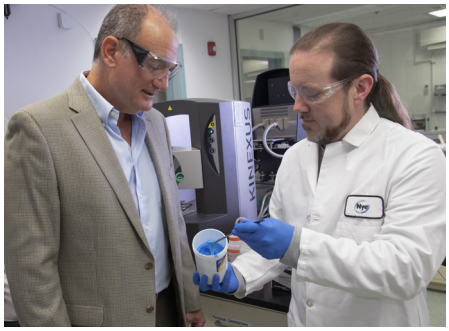
Since 1844

Nye® LubeLetter

July 2021

Lubrication

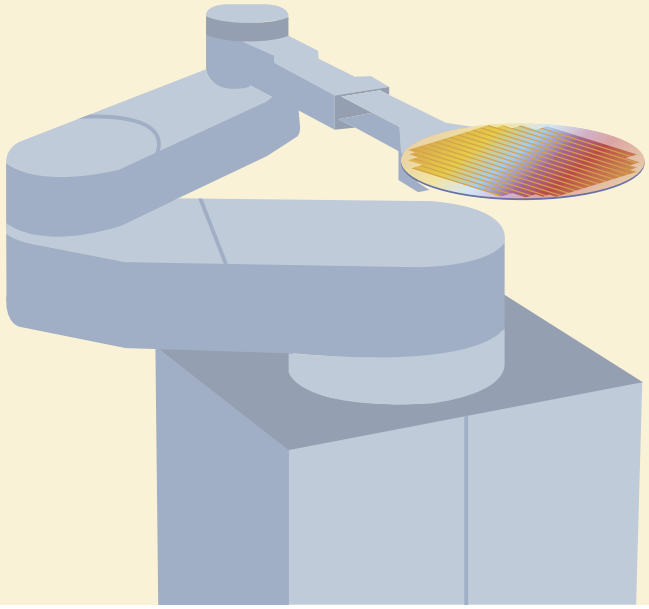
Collaboration



Innovation

Semiconductor

The semiconductor industry is booming. 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.



Lubricants are required to ensure the functionality of fabrication and processing equipment, but the wrong lubricant may result in unscheduled down time and contamination. Maintenance and downtime are expensive. Lubricants protect against friction and wear to extend component life and ensure that the systems operate reliably. Lubricant outgassing and particle generation can contaminate fab equipment and products, negatively impacting product quality and yields. To avoid these issues, it is critical to select high performance specialty greases with low outgassing and low particle generation properties.

Semiconductor manufacturing and processing equipment often operate at high temperatures and under vacuum, thus requiring high performance lubricants that will protect their linear guides and slides, bearings, ball and lead screws, and seals against wear.

Advantages of Semiconductor Greases and Oils

NyeTorr®, NyeClean® and NyeVac® are specialty lubricants formulated specifically for Semiconductor fabrication and processing equipment. These low outgassing semiconductor lubricants are chemically stable even when exposed to process gasses, making them the first choice of leading Semicon equipment OEMs and fabricators.

Features & Benefits:

- Reduce friction & wear
- Increase uptime
- Prevent contamination
- Withstand vacuum conditions
- Extend component life
- Improve yields
- Avoid latent defects
- Improve functionality & reliability

What Characteristics Should Be Considered When Selecting a Semicon Lubricant?

Low Outgassing

When a lubricant outgasses it releases condensable material that can 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. Nye's lubricants fall well below the acceptable outgassing limits determined by the semiconductor industry, 1% or less for TML and 0.10% or less for CVCM. Nye can collect these condensable materials and conduct Residual Gas Analysis (RGA) to identify the materials shed from the lubricant into a system.

Low Particle Generation

The term dynamic particle generation describes what 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 dynamic mechanical action whether it be rolling, sliding, or a combination of both. Engineers in Nye's Application Development and Validation Test Lab developed a proprietary test method and apparatus that measures and quantifies particle generation under these dynamic conditions. Results from this test provide valuable data that can be used to inform the development of specialty lubricants with low particle generation.

High Temperature Capability

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 Nye's 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 product failure. The best way to ensure lubricant cleanliness is through ultrafiltration to eliminate microscopic particulates in a lubricant. Nye can ultrafilter grease and oil to eliminate possible contaminants for semiconductor applications.

