continuous) to less than 1% (two order of magnitude). The plasma intensity varies more linearly with the pulse duty ratio compared with adjusting the rf power wattage. Pulse mode can create an extremely weak plasma that is almost invisible to human eyes. Our proprietary plasma sensor can still measure the plasma intensity quantitatively even for the plasma that is almost invisible to human eye.

Pulsed mode can generate weak yet repeatable plasma for fragile samples like 2D materials, TEM holey carbon grids, and other samples that can be easily damaged by strong plasma.

KHz, MHz, and GHz plasma

Why MHz is the best frequency to generate the plasma?

- The frequency of kHz is so slow that both electrons and ions in the plasma can be accelerated by the kHz electric field. Therefore, ions and electrons can be accelerated to very high energy in each cycle. They will eventually hit the chamber wall and electrodes and get lost from the plasma. Therefore, KHz plasma is usually very weak. **KHz rf power supply and plasma systems are generally much cheaper than the 13.56MHz rf plasma system due to the lower efficiency**.
- The frequency of the MHz electromagnetic wave is slower enough to accelerate the electrons. But ions are too heavy and too slow to respond to the MHz electric field. Ions are thermalized in the MHz plasma system. So they can survive in the plasma much longer. MHz is the sweet spot of the frequency to generate high-intensity uniform plasma.
- When the frequency increases to GHz (microwave), energy can only be transferred to the plasma through a plasma wave. Microwave tends to create multiple nodes in the metal chamber, which generates localized hot spots and results in bad uniformity. This is why dishes need to be rotated in the microwave oven to improve uniformity. Due to the bad uniformity, microwave plasma usually works in downstream mode.

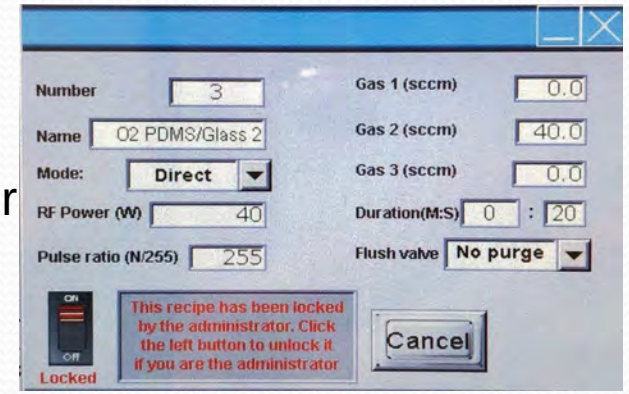
Intuitive design and easy to use

- Two different user interface: LCD touchscreen user interface and PC remote control user interface.
- Intuitive user interface. Easy to use. No extensive training required.
- Fully automatic operation. Supports 20 recipes. One button to start. Repeatable and reliable results.
- Recipe lock/unlock function to prevent unintended modification of the optimized recipes. Essential features for production runs and for shared facility.
- Smart system self-diagnostic. Notify user the operation tips, system status and problems on the LCD screen or PC user interface.

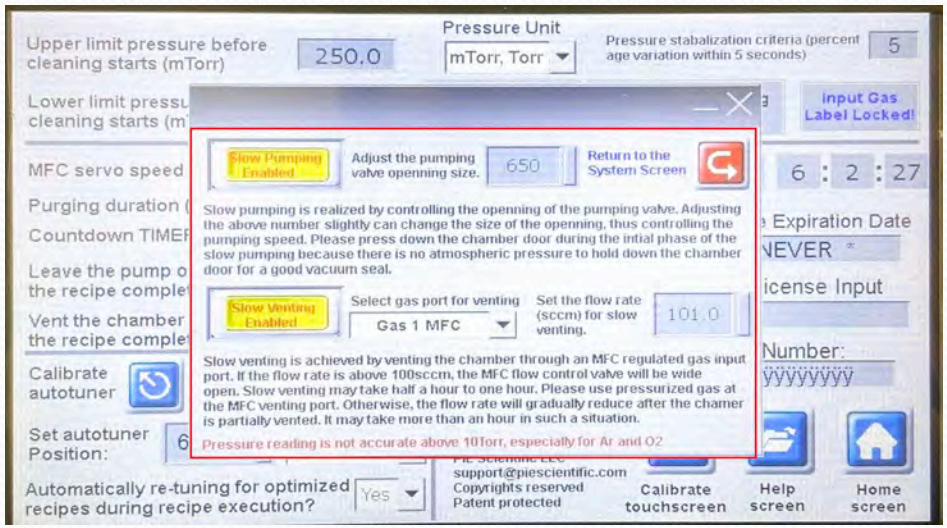
Supports total 20 recipes

#	Recipe Name	Mode Selection	Power (Watt)	Duty Ratio	Gas 1 (sccm)	Gas 2 (sccm)	Gas 3 (sccm)	Duration (M:S)	Purging Gas	Tuned? (Y/N)
1	Pure Argon	Immersion	150	255	3.0	0.0	0.0	2 : 0	No	Yes
2	Pure Oxygen	Immersion	150	255	0.0	2.0	0.0	2 : 0	No	Yes
3	Low power mix	Immersion	25	255	5.0	2.0	0.0	2 : 0	No	Yes
4	Medium pow. mix	Immersion	75	255	5.0	2.0	0.0	2 : 0	No	Yes
5	High pow. mix	Immersion	150	255	2.0	2.0	0.0	2 : 0	No	Yes
6	Remote mix MP	Remote	75	255	5.0	2.0	0.0	2 : 0	No	No
7	Remote MIX HP	Remote	150	255	20.0	3.0	0.0	2 : 0	No	No
8	Remote O2 HP	Remote	150	255	0.0	2.0	0.0	2 : 0	No	No
9	Remote Ar LP	Remote	25	255	10.0	0.0	0.0	2 : 0	No	No
10	Low power O2	Immersion	25	255	0.0	1.0	0.0	2 : 0	No	Yes

