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1798 – Ultrananocrystalline Diamond (UNCD) Coatings For Pump Seals

Presented by
Joe Libera

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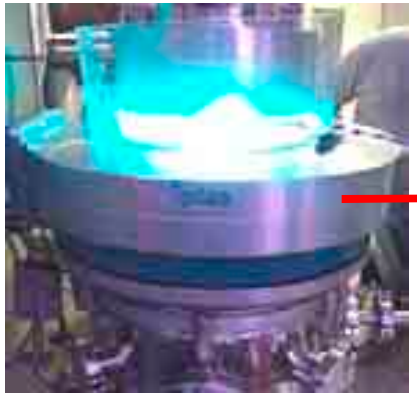
UNCD Coatings on Multipurpose Mechanical Pump Seals Reduce Friction and Eliminate Wear



UNCD Coating

Ultrananocrystalline Diamond (UNCD) Coatings For Pump Seals (CPS# 1798)

Goal: Demonstrate UNCD coating on SiC pump seals to achieve significant energy savings in IOF industries

Challenge: Develop technology to take UNCD from laboratory to commerce

Benefits: Improved wear resistance and corrosion resistance of UNCD coated parts resulting in 80% energy savings of 236 trillion Btu by 2020 in pump applications primarily due to reduced friction losses

- 8% energy savings in total pumping energy

Potential End-User Applications: SiC multipurpose mechanical pump seals, SiC large-area pump seals

FY06 Activities: Optimize 11-inch IPLAS system; Complete qualification tests for high-volume multipurpose mechanical pump application; Field tests of UNCD coated large seals for niche application

Participants: Argonne National Laboratory, Advanced Diamond Technologies, Inc., John Crane, Inc., IPLAS Innovative Plasma Systems

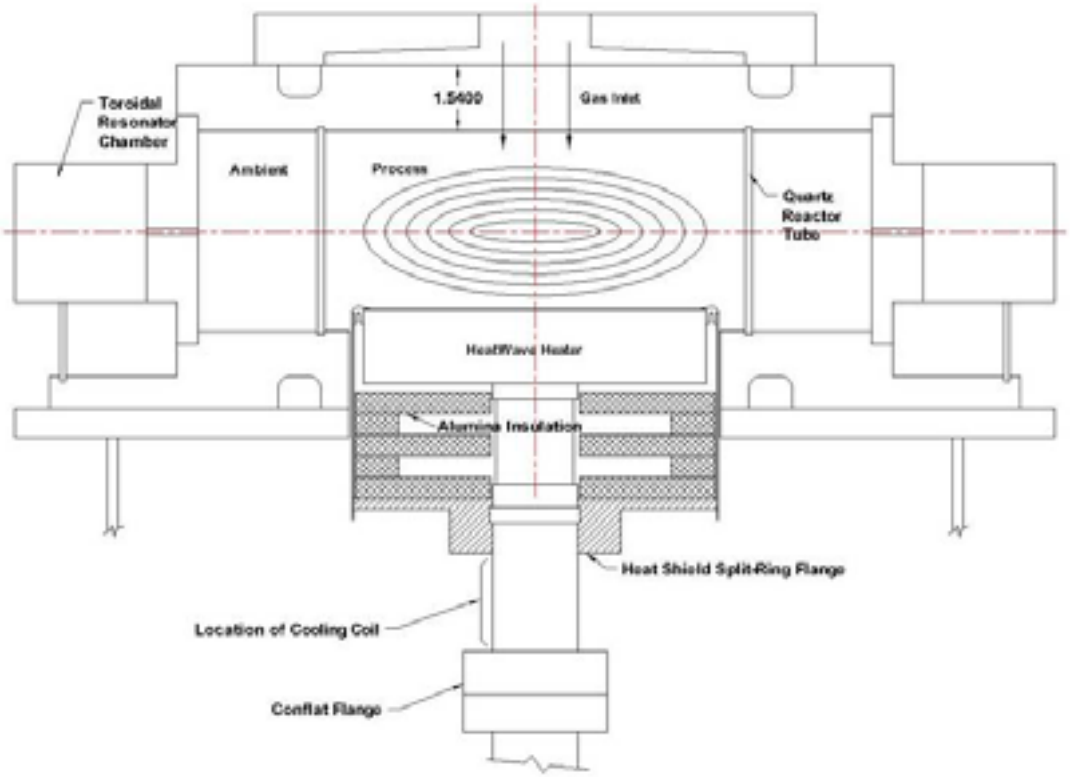
Barriers –	Pathways –	Critical Metrics
1) Uniform nucleation and growth of UNCD 1) *smooth films* 2) *good adhesion*	Understand plasma deposition and surface seeding requirements, UNCD characterization and testing	Develop seeding protocol to produce uniform UNCD films – completed
2) Scale – up UNCD deposition process	Commission 11-inch plasma system • optimize deposition rate	Multiple seals coated in 11-inch plasma system simultaneously – completed • optimize system
3) Limited seal testing facilities	Use industrial facilities and expand lab capabilities	Perform successful tests • hot water – completed • qualification tests • field tests
4) Commercialization of UNCD technology	Launch company (ADT)	Sign toll-processing agreement

