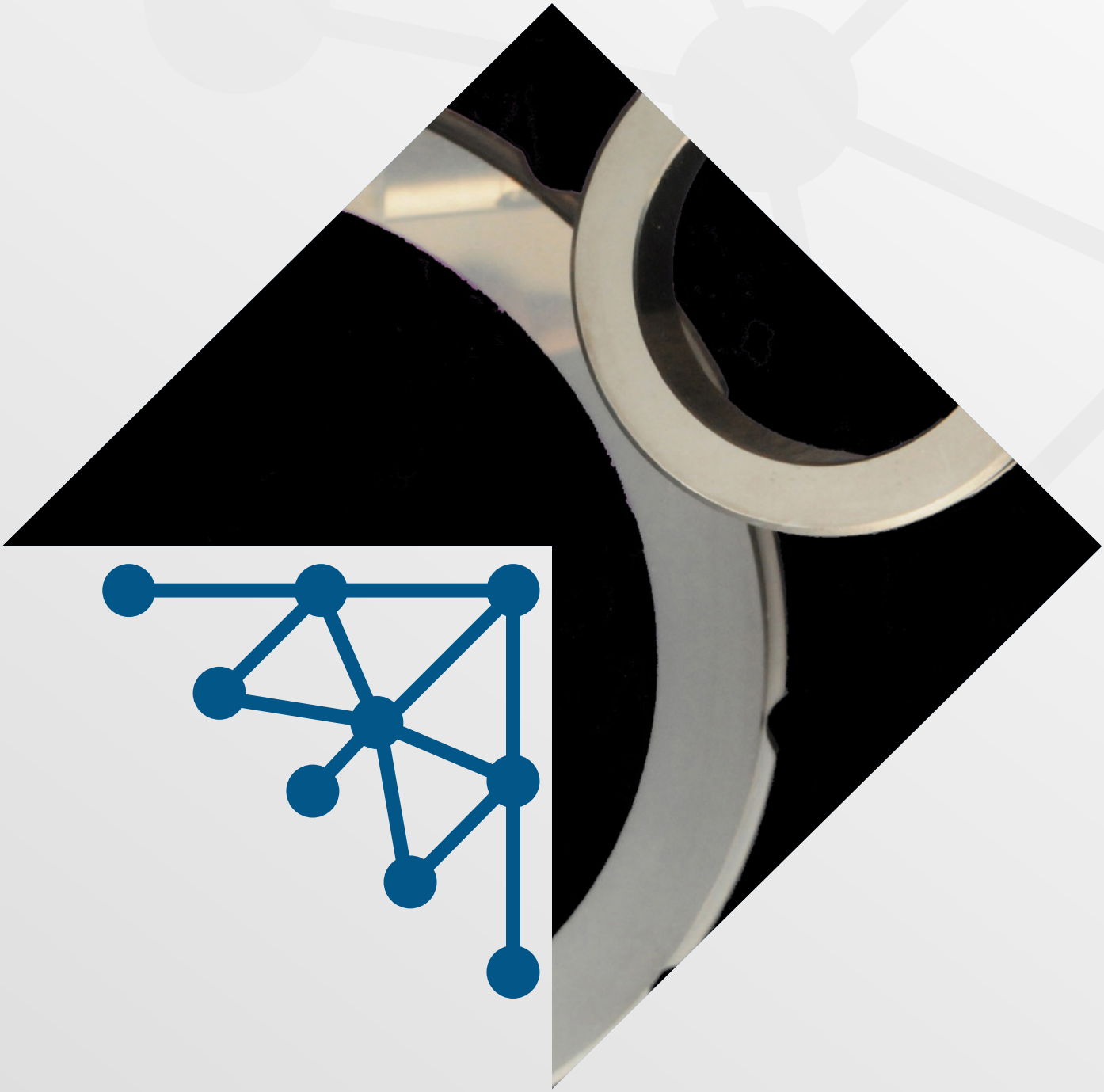
ADVANCED DIAMOND TECHNOLOGIES

UNCD® FACES

TECHNICAL INFORMATION



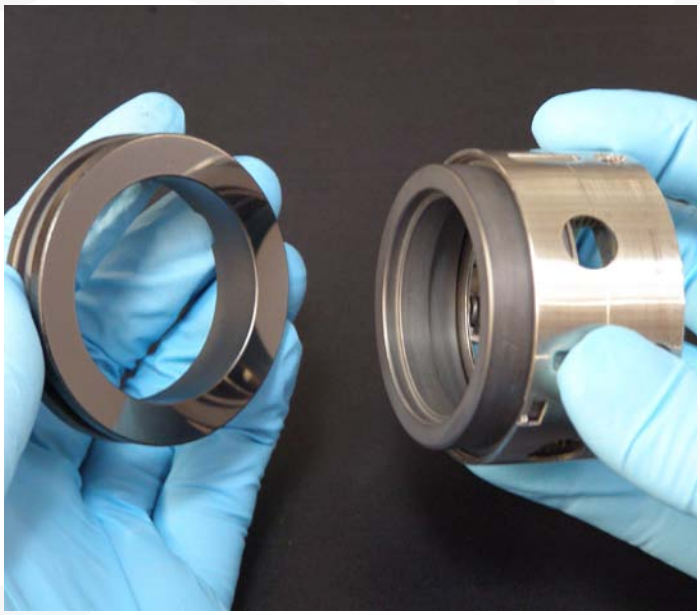
UNCD Faces

The outstanding attributes of diamond are now available for enhancing the performance of mechanical seals. UNCD® Faces are made with a patented form of diamond that is so smooth that the faces can be run directly against conventional seal face materials such as blister resistant carbons and silicon carbides. Unlike other commercial diamond seal faces, UNCD does not require the added cost of having both faces coated with diamond. In addition to excellent wear resistance and outstanding low friction, UNCD is known for its chemically inert, non-sticking, and biocompatible properties.

R&D 100 award-winning technology

Benefits of UNCD

- Longer lasting seals in demanding applications.
- More resistant to dry and poor lubricating environments.
- Increased energy efficiency.
- Enables the use of hard faces in applications pumping thermally sensitive media.
- Suitable for a wide range of media.



Mechanical pump seal with diamond faces

Products

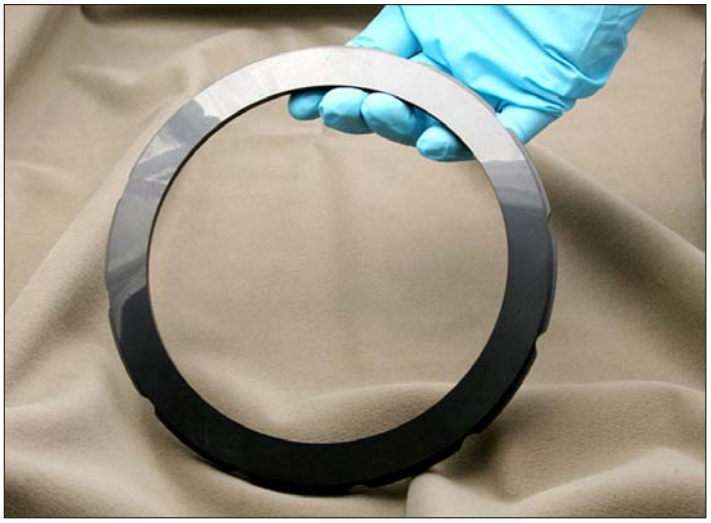
UNCD Faces

UNCD Faces are available in a wide variety of types and sizes to seal manufacturers to enhance the performance of their branded mechanical seals. Due to the outstanding low friction of UNCD, these faces perform superbly with a variety of counterface materials, including carbon and SiC.

UNCD Faces outperform SiC faces in extreme wear tests. After thousands of hours of operation, UNCD Faces have consistently outlasted SiC faces in poor lubricating conditions of 250-300 °F (121-149 °C) hot water. In head-to-head industrial tests, UNCD Faces have shown negligible or minimal wear whereas SiC faces experienced deep grooving resulting in pump leakage. UNCD Faces have also been shown, when running against SiC, to have coefficients of friction (CoF) of 0.02-0.04. These are well below the typical values when running SiC in hard-on-hard applications. The reduced friction during operation of UNCD Faces results in reduced seal cavity temperatures when running in ANSI slurry pumping applications.

Special Applications

ADT can develop custom faces for specific applications that are not addressed by our current product offerings. Please contact us to discuss your application.