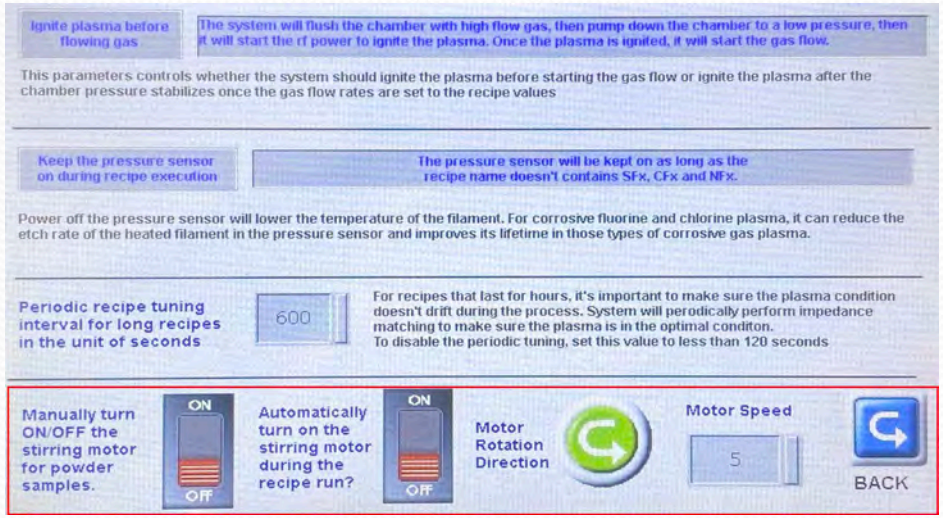
Recipe can be locked for production



Powder sample support



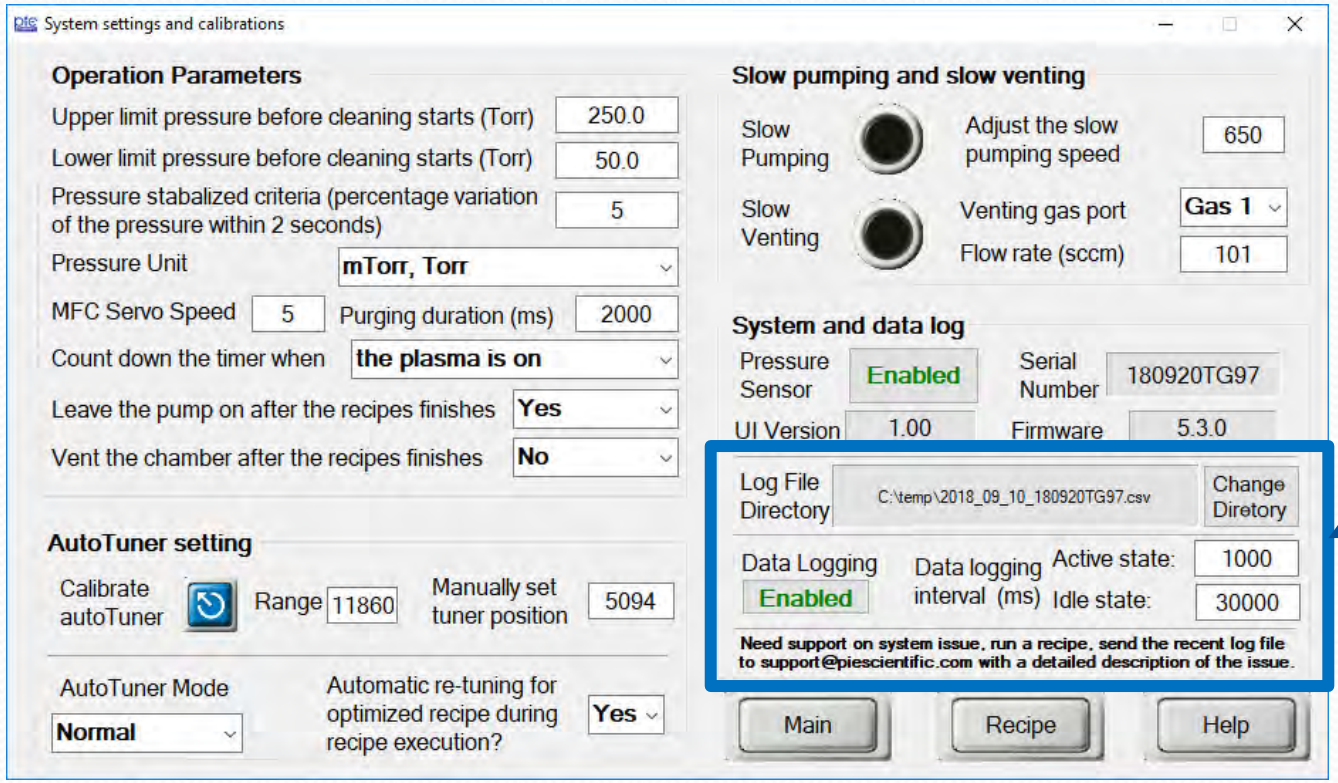
Slow pumping and slow venting features to prevent the powder and light samples from being blown away by strong air low during pumping and venting. Slow pumping and slow venting feature can be enabled in the touchscreen controller



Spare stepper motor driver to control an external stirring motor for powder samples, improve process uniformity for powder samples.

System log and run record

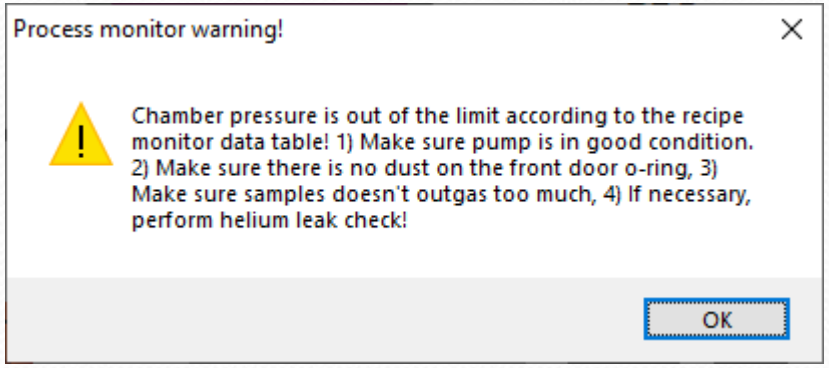
1. The capability to keep a run log is essential for some bio-medical, pharmaceutical and defense industries.
2. The PC control software provided by PIE Scientific LLC can save the system parameters and run logs in to a CSV file. The CSV file can be processed in excel.
3. PC communicates with Tergeo through an RS232 serial port. A regular USB port on PC can be easily converted to an RS232 port using an USB-RS232 converter. Then the user can simply connect the PC and Tergeo with a D-sub 9 cable.



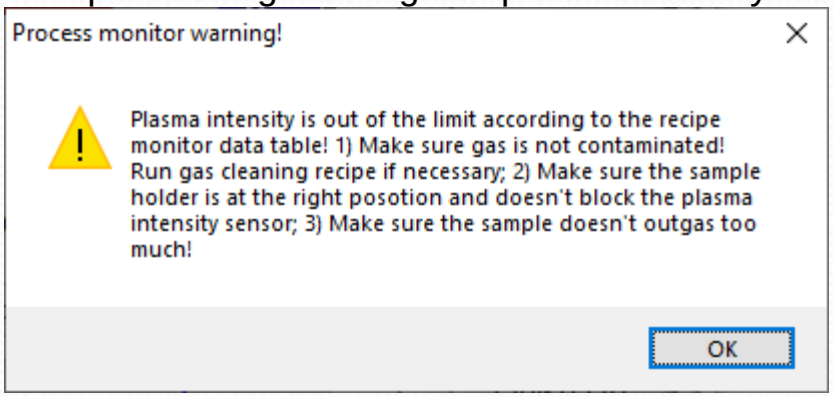
Process monitoring for production

- Monitor the process through the PC control software.
- Make sure the process is stable for day to day production.
- Alert the operator if the process drifts out of the upper and lower control limit.
- Alert can be set on rf power, chamber pressure, gas flow rate on each channel, plasma intensity reading.
- Process monitor limit can be set for each recipe.

Sample warning message on chamber pressure



Sample warning message on plasma intensity



How do we support customers all over the world?

