Specialty Lubrication Solutions
for the Semiconductor Industry

LUBRICANTS.
TECHNOLOGY.
PEOPLE.

FUCHS

MOVING YOUR WORLD

MOVING YOUR WORLD
by striving for perfection and unconditional reliability

The semiconductor industry plays a pivotal role in modern technology. The increased demand for semiconductor products such as microprocessors, memory chips and flat panel displays has been driven by the emergence of next-generation technologies including 5G, Internet of Things (IoT), artificial intelligence (AI), electrified vehicles, connected medical devices, industrial robots, and many more. These technically sophisticated applications often call for faster processing speeds and lower power consumption, requiring more complex fabrication processes. Fabrication precision is now down to sub 10-nanometer level for many processes, meaning even the smallest contaminants can result in product defects and yield loss. These systems must operate reliably to meet demands.

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Lubricants for Semiconductor Manufacturing

Maintenance and downtime are expensive. Suppliers must carefully consider all materials selected to ensure they maximize performance without introducing new sources of potential contamination. Lubricant outgassing and particle generation can contaminate fab equipment and products, negatively impacting product quality and yields. Specialty, low outgassing vacuum lubricants must be selected to improve the performance and reliability of components in fabrication and processing equipment, improve line yields, avoid latent defects, and increase uptime.

Components Lubricated

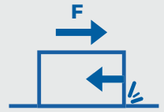
LINEAR GUIDES

BEARINGS

BALL & LEAD SCREWS

GEARS & ACTUATORS

Lubrication Advantages



REDUCE FRICTION & WEAR

EXTEND COMPONENT LIFE

PREVENT CONTAMINATION

WITHSTAND VACUUM CONDITIONS

Improved High-Temperature Performance

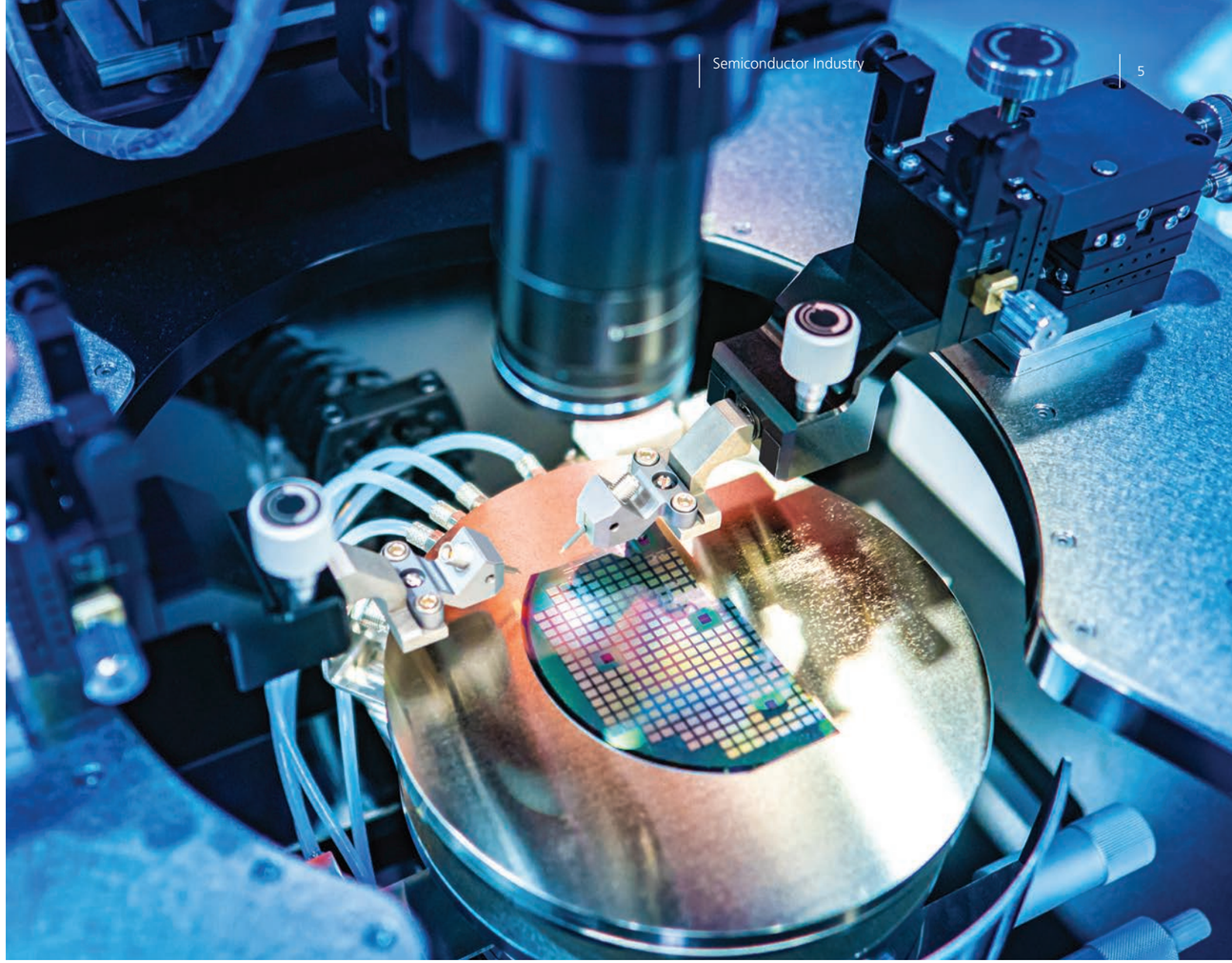
A lubricant must be able to protect the mechanical components of fab equipment at high temperatures without evaporating. Outgassing is more likely to happen at high temperatures as vapor pressure increases. Many of our in-vacuum and cleanroom lubricants are formulated to perform at temperatures up to 250 °C.