PFOA-Compliance

Nye Lubricants has investigated PFOA (perfluoro-octanoic acid) levels in all PTFE and PFPE currently used in our product formulations, as a thickener, additive or oil for greases. All Nye products for the Semiconductor Industry have less than 0.1% by weight of PFOA and its salts in compliance with REACH guidelines and other international regulations. Visit our Quality page to download Nye's PFOA statement.

Testing & Manufacturing

The materials and manufacturing methods used to prepare a lubricant can impact lubricant cleanliness. At Nye, our raw materials are required to meet stringent quality standards. Our in-vacuum lubricants are manufactured and packaged in our ISO Class 8 and Class 7 certified clean rooms to ensure our products are suitable for your manufacturing environment.

All of our products can also be tested under vacuum and high temperatures in our Vacuum Aerospace Semiconductor Test (VAST) Laboratory. Tests performed under these simulated operating conditions provide our customers with accurate outgassing, particle generation, and other important performance data that help them select the right lubricant for their precision fab equipment and high-end manufacturing processes. Nye's unique materials, such as Pennzane, and manufacturing methods, such as Ultrafiltration, have been proven to withstand the harshest conditions, on earth and in space, for nearly 50 years.

Want to learn more or discuss lubrication solutions for your application? Contact Us.

Is Your Grease Clean Enough for Your Clean Room?

What is the difference between success and failure? Sometimes it can be smaller than a grain of sand. Manufacturing equipment in vacuum and cleanroom environments are so sensitive that even microscopic particulates can cause product failure. In a bearing, for example, any particle that acts like a "speed bump" in the motion of the bearing, no matter how small and subtle, is a source of early failure. These bumps translate into vibration and ultimately wear and noise, so removing the particles is particularly important in precision bearings and instruments.

Many design engineers select lubricants dependent on their mechanical properties. For semiconductor manufacturing, it is imperative that cleanliness levels are evaluated during the lubricant selection process. Contaminants are in many design materials, and if not carefully evaluated, could be present in your lubricants.

In this article we give you the run-down on different cleanliness levels, Nye's ultrafiltration process, and why ultraclean lubricants are essential for the semiconductor industry:

Cleanliness Levels

Solid particles in lubricants come from many sources, but the most likely culprits are raw materials, the manufacturing process, and the environment. The cleanliness of a grease is described by the number of particles within a range, in which the particle sizes are counted under a microscope and are determined by the largest dimension in microns.

There are three cleanliness levels for greases:

- **Unfiltered grease:** particles present that are larger than 75 microns.
- **Filtered or "clean grease":** particles present that are smaller than 75 microns (must be less than 1,000 particles per cubic centimeter between 24 and 74 microns in size)
- **Ultrafiltered grease:** particles present that are smaller than 35 microns (must be less than 1000 particles per cubic centimeter between 10 and 34 microns in size)

What is Ultrafiltration?

The best way to ensure lubricant cleanliness is through ultrafiltration. Ultrafiltration is a rigidly controlled filtering process that detects microscopic particulates in a lubricant. The objective of this process is to remove unwanted substances or contamination from the grease or oil. Nye can ultrafilter grease in our certified clean room environments to eliminate possible contaminants for semiconductor applications.

Why You Should Choose Ultrafiltered Lubricants?

Because clean room designs are typically expensive, risk should be reduced at all costs. Particulate matter can jeopardize the operation of miniature and high-speed devices. Additionally, any solid contaminant greater in diameter than the lubricant film can separate the bearing from the race and damage one or both surfaces.

Nye's Ultrafiltration Process

Nye offers ultrafiltration services for not only our own greases, but also for those produced by other manufacturers. Many lubricant companies only filter their grease after it has been produced and before it goes into an unwashed container that can contaminate the lubricant. At Nye, we ensure ultraclean grease by following a strict manufacturing process from start to finish.

This manufacturing process includes the removal of volatile contaminants from our base oils and additives - drop by drop - using molecular stills. These stills use elevated temperatures under vacuum conditions to extract volatile molecules from the fluid. This remaining stripped fluid is separated from the volatile contaminants and becomes the new base oil for ultraclean lubricants. This process is then repeated for our additives. Our ultrafiltration process then deposits the lubricant directly into the end of use containers that have been thoroughly cleaned beforehand.