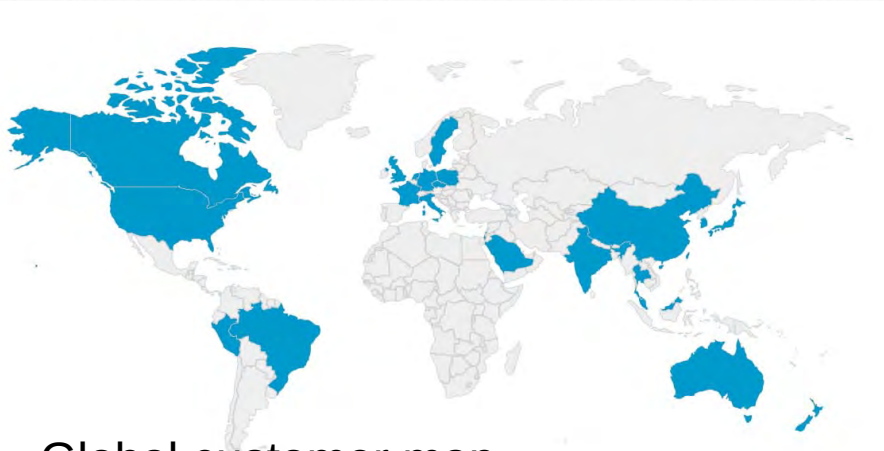
More than 70% of our sales are international export. Our customers cover North America (U.S.A and Canada), U.K., E.U (such as Germany, France, Sweden, Netherlands, etc.), Asia (Japan, S. Korea, China, Hong Kong, Taiwan, Singapore, Malaysia, Thailand, and India), Australia, New Zealand, and Israel. Reliability is the No.1 priority in our system design. Additionally, our system is designed to be easy to support globally. Here are several advanced features designed for easy to support and service.

1) Smart system self-diagnostics capability. The system constantly monitors the status of each sub-components. If it detects an issue, it will display a message on the LCD touchscreen display and prompt user what to do.

2) Remote control of the Tergeo plasma system from our U.S. headquarter. Tergeo system can be operated from an external computer. We can log onto the computer at the customer site from the United States to operate the machine and figure out any issues. Skype is one of the remote access platforms.

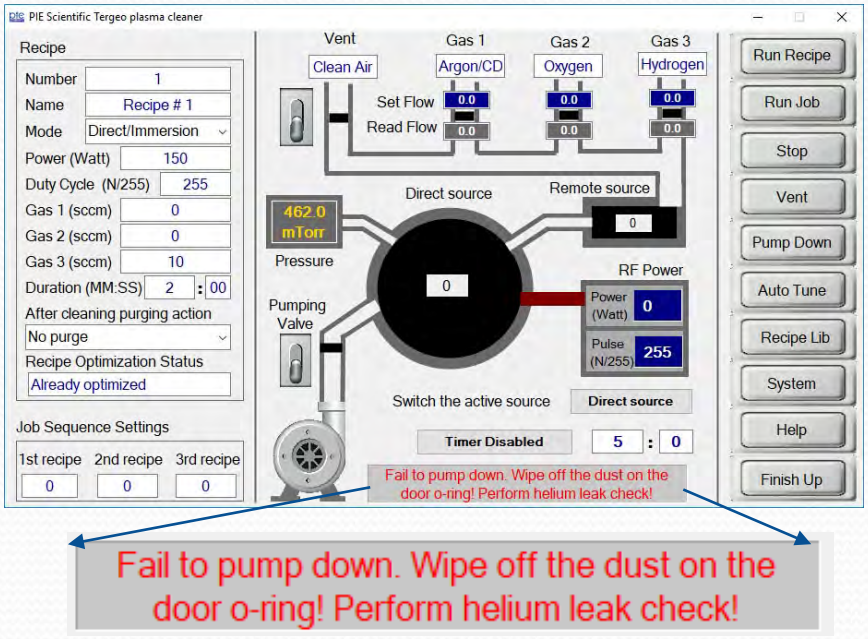
3) PC control software for Tergeo keeps a system status log. The customer can just send us the log file for us to figure out any system issue.

4) Remote video support through Skype or Facetime. We can view the LCD touchscreen of the Tergeo system and figure out any issue. We can also guide the user to service and repair the system through remote video support.



Global customer map

Smart system self-diagnostics

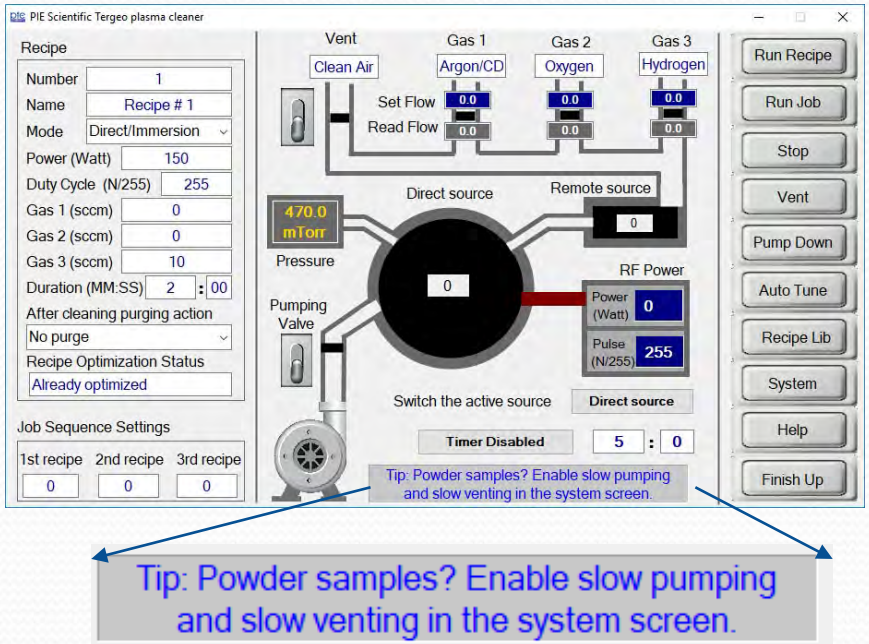


Fail to pump down. Wipe off the dust on the door o-ring! Perform helium leak check!

System self-diagnostics:

The system constantly monitors the status of each sub-components. Once it detects an issue, it will display a message on the LCD touchscreen display and prompt user what to do.

For example: one of the previously most reported issue from our customer is the dust particles on the door o-ring that cause vacuum leak. It can be easily resolved by wiping off the dust with a lint free wipe. The MKS pressure sensor used in Tergeo is sensitive to helium gas. Spraying helium gas around the vacuum joint can detect the leak point.



Tip: Powder samples? Enable slow pumping and slow venting in the system screen.

System operation guide:

When the system is in the idle state, the status display window will cycle through pre-stored tip messages and help the user to get familiar with the system faster.

System can also detect how the system is being operated (such as manual mode or recipe mode). It will provide suggestion on how to operate the system in the optimal method based on how the system is being used by the operator.