11” IPLAS UNCD Deposition System

- First unit of its kind in the world
- Capable of batch-coating multiple 2” seals
- Capable of coating of 5” seals

Optimization of 11" IPLAS UNCD Deposition System

• Optimization was first performed using 200 mm Si wafers. This was chosen because it shows the full area performance of the plasma.



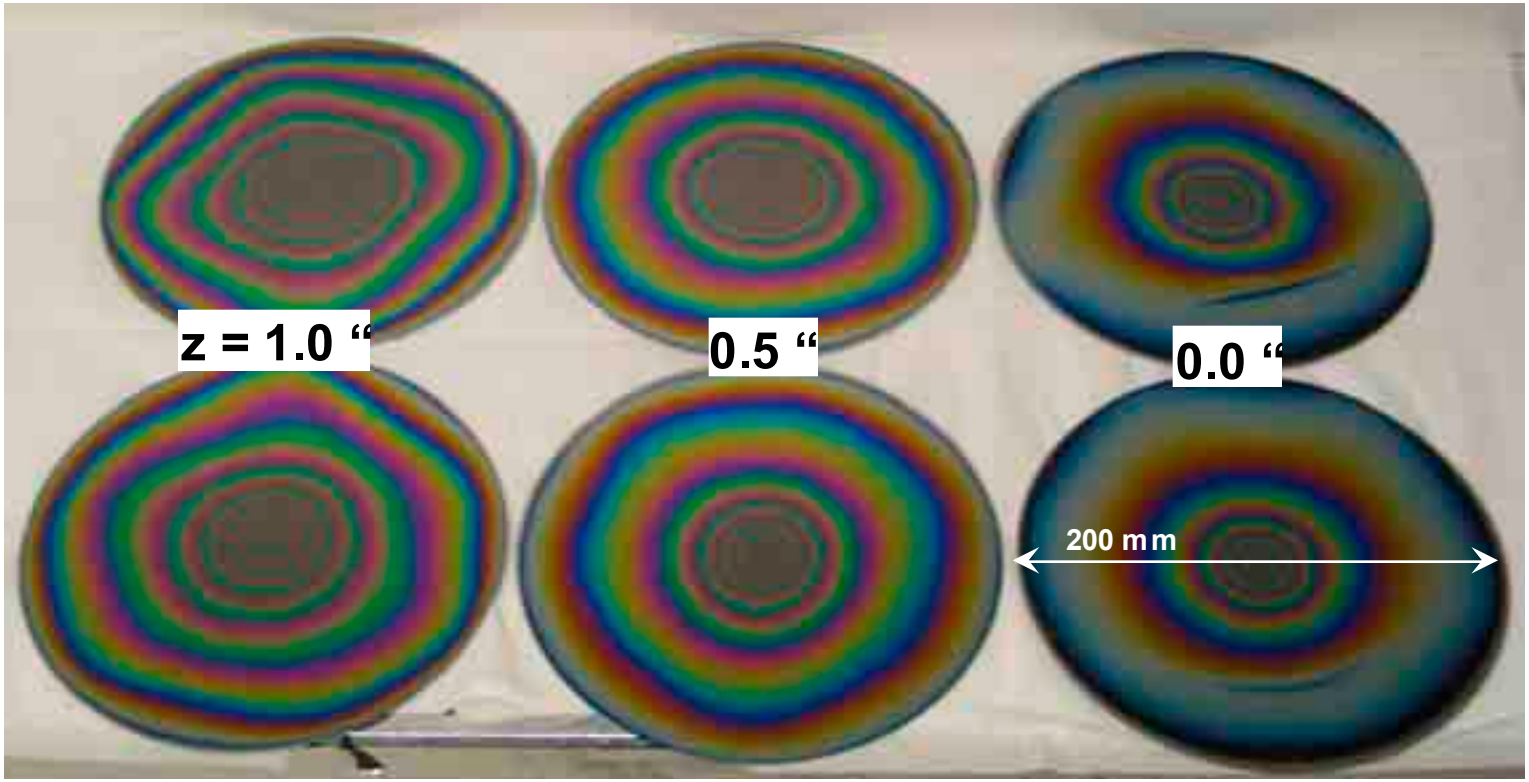
• Two separate resonators (from IPLAS) were tested