Lubricant Cleanliness Levels

Manufacturing equipment in vacuum and cleanroom environments are highly sensitive, where even microscopic particulates can cause friction and positioning errors. The best way to ensure lubricant cleanliness is through ultrafiltration to reduce microscopic particulates in a lubricant. We can ultrafilter grease and oil to reduce possible contaminants for semiconductor applications.

PFAS / PFOA Conscious

All of our products for semiconductor manufacturing equipment use PTFE with levels of PFOA less than 0.1% by weight, in compliance with current REACH and other international regulations. Although this work is not a measurement of each product's complete formulation, analysis indicates PTFE would be the most significant contributor to PFOA-levels. The regulatory environment around perfluorinated alkyl substances (PFAS) remains uncertain, but our R&D team is conducting leading research into the development of PFAS-free solutions for the semiconductor industry, ensuring that we will be prepared in the event of more stringent regulations.



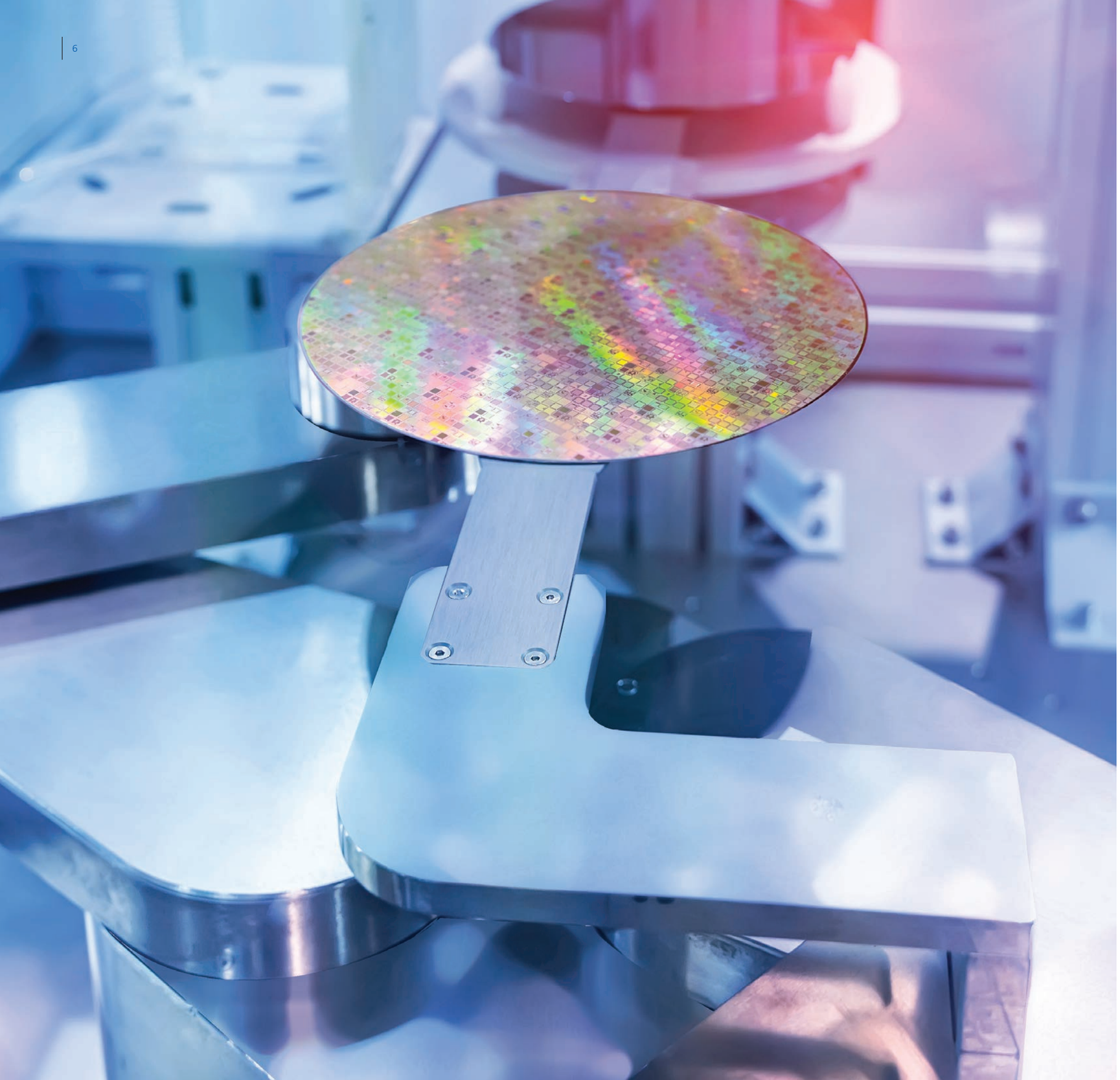
Reduce Outgassing

Outgassing is akin to evaporation; it is the release of small fractional molecules from a bulk liquid or solid material. Evaporation losses accelerate when operating in vacuum and compromise a lubricant's integrity over time. Low outgassing lubricants have a lower material loss to ensure longer-lasting lubrication.

Outgassed molecules can also condense on surfaces and contaminate wafers, processing equipment, and other sensitive components. Lubricant outgassing is measured in total mass loss (TML) and collected volatile condensable materials (CVCM) per ASTM E595. Our lubricants are tested to this standard to meet the stringent outgassing limits determined by the semicon industry.

Reduce Particle Generation

Dynamic particle generation happens when contaminants are created by being forced or expelled from a lubricated ball-screw, bearing, or gear system into the operating environment. These contaminants could include base oil constituents, thickener particles, additives, etc. and are freed from the grease through rolling, sliding, or a combination of both. Our proprietary test method and apparatus allows us to measure particle generation under these dynamic conditions.