Remote support methods

Method 1: remotely access the machine from the U.S. headquarter in the Silicon Valley

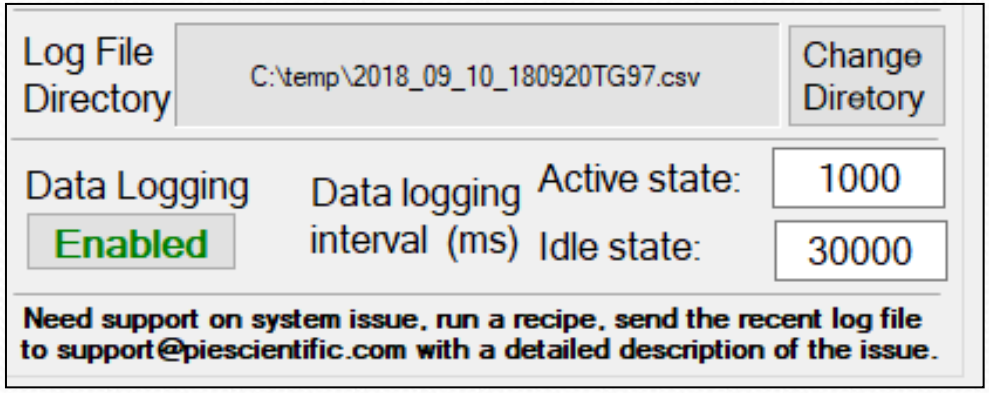
Customer site: Control the Tergeo with a PC

U.S. headquarter: remotely control the Tergeo through skype or Teamviewer remote screen sharing.

Method 2: remote video support through Skype or Facetime

View the machine in real-time to guide the user to troubleshoot the issue.

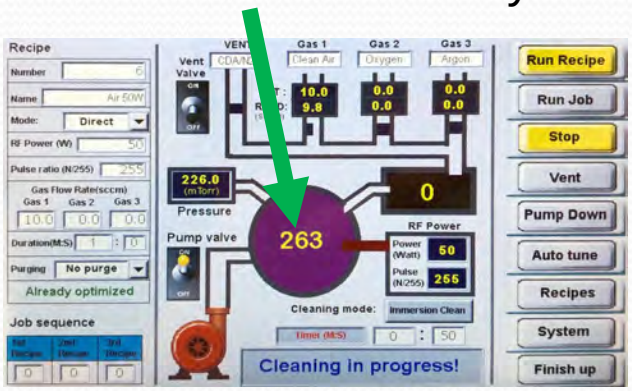
Method 3: Upload the data log file to the U.S. headquarter for analysis



Application guide

Photoresist ashing and descum

Plasma emission intensity reading

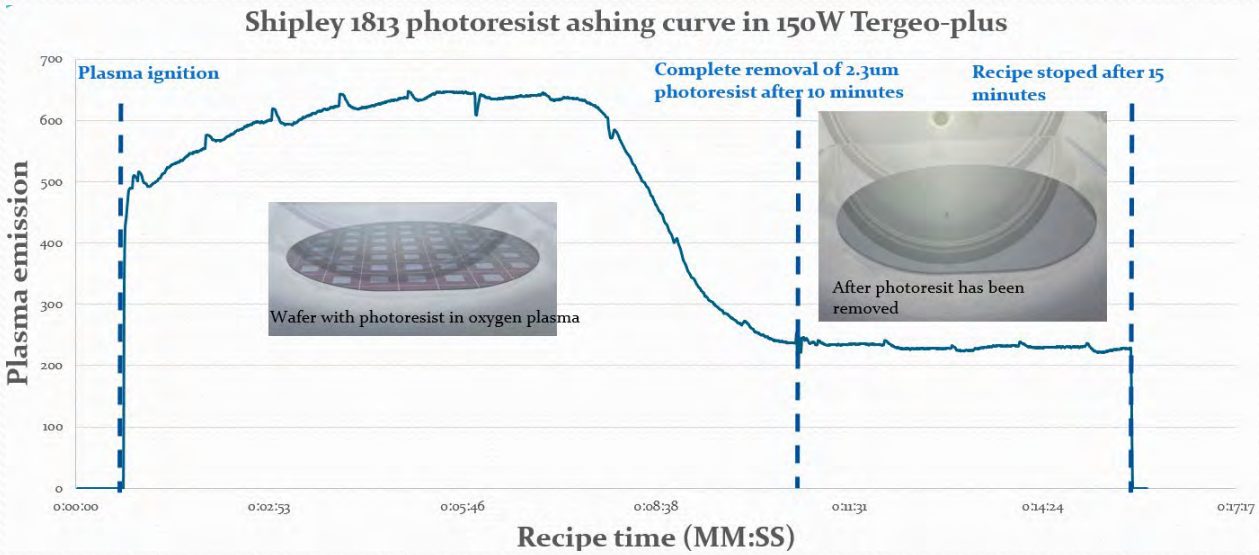


Oxygen plasma photoresist ashing speed.
Tergeo-plus, 150W rf power, 4-inch wafer, Shipley 1813 positive resist, cured

O2 flow rate (sccm)	3	5	5	10	20	30
Argon flow rate (sccm)	0	0	5	0	0	0
Chamber pressure (mTorr)	65	92	123	157	250	336
Plasma intensity reading	298	263	820	210	157	144
Etching speed (nm/min)	186.57	231.17	183.00	160.20	97.20	34.60

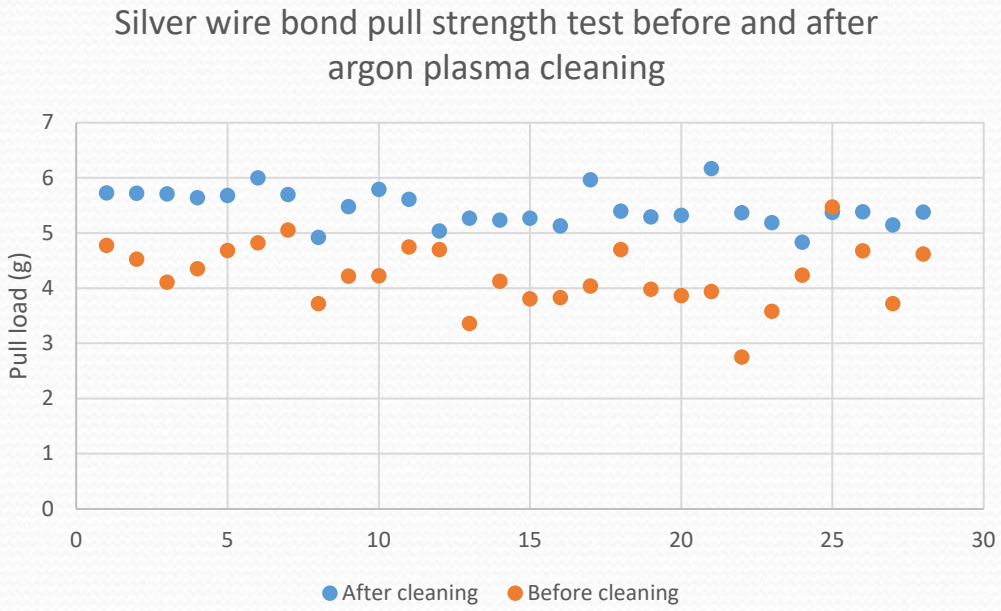
Gentle downstream/remote mode is available as an upgrade option