UNCD Faces

ADT supplies UNCD Faces for practically any seal ring design to meet customers' requirements. UNCD is a pure-phase diamond material that is much harder and wear resistant than materials described as "diamond-like" such as DLCs and is suitable for both contact and non-contacting seal designs. To request a quote for UNCD faces, simply provide us an engineering drawing of your seal ring. We will use your drawing for costing the machined substrate that will be UNCD coated, and promptly respond to you with a quote.

The standard substrate material is alpha self-sintered silicon carbide, sourced from industry-leading suppliers. For proprietary drawings, a non-disclosure agreement is available to protect your drawings.

ADT has engineering and technical support to help ensure that OEMs and seal manufacturers can quickly incorporate UNCD Faces into existing products and develop new products based on the unique properties of UNCD.

Engineering Support

Our technical experts and support staff will work with you to understand your needs and deliver a manufactured UNCD Faces product that best meets your requirements. ADT has extensive surface characterization capabilities and dynamic seal testing loops that can be used to reduce the development time to introduce diamond into your products.

Value Proposition

Value

The nanometer-sized grains of UNCD result in extremely smooth as-deposited films that provide the excellent wear resistance and reduced friction characteristics of diamond. Cooler sealing surfaces extend the life of the seal, which provides increased robustness, reduced maintenance costs, and the ability to use SiC faces in temperature sensitive applications. Diamond is known to be chemically inert, non-sticking, and biocompatible.

Validation

The coefficient of friction (CoF) of UNCD running against SiC has been measured nominally at 0.02 – 0.04, well below the seal industry standard when running "hard-on-hard" (SiC vs. SiC). These friction results were measured using actual pump seals and were confirmed indirectly by measuring a significant reduction in seal chamber temperatures when UNCD seals were running. The wear of UNCD versus carbon faces in an aggressive hot-water evaluation (250 °F and 150 psig/121 °F and 1034 kpa) has been measured at orders of magnitude lower than the wear of alpha-SiC (self-sintered) faces running against carbon.

Readiness

UNCD Faces are available today for enhancing mechanical seal performance, and can be made to meet customer's specific seat type and dimensional requirements.

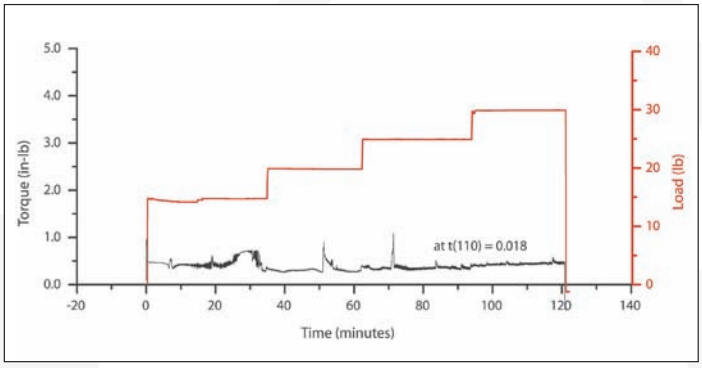
Testing Results: UNCD Faces CoF

Coefficient of Friction (CoF)

The CoF of UNCD faces running against SiC primaries has been routinely measured between 0.018 and 0.04 (see figure below). The CoF test rig measures the resulting torque of a rotating 1.375 inch (35 mm) pusher seal at various face loads. The CoF is calculated from a series of data points considered representative of the data collected toward the end of the test when the dynamic events associated with the start up and load variations have stabilized. The same test using SiC running against SiC measured greater than 0.18 and SiC against resin-bonded carbon routinely measures between 0.08 and 0.1.

Stationary Ring	Rotating Ring	CoF (in water)
UNCD	SiC	0.018 - 0.040
SiC	SiC	> 0.180
UNCD	C	0.06 - 0.1
SiC	C	0.08 - 0.1

To validate the benefits of the friction measurements made on the CoF test rig, a slurry-rig was instrumented at Argonne National Laboratory to measure the temperature of seal chambers when pumping a 10 wt% solid abrasive in Goulds 3196 pumps. The seal chambers of the pumps using UNCD Seals were found to operate six degrees (Fahrenheit) cooler than those pumps using industry standard SiC face seals. The low friction enables UNCD faces to be paired with SiC primaries in applications that would otherwise require softer carbon faces due to intermediate dry operation or temperature sensitive media. UNCD's lower friction can provide more robust single seal solutions in applications that might otherwise require the added costs and maintenance issues associated with double seals.