•Optimal conditions for wafer growths: 125 mbar, 400 sccm total flow, 1% CH_4, 1.5% H_2, balance Ar, 2.5 kW

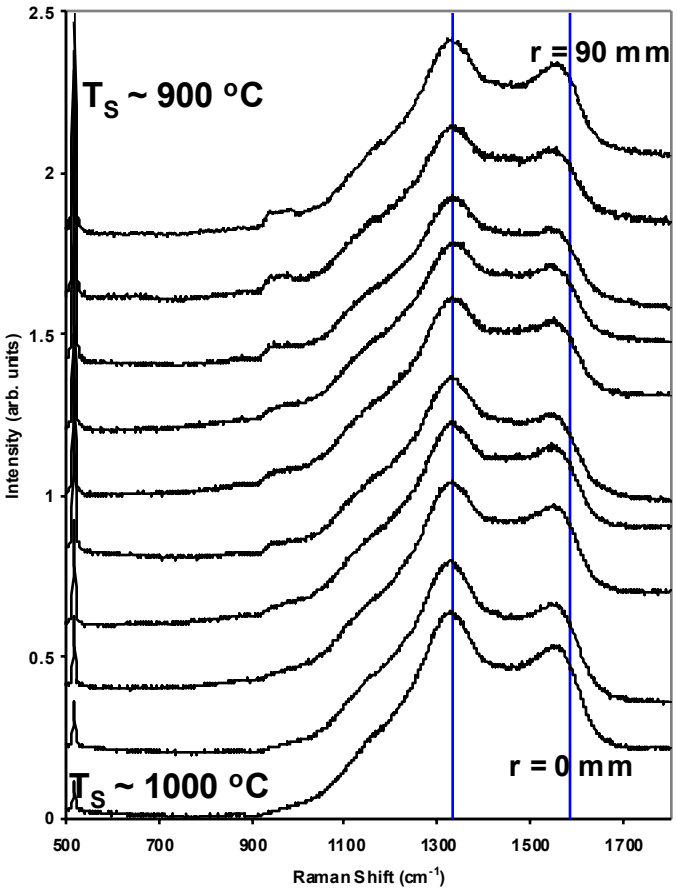
•Optimal conditions were found to be unique to the 11" reactor and different than in the 6" reactor.

Growth on 200 mm Si wafers

- The following growths on Si are the largest ever UNCD growths. These growth demonstrate excellent azimuthal uniformity, phase purity and film smoothness (R_a = 4 - 8 nm).