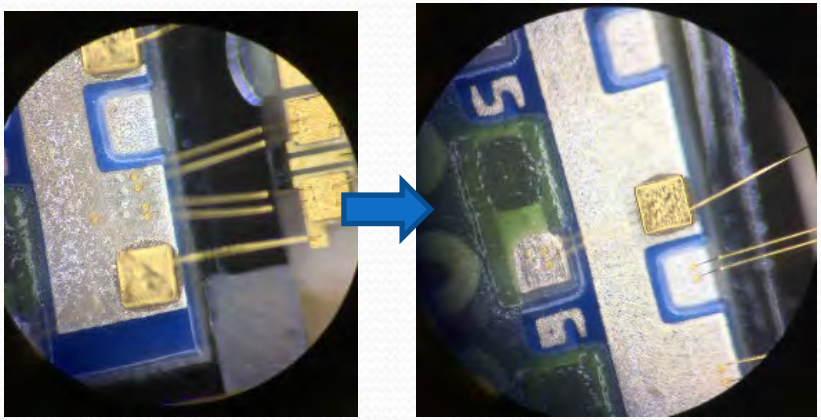
Tergeo plasma system can measure plasma emission light intensity. The plasma emission light can vary a lot with different gas species. During O_2 plasma photoresist ashing process, it can generate CO, CO_2, H_2O type byproduct, which can change the plasma emission intensity a lot. Therefore, it's possible to monitor the progress of the ashing process by monitoring the plasma emission intensity.



Wire bonding and flip-chip bonding in IC/MEMS packaging

Remove organic, oxide and fluoride surface contamination, render surface hydrophilic, improve bonding strength and packaging reliability





Tarnished silver pad looks dull before plasma cleaning. The pad looks significantly brighter and shinier after 3-minute argon plasma cleaning.

YouTube video compares chip packaging before and after argon plasma cleaning: https://www.youtube.com/watch?v=axQGydpqUAk

2-D materials research

Applications:

- Substrate cleaning before growing 2D materials.
- Plasma functionalization without damage the 2D materials using our unique downstream and pulsed plasma.
- 2D materials etching and removal.

Unique features on Tergeo for 2D materials research

1. Fast direct plasma etching mode and gentle downstream plasma cleaning mode in one system.
2. Continuous and pulsed plasma for high intensity and extremely weak plasma, wide dynamic range on the plasma intensity.
3. Direct/downstream and continuous/pulsed mode together can change the etching speed by more than 3 orders of magnitude.
4. Plasma emission intensity sensor for quantitative measurement and control of the plasma intensity.

PDMS and Glass bonding

Bond PDMS/Glass immediately, No need to cure the device in an oven

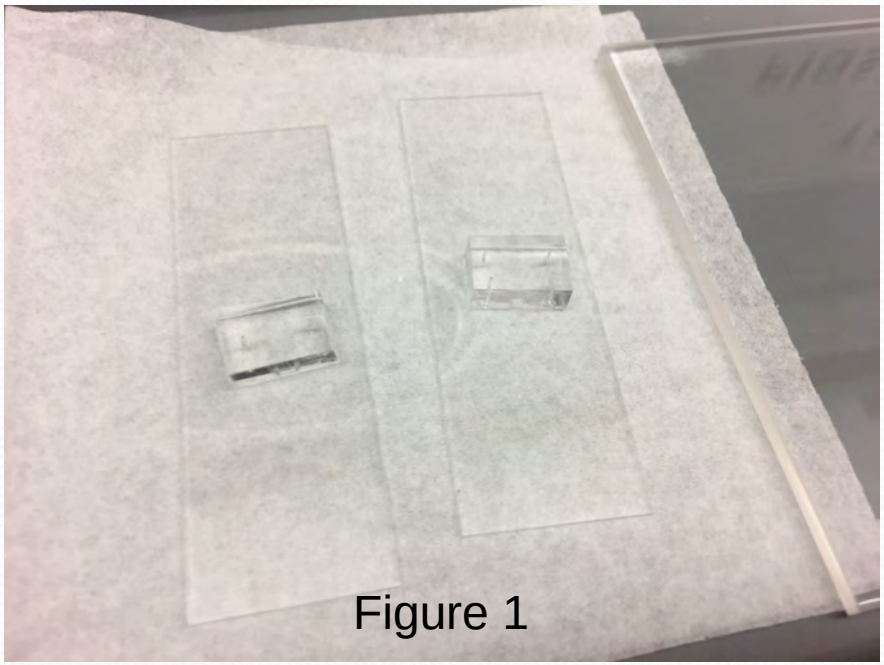


Figure 1

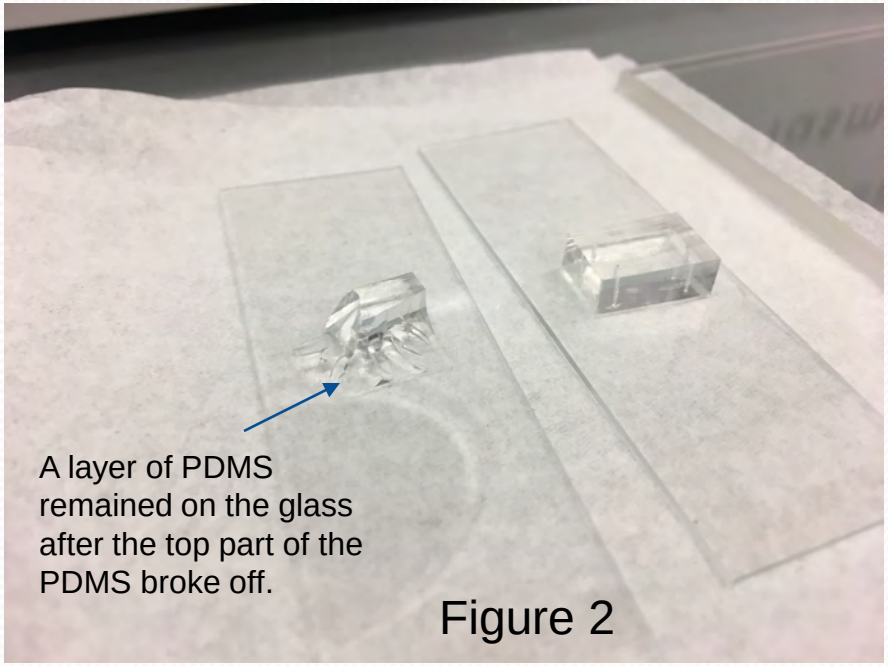


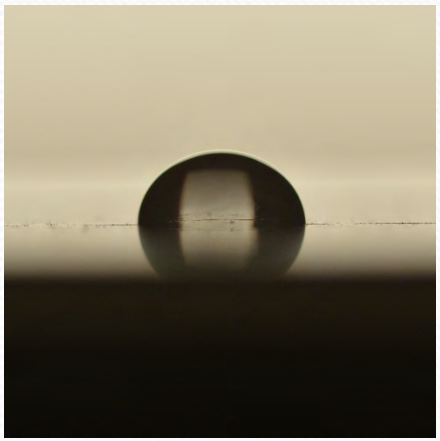
Figure 2

Figure 1, After plasma processing, PDMS bonds to glass immediately, trapped gas at the interface is automatically squeezed out. **No need to cure the PDMS/Glass bond in an oven for a couple of hours.**

Figure 2, One minute after bonding, the user tries to break the PDMS/Glass bond. The bond is so strong that the PDMS/Glass bonding interface remains intact even after the top part of the PDMS was pulled off.