ADT routinely processes faces for seals with shaft diameters ranging from 0.375 to 10 inches (10 to 254 mm). Processing capabilities exist to handle both contacting and non-contacting face designs. ADT also has the test and characterization capabilities to qualify seal face materials, evaluate seal wear resistance, and characterize specific end-use performance.

Testing Results: Hot Water

Advanced Diamond Technologies on-site seal testing

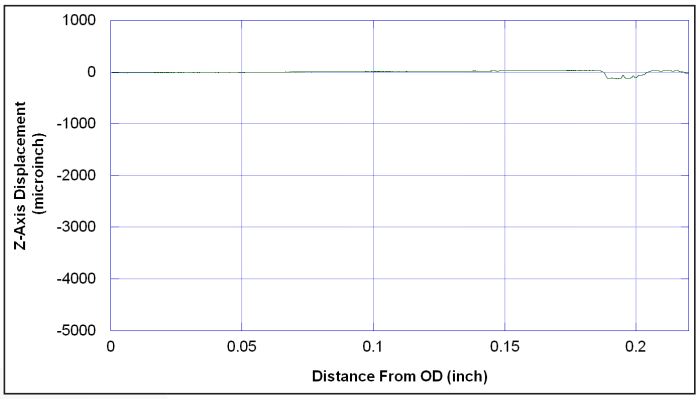
Dynamic Hot-Water Testing

UNCD Faces have been evaluated and testing in over thirty 100 hour dynamic "hot water" tests. These tests included critically evaluating both the mating and primary faces before and after being exposed to a poorly lubricating environment of hot water at 250-300 °F (121-149 °C) and 100-150 psig (690-1034 kpa) using ANSI 3196 (Goulds) pumps. These conditions have been shown to create very aggressive face wear which enables the comparison of different face materials. The 100 hour hot water test simulates over two years of normal operation. The evaluations were run using a conventional blister-resistant carbon primary running against either an alpha-phase, self-sintered SiC mating ring or the UNCD Face using the same SiC.

UNCD Faces within standard multi-spring pusher seals have neither failed nor leaked within this series of 100 hour evaluations. The UNCD faces have measured minimal wear (tens of micro inches) after completing the 100 hour test. Standard SiC rings, however, exhibit deep grooves measuring well over 4,000 micro-inches which developed in 50 to 75 hours. None of the standard SiC seals ran for the targeted test length of 100 hours due to seal leakage. The standard seals leaked so severely that the tests were consistently aborted. The full technical article detailing these results was published in "Using Ultrananocrystalline Diamond to Improve Mechanical Seal Performance" in the January 2008 issue of *Maintenance Technology* (now *Efficient Plant*) magazine, www.efficientplantmag.com.

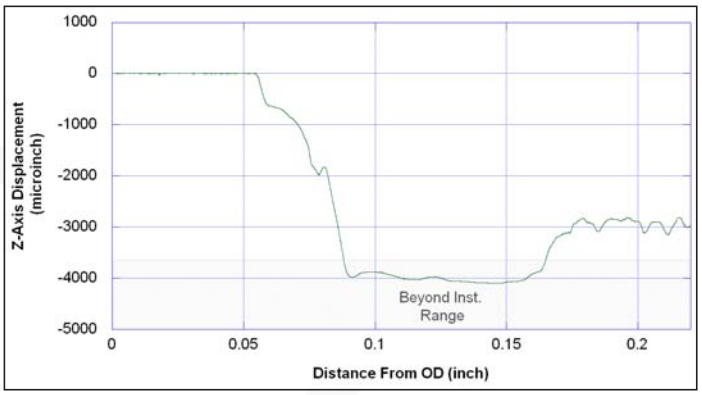
UNCD Seal Face

Surface condition of a UNCD seal face after running in 250 °F water at 100 psig (121 °C at 690 kpa), showing almost no wear.



SiC Seal Face

Surface condition of a silicon carbide seal face after running in 250 °F water at 100 psig (121 °C at 690 kpa), showing deep grooves.