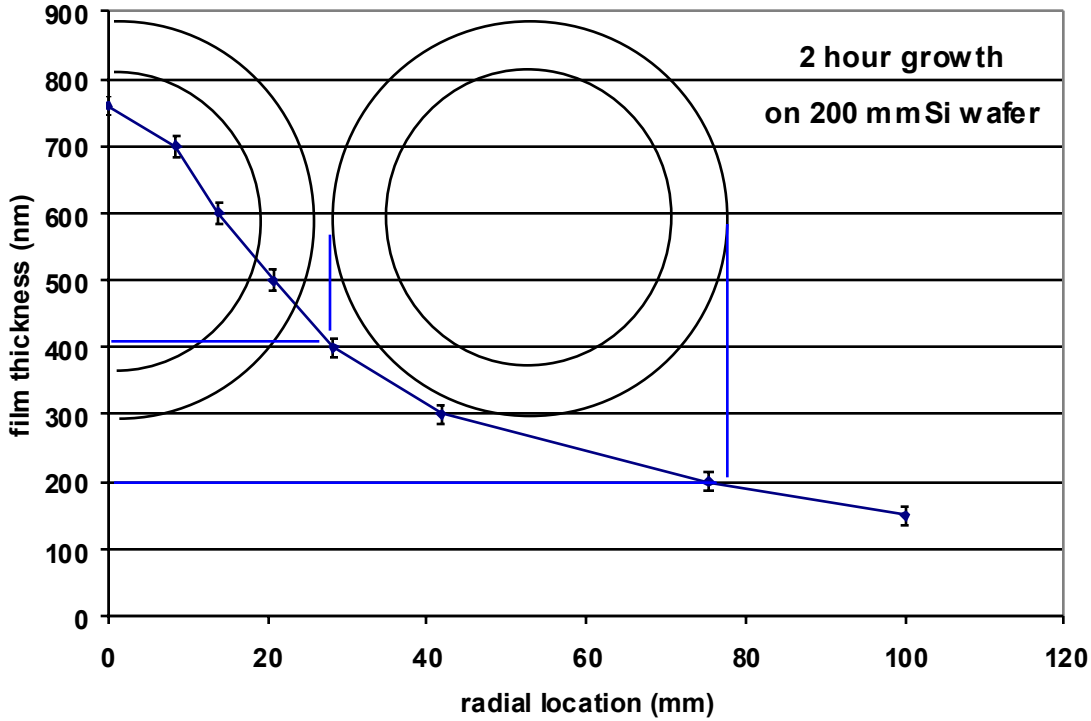


Growth on 200 mm Si wafers



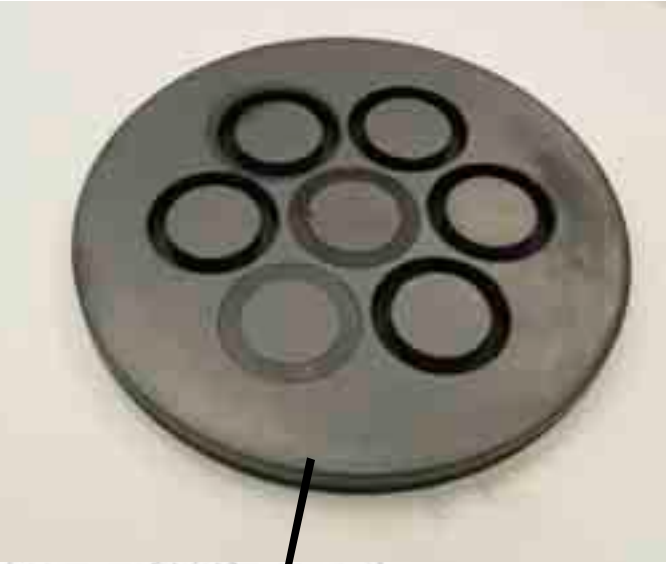
- Optimal condition for wafer growths 125 mbar, 400 sccm total flow, 1% CH_4, 1.5% H_2, balance Ar, 2.5 kW
- Phase purity is indicated by a uniform high-temperature Raman signature over the entire wafer.
- A consistent thickness profile was observed resulting from the unique plasma characteristics.