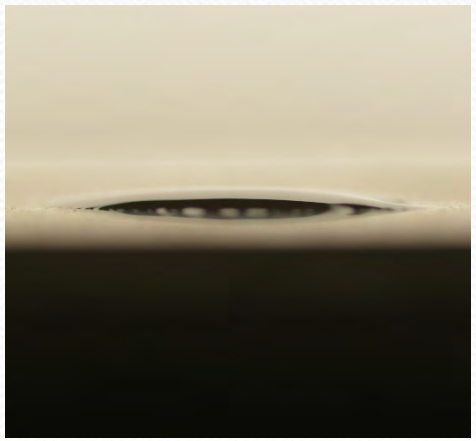
Surface activation for bio-polymer/plastic before coating

Typical process gas: room air (N2+O2), pure O2, argon, or argon+O2
Processing time: 20 seconds to 5 minutes

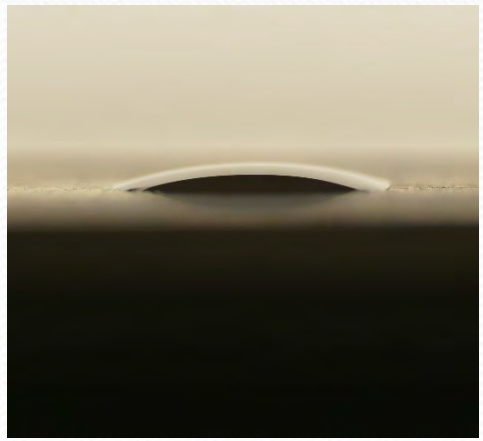


Before cleaning,
Water contact angle >80^{o}

Right after 50W, 60s plasma cleaning.
Water contact angle is too low to be measured.



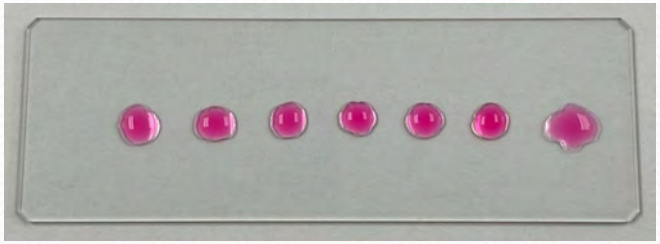
3 hours after plasma cleaning.
Water contact angle =12^{o}



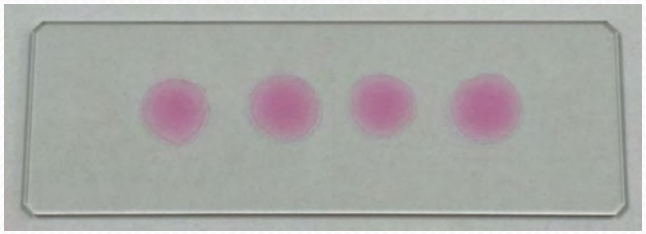
63 hours after plasma cleaning.
Water contact angle =21^{o}

Glass, wafer, and well plate cleaning

Glass slides

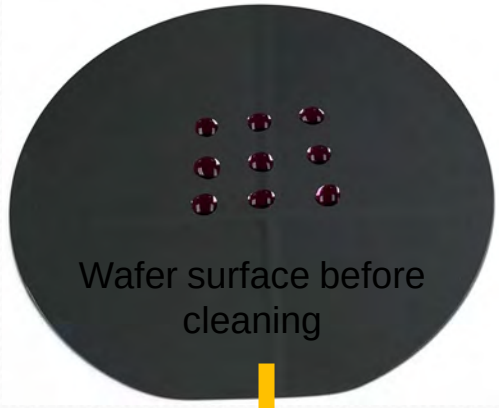


Glass slide surface before cleaning

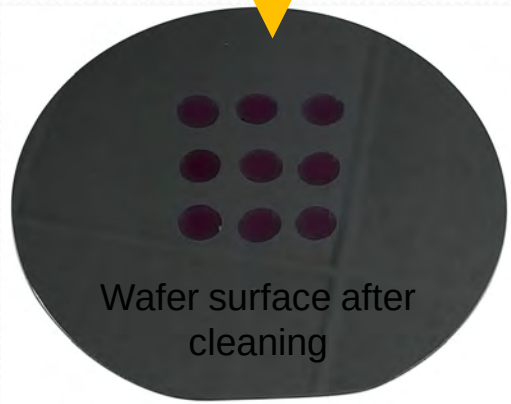


Glass slide surface after cleaning

Wafer



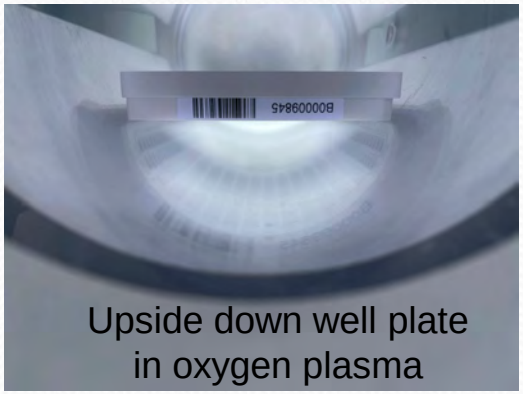
Wafer surface before cleaning



Wafer surface after cleaning

Well plate

Well plate in ambient air plasma on a quartz holder

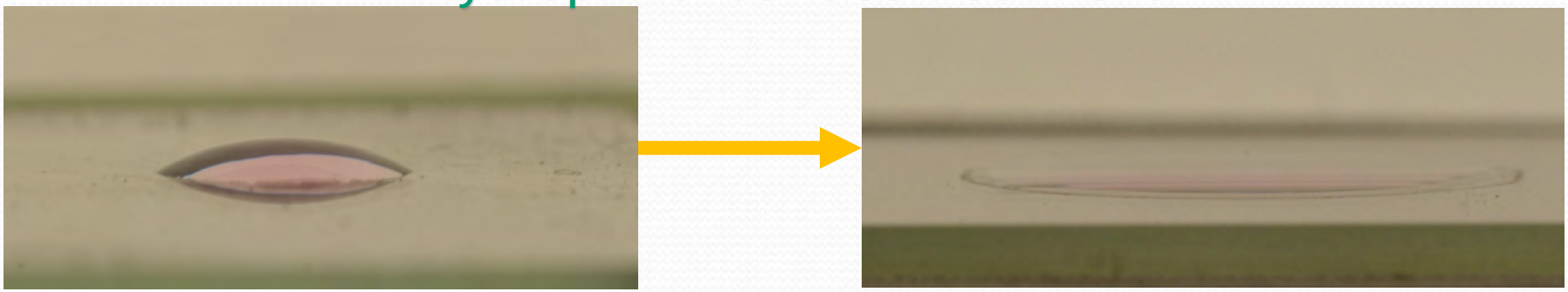


Upside down well plate in oxygen plasma

Activate surface and remove organic contamination.