The extreme wear resistance of UNCD Seal Faces has been confirmed by **Argonne National Laboratory**, Advanced Diamond Technologies, Inc. (ADT), and a major seal manufacturer. ADT has a hot water test rig and the necessary characterization equipment to conduct these tests in its facilities. This testing equipment is used to rigorously evaluate suppliers.

Frequently Asked Questions

What is UNCD?
UNCD (a form of nanocrystalline diamond) captures many of the best properties of natural diamond in a scalable thin film technology enabling diamond to be integrated into a wide range of products including mechanical seal faces. UNCD encompasses a proprietary family of materials manufactured using patented chemical vapor deposition processes. UNCD coatings are not diamond-like carbon films, but phase-pure crystalline diamond materials. For more information about UNCD, please check www.thindiamond.com.

What are the advantages of UNCD Faces?
Advantages of UNCD Faces include lower wear, lower friction, chemical resistance, non-sticking, biocompatibility, and can be mated against both soft and hard face materials.

Why should I use UNCD Faces?
Some reasons are: improve seal reliability, minimize seal leakage, longer seal service life, lower maintenance and operational costs, reduced heat generation for handling temperature sensitive fluid, dry running capability and increased energy efficiency.

Why does UNCD improve mechanical seal performance?
Heat and wear are common reasons for mechanical seal failure. UNCD's very fine grain size and hardness result in exceptionally low friction and outstanding wear resistance for improving mechanical seal performance.

How thick is the UNCD film on the seal face?
The UNCD film on the seal face is only several micrometers thick.

How flat is the UNCD coated seal face?
The flatness is retained from the pre-coated seal face.

Is adhesion of UNCD coating a concern?
No, UNCD has excellent adhesion to the silicon carbide substrate. We pretreat the silicon carbide surface to ensure strong adhesion. The adhesion of the UNCD to the SiC has been measured to be stronger than the intrinsic strength of the SiC.

What counterface materials can be mated with UNCD?
UNCD is so smooth that it can be mated for high seal performance with either soft (carbon) or hard (silicon carbide) faces. Commercial diamond faces of other manufacturers have much coarser larger grain size than UNCD which require a diamond mating face to prevent the counterface from getting chewed up.

Can a UNCD face be mated with itself?
Our focus thus far has involved mating UNCD against conventional seal face materials. Using just one diamond face, instead of both faces diamond, helps lower the cost for the mechanical seal.

How much cooler is the sealing surface due to UNCD's low friction?
The degree of cooling depends on the application. However, with UNCD faces, less heat will be generated that needs to be flushed from the seal.

How smooth is the UNCD coating?
Coating roughness depends on several factors, including the roughness of the substrate and thickness of the coating layer. UNCD coating is smooth as deposited with a typical surface roughness of about 30 nm RMS (approx. 1 microinch).

What tests have been conducted to prove UNCD performance?
Extensive validation tests of UNCD including wear and friction have been conducted over the past several years by us, Argonne National Laboratory, and seal manufacturers.

How does the increased cost of a UNCD seal compare to increased performance?
Every application seems unique. Customers should consider the total cost of ownership of the seal rather than just the purchase price. UNCD can be a great bargain when factoring such benefits as a more reliable seal, and lower maintenance and operational costs. Downtime for many process applications can be very expensive.

How do you grow the UNCD film?
The UNCD film coating is applied to the carbide substrate using a chemical vapor deposition (CVD) method. This method results in converting carbon from a gas to a solid diamond structure using elevated temperatures.

What materials can be coated with UNCD?
We can deposit thin films of UNCD on a variety of substrate materials. Our standard substrate material for UNCD seal faces is alpha self-sintered silicon carbide which is sourced from a variety of leading manufacturers. Chances are good that we can accommodate your chosen grade and brand of silicon carbide.

Can UNCD facing be repaired or recoated?
Due to the extreme hardness and chemical inertness of UNCD, it is typically impractical to repair. In most cases it is more cost effective to replace than to repair or recoat.

What is the warranty provided with UNCD?
Our warranty is defined in our standard terms and conditions of sale shown at our website.

About Advanced Diamond Technologies, Inc. and the history of UNCD Seals
Advanced Diamond Technologies, Inc. (ADT) is a leading advanced materials company pioneering the use of nanocrystalline diamond films for engineering applications.