All of this happens in our ISO class 8 and class 7 certified clean rooms. These are strictly regulated areas to prevent cross-contamination of any kind. Our technicians are thoroughly trained and wear special garments including hair nets, booties, gloves, and gowns.

Reduce Risk with Ultrafiltered Grease

Often, it is not until there is a high percentage of rejects or, worse, failures in the field that the spotlight turns toward the lubricant. By considering the cleanliness of your lubricant in the design phase, you greatly reduce your risk for product failure.

Case Study: PFOA-Compliant Grease for Semiconductor Manufacturing

Background

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. Nye was 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.

Challenge

- Can replacement grease meet the 10 million cycle life requirements under vacuum, high load, and high temperatures?

Soultion

NyeClean® 5057

A completely fluorinated grease thickened with PTFE formulated for vacuum environments.

- Complies with REACH PFOA regulations
- High temperature serviceability up to 250 °C
- Extends bearing life
- Reduces friction & wear
- Offers minimal outgassing, particle generation, & vapor pressure

Properties	Test Conditions	NyeClean® 5057	Test Method
Chemistry	–	PFPE / PTFE	–
Temperature Range	–	-50 to 250 °C	–
Kinematic Viscosity	40 °C	192 cSt	ASTM D445
	100 °C	35 cSt	
NLGI Grade	–	2	ASTM D1403
Oil Separation	24 h, 100 °C	6 wt%	ASTM D6184
Evaporation	24 h, 100 °C	0 wt%	CTM*
4-Ball Wear	1 h, 1200 rpm, 75 °C	20 kgf= 0.44 mm 40 kgf =1.15 mm	ASTM D2266
Microscopic Particulate Contamination	10-34 μm	<250 particles/mL	FED-STD-791 Method 3005.4
	35+ μm	0 particles/mL	
Knudsen Vapor Pressure	150 °C	1.24E-08 Torr	CTM*
	200 °C	2.66E-08 Torr	

*CTM: Nye Company Test Method

Results

Nye formulated a new product for this customer, NyeClean® 5057. Nye provided the customer with validation data and on-demand technical support throughout the entire qualification process to prove that NyeClean® 5057 has performed as well or better than the 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.

In-Vacuum Testing for Semiconductor Lubricants

Lubricants are required to ensure the functionality of semiconductor fabrication and processing equipment, but the wrong lubricant may result in unscheduled downtime and contamination. Lubricant outgassing and particle generation can contaminate fab equipment and products and have a negative impact on product quality and yields. To avoid these issues, it is critical to select high performance, long-lasting greases with low outgassing and particle generation properties.

To reduce risk for our customers, Nye's vacuum greases are validated in our state-of-the-art laboratory dedicated to in-vacuum testing. Nye's Vacuum, Aerospace, and Semiconductor Testing (VAST) Laboratory allows us to test our lubricants 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 work in their application. Ultimately, this service helps our customer make the most informed lubricant choice.

Here are some of the properties that can be measured in the VAST Lab:

- Particle Generation
- Vapor Pressure & Outgassing
- Relative Life
- Friction & Wear

Particle Generation

The term dynamic particle generation describes what 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 dynamic mechanical action whether it be rolling, sliding, or a combination of both.

Dynamic Particle Generator

The Dynamic Particle Generator is used to classify lubricant particle generation into ISO and Federal cleanliness levels for Aerospace, Cleanroom, and Semiconductor applications. 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. The ability to run Residual Gas Analysis on the materials released from the lubricant is also available. Test provides ISO and Federal cleanliness levels on your lubricant.

Vapor Pressure & Outgassing

When a lubricant outgasses it releases condensable material that can contaminate wafers, processing equipment, and other sensitive components. Vapor Pressure (VP) is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases at a given temperature in a closed system. The higher a material's VP, the more likely it is to outgas at pressures nearing atmospheric. Therefore, it is essential that all materials used in semiconductor, in-vacuum, and aerospace possess low vapor pressures to ensure that they will be able to endure low pressure environments without outgassing and contaminating the surrounding surfaces and environment.