Rendering the glass slides to super hydrophilic, then to strongly hydrophobic

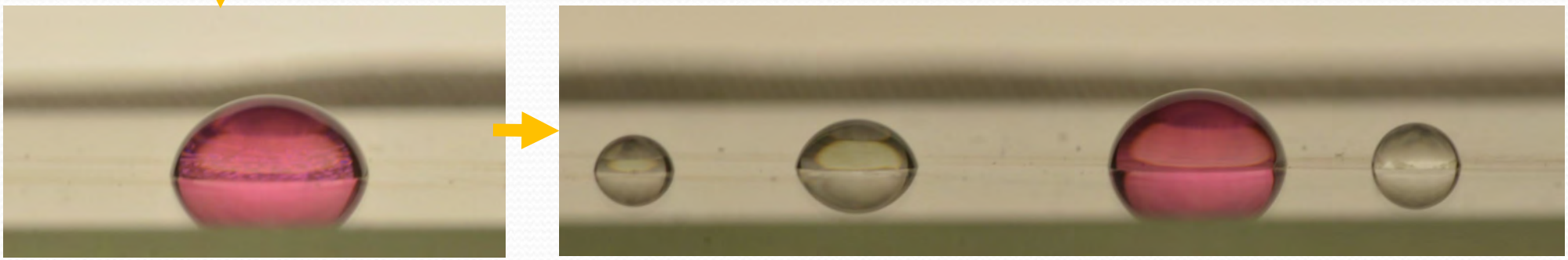
Hydrophilic surface treatment



Original glass slides

Right after 1-minute air plasma treatment

Hydrophobic surface treatment

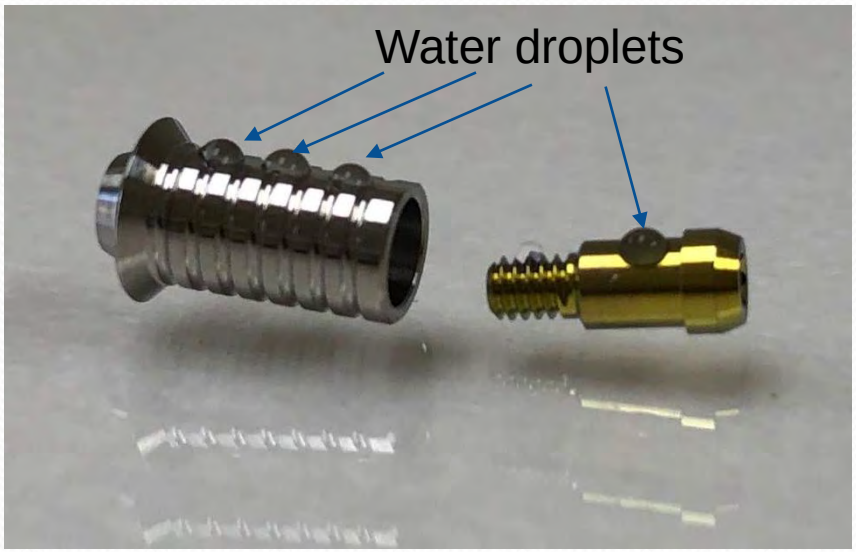


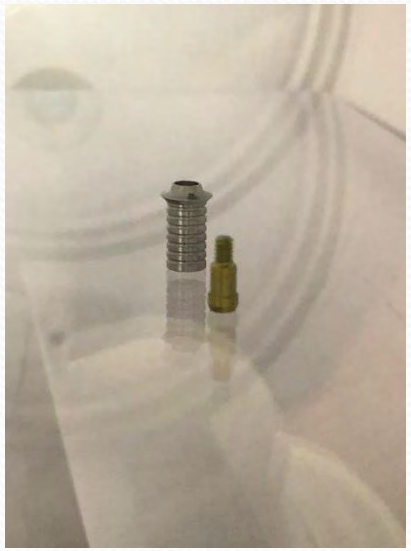
Right after proprietary hydrophobic plasma surface treatment

15 hours after hydrophobic surface treatment

Medical implant cleaning and activation

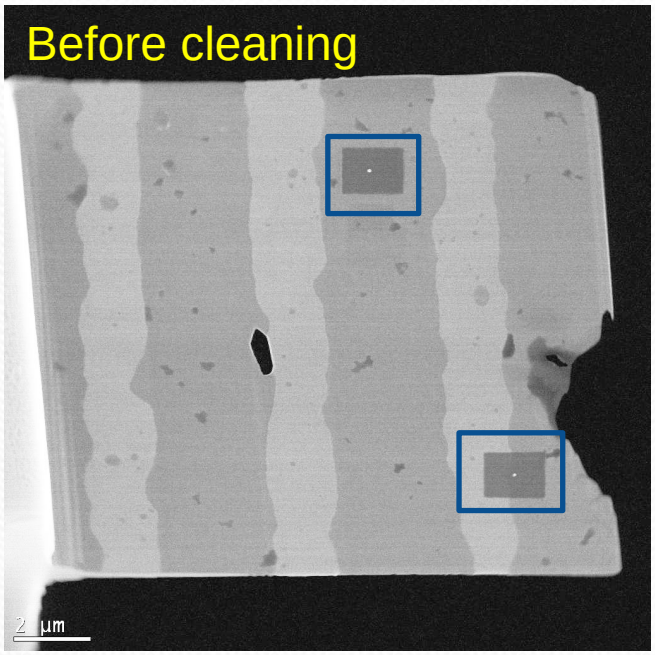
Dental implants before plasma processing