UNCD was invented at Argonne National Laboratory, and Argonne's basic research on UNCD was funded by the Department of Energy's Office of Science. The Industrial Technologies Program (ITP) in DOE's Office of Energy Efficiency and Renewable Energy played a critical role in translating the UNCD technology from basic science into one with industrial benefits — namely UNCD Seals.

After the core UNCD technology was licensed from Argonne into ADT, the National Science Foundation (NSF) has greatly accelerated the development and scale-up of UNCD for pump seal applications via SBIR Phase I, II and IIB grants.

To learn more about ADT, and the UNCD technology, visit ADT's corporate website, at www.thindiamond.com.

UNCD Faces - Datasheet

Product Description

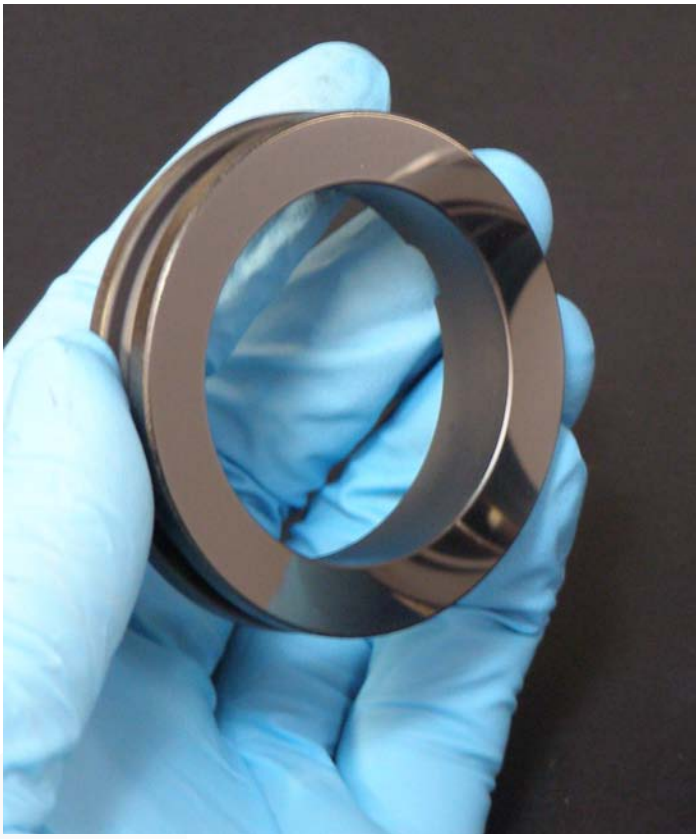
UNCD® is a form of diamond that features very low friction, chemical inertness, and superior wear resistance. UNCD Faces are offered to OEM and seal manufacturers enabling easy access to the benefits of diamond faces. Custom and small-lot quantities of UNCD Faces are routinely produced to our client's engineering drawings providing a "drop-in" improvement to current products and enabling new products with the benefits of diamond. UNCD Faces have a smooth, thin film of UNCD on silicon-carbide (alpha phase, self-sintered) to improve mechanical seal service life and performance and can be mated against either conventional SiC or carbon counterfaces.

Benefits of UNCD Faces

- Offer the compelling benefits of diamond to your customers with a minimum investment and risk
- Longer lasting seals in demanding applications
- Increased energy efficiency
- Reduced downtime and maintenance costs
- Performs exceptionally well against carbon and silicon carbide counterfaces
- Greater tolerance to dry running and poor lubricating conditions, abrasive slurries, and liquids above their boiling point

Applications and Features

UNCD Faces are designed for industrial applications including chemical, pharmaceutical, petrochemical, food and beverage processing, power generation, pipeline, and pulp and paper. They are particularly suitable for poor lubricating environments, including hot-water and applications that include temperature sensitive media. The low friction of UNCD Faces enables them to be mated with a variety of rotary seal materials including carbon-graphite and silicon



carbide. The coefficient of friction (CoF) of the UNCD-silicon carbide combination is between 0.02 - 0.04, well below the CoF values of running carbon against silicon carbide.

In extreme wear tests, the combination of running UNCD against carbon has far outperformed silicon carbide running against carbon.

Product Offering

UNCD Faces can be produced to customers engineering drawings in sizes up to 12 inches OD.

For a quotation for your application, please provide the outside dimensions and/or an engineering drawing and your volume requirements. ADT will provide a quotation for your approval.

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