ASTM E595

Nye outgassing testing (per ASTM E595 Vacuum Stability) is designed to screen materials for volatile contamination. This test provides percent Total Mass Loss (TML) and percent Collected Volatile Condensable Materials (CVCM) data for our lubricants. Nye engineers can monitor the outgassing via Residual Gas Analysis to determine the elemental species contained in the outgassing material. This testing provides customers a better understanding of our materials' stability in a static vacuum environment and the ability to identify what materials are outgassing. This test can aso show how much of the outgassing is condensable to give an indication of the lubricant's material suitability within sensitive mechanisms in a vacuum environment.

Knudsen Vapor Pressure Chambers

Nye Lubricants employs the Knudsen method of determining the VP of lubricants. This method requires a very small sample, which reduces testing costs and increases testing efficiency. The sample is placed in a small, capped cell with an orifice in the cap of known diameter. The cell (containing lubricant) is then placed in one of the vacuum chambers, at a desired temperature and for a desired duration. The mass loss from the lubricant within the cell 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 particular temperature.

Relative Life

Downtime and maintenance are costly. To maximize uptime and the time between service intervals, a long-lasting grease should be selected. Lubricants can be tested to your applications cycle requirements.

Spiral Orbit Tribometer

Originally developed by NASA to evaluate space applications, the Spiral Orbit Tribometer (SOT) is a method of tribometry designed to bridge the gap between tribo-contact testing and longer-term bearing tests. The 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 is a simulation of a thrust bearing and provides results that indicate the lubricant consumption, degradation, and life. As this test is done in ultra-high vacuum and the materials in contact can be customized, the SOT can provide a great deal of insight into the performance of application critical lubricants.

Vacuum Bearing Test Rig

The Vacuum Bearing Test rig will offer engineers data that can be used to determine the realistic life expectancy of our lubricants test on 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. Our high vacuum test can assess how our lubricants will perform 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.

Friction & Wear

Maintenance and downtime are expensive. It is important to consider a lubricant's ability to protect components against friction and wear under specific loads, speeds, and geometries.

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 measures friction in a mixture of rolling/sliding contacts to simulate applications, like rolling element bearings and gears. Unlike other tribological tests where speed is either measured as the number of rotations during a period of time or the oscillatory frequency, 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.

Ready to learn more? Explore our lubricants for Semiconductor applications!

Meet Nye - Robert Hoffman

As a Regional Engineering Manager Bob Hoffman helps customers in the Western United States find lubrication solutions for their specific applications. In addition to serving these areas, Bob specializes in lubricants for customers in the aerospace, semiconductor, and medical markets. Prior to working at Nye, Bob worked in engineering and business development for several prominent equipment manufacturers, supplying electronics packaging systems such as pick-and-place, dispensing, and inspection. In that role, he has worked with many of Nye's existing aerospace and electronics customers, and he acts as one of Nye's resident experts in dispensing technology. Bob holds a Bachelor of Science degree in Electrical Engineering from the University of California, Los Angeles.

What is outgassing and how does it affect the performance of semiconductor lubricants?

All materials outgas to some degree, and outgassing is akin to evaporation; it is the release of smaller fractional molecules from the bulk liquid or solid material. Outgassing is the cause of "that new car smell" as the plastic and elastomeric materials on the interior of a new car give off vapors from the freshly fabricated materials such as the door panels, seats, carpet, and seals. Evaporation and outgassing increase as the temperature rises, and generally the smaller, fractional molecules are the first to outgas. The rate decreases as the larger molecules take more energy to release. Therefore, it is possible to "vacuum-strip" a material in a thermal chamber to remove the lighter, unwanted outgas constituents before application in the system, to some degree.

Outgassing also increases with lower molecular weight materials, which is why the evaporation of lower viscosity base oils is higher than in more viscous base oils, and still higher than in crosslinked plastics, at a given temperature. In a situation where an outgassed molecule becomes airborne, it can condense on a surface and care must be taken that the condensate does not adversely affect the optical or surface properties of the material onto which it condenses. For example, light molecular weight silicone materials, which are notoriously migratory, are not allowed in certain factories, where painting, bonding and adhesion processes might be adversely affected, were the silicone molecules to deposit on the surface being processed.