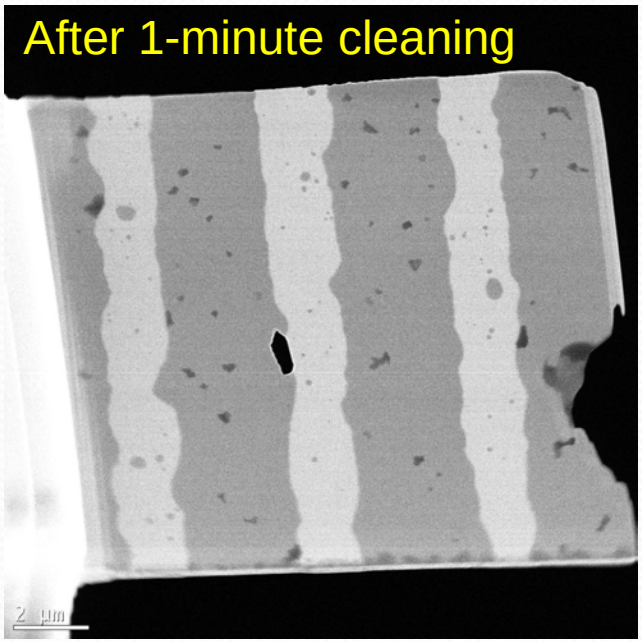


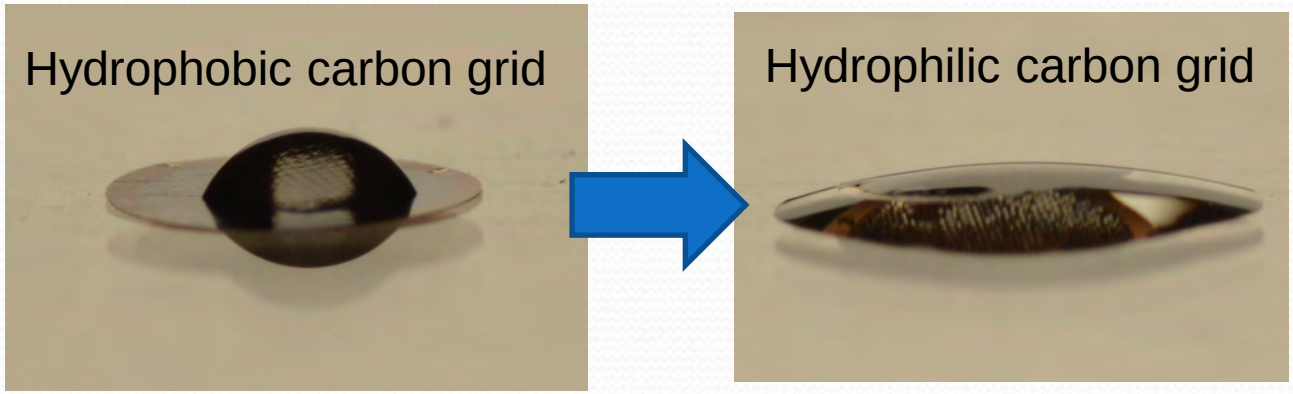


Video showing the water contact angle before and after the pure O2 plasma processing:
Before plasm processing:
https://www.piescientific.com/Customer_demo_results/Medical_Implant/75W_pure_oxygen/Before.MOV
After argon plasma processing:
https://www.piescientific.com/Customer_demo_results/Medical_Implant/75W_pure_oxygen/After.MOV

SEM/TEM sample cleaning



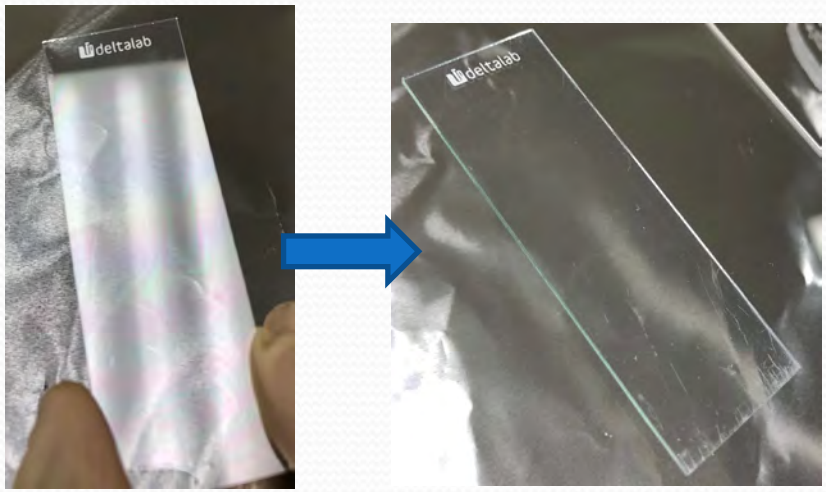




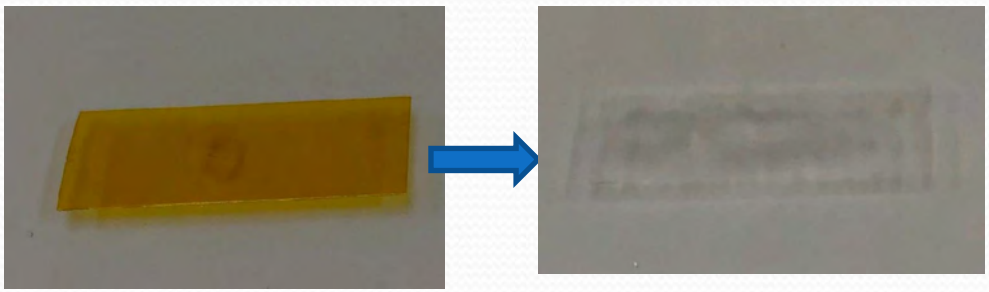
Decapsulation for SEM failure analysis

1. Remove parylene conformal coating in PCB failure analysis with oxygen plasma
2. Remove polyimide capping layer with oxygen
3. Remove nitride and oxygen capping layer with CF4+O2 plasma

Remove 5um parylene coating on a glass slide sample in 20 minutes

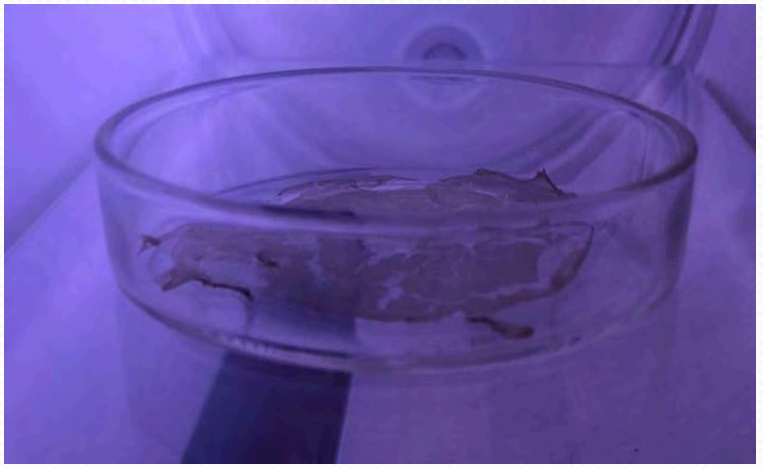


Kapton tape (1 mil (25um) polyimide film over 3 mil silicone adhesive)
25um polyimide film is mostly remove after 3-4 hours of oxygen plasma. Only the silicone adhesive layer remained.

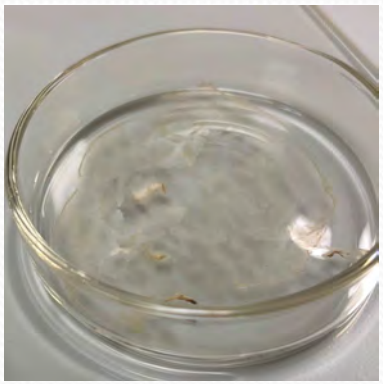


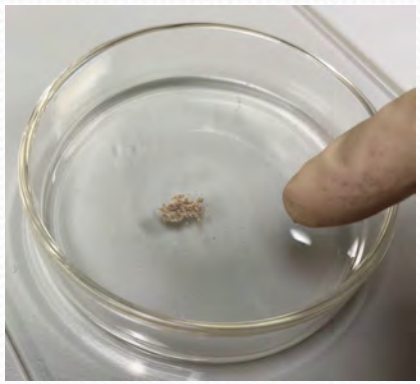
Plasma ashing to remove organic materials

Paper in Ar+O2 plasma



After 10 hours of plasma ashing





Only inorganic matters are left for analysis

Remove organic materials to reveal the inorganic matters. For example, analyzing asbestos in paint, content of the inorganic matters in coal powder.

- The change of the plasma color is due to the change of the ashing by-products COx and H2O. Our unique plasma intensity sensor reading can pick up the change of the plasma emission.
- Slow venting option to prevent the ash powder from being blown away during venting.