CASE STUDY

PFOA-Compliant Grease for Semiconductor Manufacturing Bearings

Challenge

New environmental regulations surrounding perfluorooctanoic acid (PFOA) have led many engineers and manufacturers to reconsider the materials they source in every aspect of their design. We were approached by a leader in the production of state-of-the-art vacuum robots that are designed specifically for tool automation in semiconductor wafer processing and other complex manufacturing environments. The customer needed to replace a grease that was discontinued by the manufacturer due to their inability to meet REACH-PFOA requirements. They needed a compliant vacuum grease that would promote long bearing life and reduce downtime costs. The grease had to meet a 10 million cycle life requirement under vacuum, high load, and high temperature conditions.

Solution

A new product, NYECLEAN® 5057, was formulated for this customer. This fluorinated grease complies with REACH PFOA regulations while exhibiting minimal outgassing, particle generation, and vapor pressure in a vacuum environment. NYECLEAN® 5057 has a very high temperature serviceability up to 250 °C and reduces friction and wear to extend bearing life.

Results

We provided the customer with validation data and on-demand technical support throughout the entire qualification process to prove that NYECLEAN® 5057 performed as well or better than the discontinued competitor's product, with the additional benefit of NYECLEAN® 5057 being PFOA-compliant. After providing outgassing, vacuum stability, vapor pressure, and other test data and continuing to perform well as it quickly approaches the 10 million cycle target, NYECLEAN® 5057 was chosen as the customer's replacement grease. The grease has since generated interest from several bearing, linear guide, and ball screw/lead screw manufacturers, including those who supply the automotive and medical industries. As REACH requirements continue to evolve, FUCHS is continuing to lead the industry by developing new, cutting-edge, sustainable solutions.

Lubricants for Semiconductor Robotic Systems

Semiconductor manufacturing foundry and fabrication facilities utilize a multitude of robotic systems to both transport wafers throughout the plant and to position and transfer wafers within semiconductor wafer manufacturing equipment. These robots typically require high speed motion to ensure maximum productivity and require extremely precise, highly repeatable wafer placement to reduce defects and ensure product consistency throughout each step of the manufacturing process.

Bearings and Gears

To meet such stringent precision requirements, lubricants for bearings and gears in semiconductor manufacturing equipment must prevent wear, offer long-life lubrication and minimize friction torque. These lubricants must meet cleanliness requirements, resist corrosion in environments that contain aggressive process gasses or chemicals, and maintain their consistency in service with minimum dynamic particle generation. Lubricants must be formulated to ensure the appropriate film thickness to reduce friction between moving parts and prevent wear and component seizure. Under vacuum process conditions, gears and bearings can be exposed to ultra-high vacuum, high temperatures, harsh chemicals, and corrosive and oxidative gases. This environment requires lubricants with low outgassing and low dynamic particle generation, chemical inertness, long life, and excellent wear resistance.

PFPE lubricants: NYECLEAN 5057 & 5097R and NYETORR 5300, 5300XP, 6300 & 6300S
MAC lubricants: NYETORR 5200, 6200 and 6200-FL

Linear Guides, Slides, Ball Screws/Lead Screws

Semiconductor automation, robotic and wafer positioning systems use linear guides, slides and ball screws/lead screws to enable highly precise movements. Lubricants are essential to help reduce friction and wear in a linear guide system and to maintain running accuracy and repeatability. Lubricants must also exhibit excellent vacuum stability, chemical-resistance within vacuum processing and cleanroom environments, and outstanding “stick-slip” performance.

PFPE lubricants: NYETORR 5300XP, 5350
MAC lubricants: NYETORR 5200, 6200, and 6200-FL

Valves

High-performance valves control the flow rate and pressure of fluids and must offer reliable, fast, and accurate control which requires the use of high-performance lubricants. Greases for lubricating valves are similar to those used for lubricating gears and bearings, with the additional requirement to remain in place under high differential pressures which may require a stiffer consistency formulation.