What should semiconductor manufacturing systems and handling equipment OEMs and fabs consider when selecting lubricants for their equipment?

The semiconductor manufacturing market is divided between front-end device manufacturers and back-end assembly and test functions. On the front end, where multi-million-dollar systems are installed to apply chip circuitry to wafers using lithography and vapor deposition, lubricants are selected for high-vacuum compatibility and the ability to withstand high temperatures and sometimes harsh chemicals. There is an extreme sensitivity to making sure the lubricant doesn't outgas or migrate in any way that would contaminate the wafers being processed. These systems present very costly down-times if they are not running and fully functional, so they need to be extremely reliable and designed for the longest time possible between maintenance intervals. Usually, the Equipment OEMs specify the lubricant performance needed and many of the high-end device designers have expertise in this arena. Companies who are responsible for FAB will typically follow the guidance of the OEM manufacturers.

During back-end assembly and testing, high speed robots are used to pick-and place the individual chips from the wafers into packages such as lead-frames, ball grid arrays and multi-chip modules. High speed wire bonding, encapsulation, curing, and electrical testing are subsequent processes that use sophisticated robots as well. In these processes, vacuum is rarely a consideration, although the processes are still done in cleanrooms. However, the cleanrooms are not as extreme as the front-end side, the chips are less sensitive to contamination once fabricated, and throughput and cost allow for a lower cost lubrication solution. In the design of these robotic systems, it is very common to integrate off-the-shelf components, such as linear drives, slides, motors, and bearings. The system designer is often reliant on the component supplier to select the appropriate lubricants for their components. The need for higher lubricant performance is often only a discussion after they encounter a problem brought to them by their back-end systems customers. It is important to view the lubricants as a critical design component early in the process to avoid system downtimes.

How do lubricants for wafer fabrication manufacturing and flat panel display manufacturing differ?

Both systems require extreme levels of cleanliness, vacuum compatibility, and high reliability. Many of the fabrication processes differ, in that flat-panel displays are arrays of fairly-large-feature-size devices that act as switches or gates that allow pixels to be on or off in LCD, LED, OLED, and plasma displays, among a very diverse field of display technologies. These substrates often start as heavy 3-meter square pieces of glass onto which devices are deposited, and they can be eventually cut into TV-size or mobile-phone-size displays. It is much easier to move a very thin 300mm silicon wafer around, in comparison to a 3-meter square piece of glass or solar panel. Moving large materials requires larger robots that are lubricated with greases with better anti-wear properties that can support higher loads

The pixel sizes in flat panel displays are small, though much bigger than the sub-10-nanometer features that are applied to 200-300 mm wafers in the manufacture of semiconductor devices such as microprocessors, memories, and control logic. When manufacturing these wafers, even the smallest contaminants from lubricants can result in product defects and yield loss. Robotics involved in wafer fabrication, therefore, require cleaner lubricants with lower outgassing properties.

Why is it important to validate the performance of lubricants in vacuum?

Vacuum lubricants that are widely used in space and semiconductor applications both face very high consequences from lubricant contamination or lubricant failure if not properly managed. We say it is possible to send an astronaut up into space to repair a satellite— you just can't get them back. In cases like these, it's better to ensure an application's reliability before launch. Especially in today's semiconductor shortage environment, it is vital that the appropriate semiconductor vacuum lubricant get selected and applied in the best way, to assure up-time and productivity of the device manufacturing system.

What is your favorite part about working at Nye?

I like the diversity of our customer base, and our heritage that spans from "whale ships to spaceships.". Some days, I could get a call from someone who wants to repair the treadmill in their garage, and then later the same day it could be a customer looking for help on a mission to Jupiter or Mars. In the 10+ years I have been with Nye, many innovators out here in the western US have come to Nye for help with cell phones, medical devices, satellites, electric vehicles, food and drink processing, alternative energy systems, and a very wide diversity of components such as bearings, connectors, and seals of all sizes and shapes. It has been fun to see many of these new products, improved with Nye's lubricants, come into our world and in some way change the playing field. I learn something new every day and being part of FUCHS opens another whole world of interesting projects.

Stay tuned for more updates next month!

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