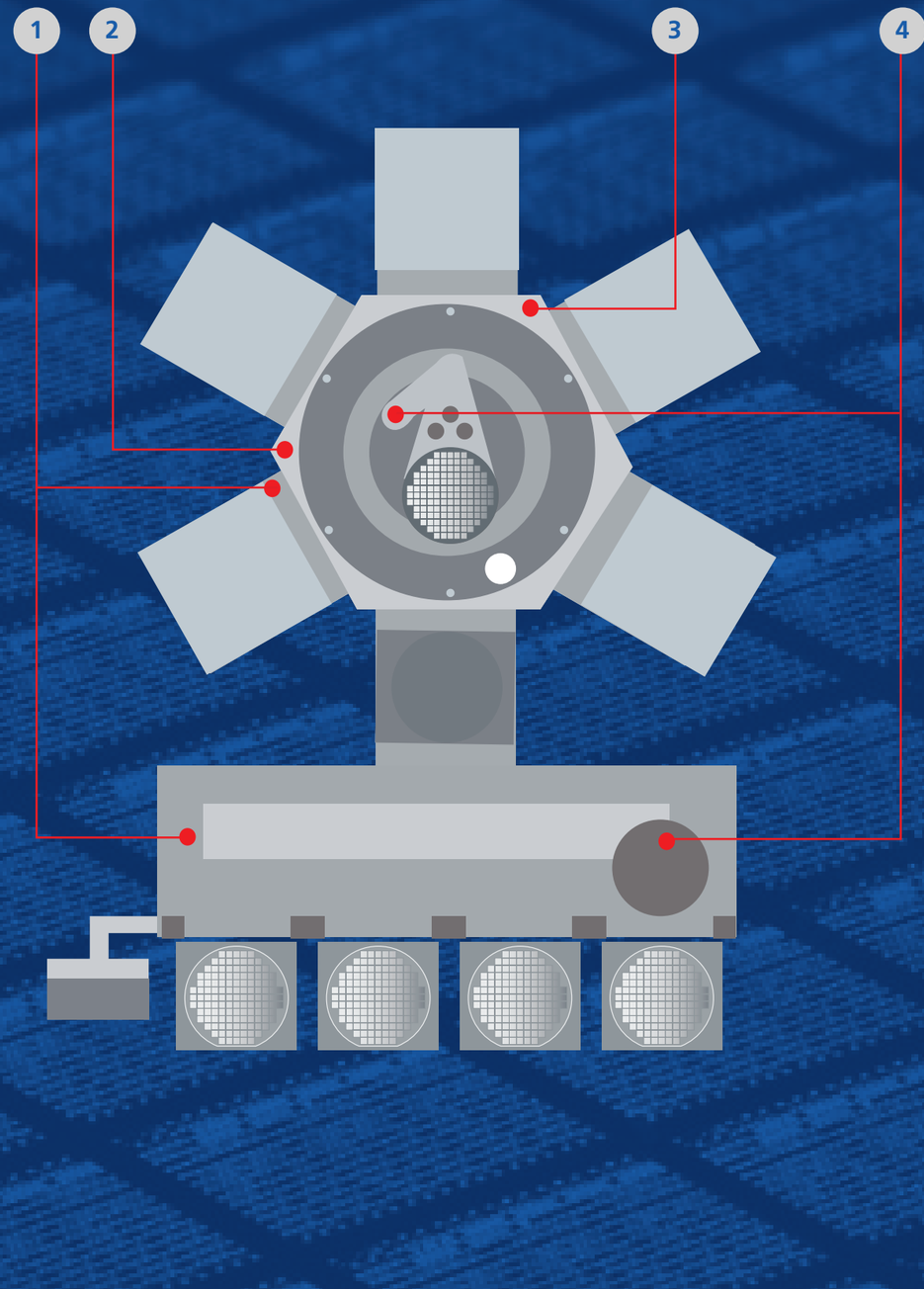
PFPE lubricants: NYETORR 5300 & 6300
MAC lubricants: NYETORR 5200 & 6200

O-rings and Seals

O-rings and seals play an important role in maintaining ultra-high vacuum in process tools and containing chemistries and gases within varying environments. O-rings and seal failure can cause a loss of vacuum and result in significant safety concerns and costly impacts to the manufacturing process. Properly selected lubricants can improve the performance of these components and extend their service life by minimizing friction and wear. The lubricants must exhibit low outgassing and low particle generation, chemical inertness, resistance to solvents, high thermal stability, low friction, low oil separation, and good stability. Lubricants must also be compatible with the synthetic elastomeric polymers such as fluoropolymer elastomers, which are most often used to make O-rings and seals.

PFPE lubricants: NYETORR 5300, 6300 and 5381

1. Linear Slides / Rails & Ball Screws
2. Gaskets / O-Rings
3. Vacuum Feedthroughs / Vacuum Pumps
4. Wafer Transfer Robot Bearings



Testing Capabilities

Our semicon lubricants are tested and validated for their performance in our state-of-the-art laboratory dedicated to in-vacuum testing. In this laboratory lubricants can be tested under simulated environmental operating conditions (i.e., vacuum, extreme temperatures) and provide our customers with performance data that helps them understand how our lubricants will perform in their application. Ultimately, this service helps our customer make the most informed lubricant choice.

Friction & Wear

SRV Tribometer

The SRV (Oscillating, Friction & Wear) test rig can run custom tests with options that include: rotational and linear oscillatory motion, tests up to 2,000 N load, 2,000 RPM, and a maximum temperature of 180 °C. Specimens include ball on disc, pin on disc, cylinder on disc, and custom geometries.

Mini Traction Machine (MTM)

The Mini Traction Machine (Figure 2) measures friction in a mixture of rolling/sliding contacts to simulate applications like rolling element bearings and gears. The MTM allows for the speed element to be a combination of sliding and rolling speed to produce the entrainment speed. The MTM provides a very good testing method for scuffing and galling of metal surfaces by allowing for the ball and disc to be driven in different directions (contrarotation). This produces a tribological test that can operate with high sliding / rolling speeds and low entrainment speed.

Relative Life

Spiral Orbit Tribometer

Originally developed by NASA to evaluate space applications, the Spiral Orbit Tribometer (SOT) produces relative lifetime calculations based on the number of orbits made below a friction level which is normalized to the amount of lubricant on the ball bearing. The testing (Figure 1) is done in ultra-high vacuum and simulates a thrust bearing. The results indicate the lubricant consumption, degradation, and life.

Vacuum Bearing Test Rig

Data from the Vacuum Bearing Test rig can determine the life expectancy of our lubricants test in angular contact bearings in high vacuum environments. This rig can support customer supplied bearings to simulate how a lubricant will perform in a specific application, under certain test conditions. Our high vacuum test can assess performance at temperatures up to 200 °C and determine mass loss under specific operating conditions. The rig also uses electrical resistance across the bearing to determine which lubrication regime (boundary, mixed or elasto-hydrodynamic) our products qualify under, given the test parameters.

Cleanliness

Particle Generation

The Dynamic Particle Generator is used to classify lubricant particle generation into ISO levels. It utilizes an ISO 3 clean air system, precision ball screw, and particle counter to characterize the number of particles down to 0.1 micron produced by various greases as the test is run.

Outgassing

Outgassing testing (per ASTM E595 Vacuum Stability) screens materials for volatile contamination. This test provides percent Total Mass Loss (TML) and percent Collected Volatile Condensable Materials (CVCM) data for our lubricants. Additionally, under specialized circumstances, Residual Gas Analysis can be used in parallel with E595 in an effort to identify the species being volatilized during the standard E595 test.

Vapor Pressure

The Knudsen method is used to determine a lubricant's vapor pressure (VP) and requires a very small sample, reducing testing costs and efficiency. The sample is placed in a small, capped cell with an orifice in the cap of known diameter. The cell is then placed in one of the vacuum chambers, at a desired temperature and duration. The mass loss from the lubricant is factored into the Knudsen equation, along with the other known variables of temperature and time, to calculate the Knudsen VP of that material at that temperature.

Figure 1: Spiral Orbit Tribometer

Figure 2: Mini Traction Machine

Synthetic Oil & Greases for Semicon Manufacturing Components

PFPE vs MAC Lubricants

Both PFPE and MAC lubricants offer low vapor pressure and low outgassing. PFPE lubricants offer better high temperature performance (up to 250° C) when compared to MAC lubricants (up to 150° C). Because of their unique additive packages, MAC lubricants provide better protection against wear when compared to PFPE lubricants. Both chemistries can be ultrafiltered, are compatible with plastics and elastomers, and comply with PFOA regulations.

NYETORR® vs NYECLEAN®

Our NYETORR® and NYECLEAN® products are chemically stable, non-toxic, low-vapor-pressure, synthetic lubricants for semiconductor components like bearings, linear guides, ball screws, and other sensitive mechanisms.

NYETORR®
Recommended for use in ultra-high vacuum applications exposed to high temperatures.

NYECLEAN®
Recommended for use in cleanroom applications where little to no vacuum is present.

Oil for Vacuum & Cleanroom Applications

Product Name	Temperature Range (°C)	Base Oil Chemistry	Pour Point (°C)	Base Oil Viscosity ASTM D445 (cSt)			Evaporation CTM-2 (24 h, 100 °C) (wt%)	Vacuum Stability ASTM E595 (125 °C, 7 x 10-3 Pa, 24 h)		Vapor Pressure Knudsen (25 °C) (Torr)	Density (g/cc)	SRV Coefficient of Friction & Ball Wear Scar ASTM D5707 (100N, 50Hz, 1mm stroke, 2 h, 40 °C)		Particulate Cleanliness Levels* IEST-STD-CC-1246D
				-40 °C	40 °C	100 °C		TML (wt%)	CVCM (wt%)			CoF	Ball Wear Scar (mm)	
NYETORR® 5201	-45 to 125	MAC	-55	80,500	108	15	0.00	0.12	0.013	4.50×10^{-11}	0.84	0.19	0.80	Level 100
NYETORR® 5301	-65 to 250	PFPE	-75	2,300	140	45	0.03 (200 °C)	0.23	0.033	6.00×10^{-11}	1.80	TBD	TBD	Level 50
NYETORR® 5361	-50 to 250	PFPE	-53	TBD	192	35	0.00	0.03	0.010	8.18×10^{-11}	1.89	0.14	0.53	Level 50
NYETORR® 5381	-40 to 250	PFPE	-30	52,806 (-10 °C)	809	72	0.01	0.07	0.004	3.00×10^{-14}	1.91	0.10	0.54	Level 50
NYETORR® 6201	-45 to 150	MAC	-55	80,500	108	15	0.00	0.11	0.010	6.91×10^{-11}	0.84	0.18	0.80	Level 50
NYETORR® 6301	-75 to 250	PFPE	-80	5,818	187	56	0.00	0.00	0.002	2.79×10^{-12}	1.83	0.08	0.84	Level 25
NYETORR® 6371	-65 to 250	PFPE	-69	TBD	446	126	0.02	0.02	0.002	4.02×10^{-13}	1.83	0.10	0.66	Level 25

Grease for Vacuum & Cleanroom Applications

Product Name	Temperature Range (°C)	Base Oil Chemistry	Base Oil Viscosity ASTM D445 (cSt)			Thickener Type	NLGI Grade ASTM D217	Oil Separation ASTM D6184 (24 h, 100 °C) (wt%)	Evaporation CTM-1 (24 h, 100°C) (wt%)	Vacuum Stability ASTM E595 (125 °C, 7 x 10^{-3} Pa, 24 h)		Vapor Pressure Knudsen (25 °C) (Torr)	Density (g/cc)	SRV Coefficient of Friction & Ball Wear Scar ASTM D5707 (100N, 50Hz, 1mm stroke, 2 h, 40 °C)		Low Temperature Torque ASTM D1478 (g.cm, 25 °C)		Ultrafiltration Cleanliness Levels** (10-34 µm, particles/cc)	Dynamic Particle Generation	
			-40 °C	40 °C	100 °C					TML (wt%)	CVCM (wt%)			CoF	Ball Wear Scar (mm)	Starting	10-min run		1200 RPM	2400 RPM
NYETORR® 5200	-45 to 150	MAC	77,000	108	15	PTFE	1	2.8	0.00	0.068	0.007	5.32×10^{-11}	1.05	0.114	0.44	221	274	< 300	ISO 3.1	ISO 3.6
NYETORR® 5300	-65 to 250	PFPE	2,300	140	45	PTFE	1.5	5.8	0.02	0.320	0.045	1.17×10^{-11}	1.91	0.159	0.68	236	142	< 300	ISO 3.8	ISO 4.7
NYETORR® 5300XP	-65 to 200	PFPE	2,300	140	45	PTFE	2	3.1	0.06	0.075	0.018	6.85×10^{-11}	1.85	0.113	0.58	207	121	< 300	ISO 4.1	ISO 4.9
NYETORR® 5350	-55 to 250	PFPE	23,880	152	28	PTFE	2	5.6	0.00	0.757	0.415	4.47×10^{-09}	1.90	0.139	0.65	221	118	TBD	ISO 3.2	ISO 4.0
NYETORR® 6200	-45 to 150	MAC	77,000	108	15	PTFE	1	3.5	0.00	0.058	0.025	2.44×10^{-11}	1.05	0.120	0.46	207	263	< 300	ISO 3.6	ISO 4.3
NYETORR® 6200-FL	-45 to 150	MAC	77,000	108	15	PTFE	TBD	TBD	TBD	0.060	0.015	2.30×10^{-12}	TBD	0.135	0.56	TBD	TBD	<300	ISO 4.0	ISO 4.8
NYETORR® 6300	-65 to 250	PFPE	5,818	187	56	PTFE	2	4.8	0.02	0.036	0.006	2.79×10^{-12}	1.89	0.110	0.68	221	125	< 300	ISO 4.2	ISO 5.1
NYETORR® 6350EL	-80 to 250	PFPE	13,380	200	48	PTFE	2	6.3	0.06	0.060	0.008	5.76×10^{-12}	1.89	0.160	0.76	177	158	< 400	ISO 3.9	ISO 4.5
NYETORR® 6370EL	-90 to 250	PFPE	TBD	362	103	PTFE	2	4.7	0.00	0.060	0.001	6.43×10^{-12}	1.83	0.174	0.91	207	94	< 400	ISO 3.6	ISO 4.2
NYECLEAN™ 5057	-50 to 250	PFPE	TBD	192	35	PTFE	2	6.0	0.04	0.225	0.054	1.62×10^{-11}	1.90	0.151	0.61	177	105	< 250	ISO 3.9	ISO 4.4
NYECLEAN™ 5088	-10 to 250	PFPE	TBD	800	58	PTFE	2.5	1.6	0.00	0.390	0.022	3.48×10^{-12}	1.91	0.364	1.29	295	162	< 500	TBD	TBD
NYECLEAN™ 5097R	-60 to 180	PFPE	2,300	140	45	PTFE	1.5	6.9	0.17	0.441	0.044	5.47×10^{-11}	1.90	0.166	0.73	177	114	TBD	TBD	TBD

**Level 25 = 1 25µm particle max. Level 50 = 1 50µm particle max. Level 100 = 1 100µm particle max ** All greases exceed Mil-G-81937 - 10-34µm, < 1000 particles/cc.*

The typical properties shown on this document should not be used as a basis for preparing specifications.
CTM = Company Test Method

FUCHS Lubricants

Innovative lubricants need experienced application engineers

Every lubricant change should be preceded by expert consultation on the application in question. Only then the best lubricant system can be selected. Experienced FUCHS engineers will be glad to advise on products for the application in question and also on our full range of lubricants.

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