Growth on 200 mm Si wafers



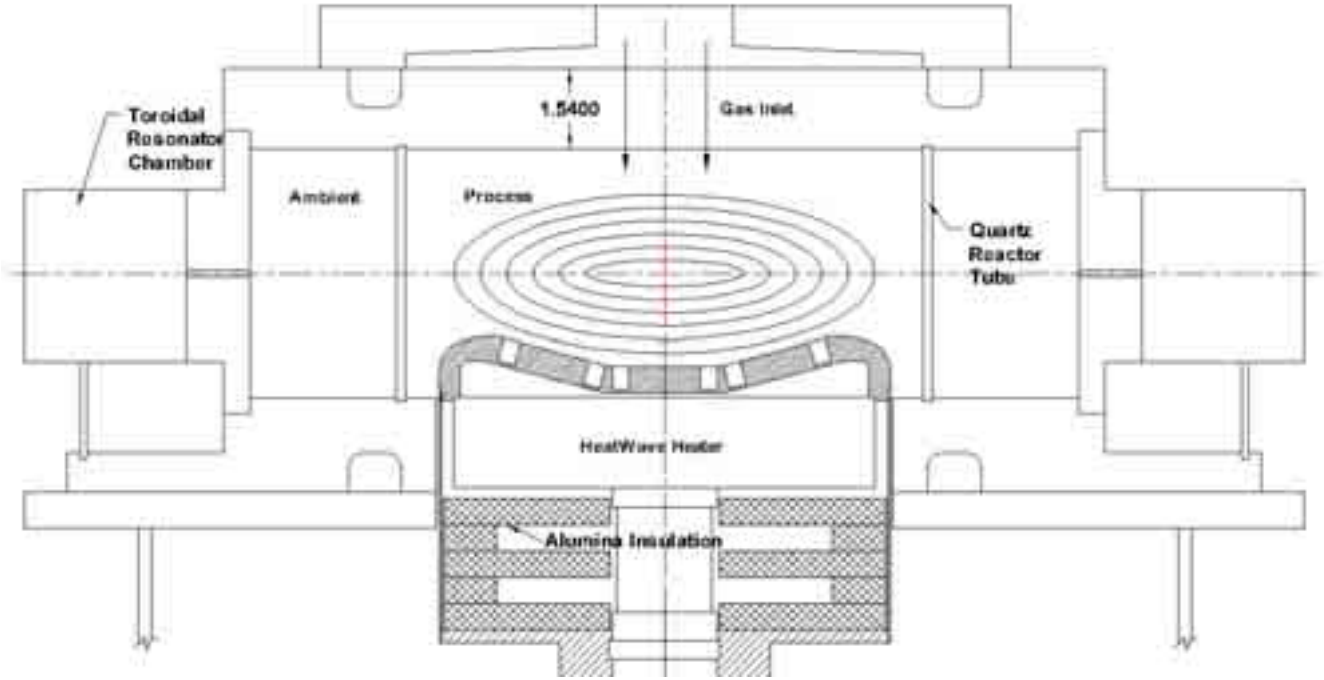
- The thickness profile shown was obtained from a Si wafer grown using the optimal growth conditions. The corresponding seal locations are shown for the two unique positions of the 7-seal susceptor design.
- The thickness profile is primarily attributed to the plasma shape and is generally unaffected by plasma operating parameters.

Multiple Seal UNCD Coating in the 11" IPLAS System



- Coating of UNCD followed closely the results presented so far for the Si wafer growths. Seal coatings meet manufacturers flatness and roughness requirements.
- Further optimization of processing parameters to boost production rates is ongoing.

Further Optimization Strategies



- New substrate designs that take advantage of the 11” reactor unique plasma properties in order to boost production will be implemented.
- Further production and quality gains will be made by adding multiple zone heating.

Friction Test Apparatus Utilizing Pump-Equivalent Fixtures

- A friction test apparatus was constructed to measure friction on 2” pump seals.
- The friction tester uses primary (carbon) and mating rings (UNCD/SiC) and seal cartridge obtained directly from the target pump equipment.
- The apparatus very closely simulates mechanical face loading conditions experienced by seal faces in a pump.
- Friction measurements of the UNCD/SiC vs. carbon seal face combination have indicated a 50% reduction over uncoated SiC.

Pump Test Loops for Seal Pre-Qualification Tests

- Two pump loops using the 2” seals were installed at ANL for prequalification test.
- These pumps provide short term proving tests for UNCD-coated seals produced in the 11” reactor.

Discuss commercialization plans, pathways, and risks

- Further optimization of the 11” deposition system is required to increase production rates, optimize friction properties and assure consistent operation over long term operation.

- Initial tests have shown that it is possible to lower the seal substrate holders without turning off the plasma. This is important to be able to permit substrate interchange without stopping the plasma or turning off the heater. This will form the basis of automation concepts using semi-continuous operation.

- Commercialization efforts by our industrial partner ADT (Advanced Diamond Technologies) are proceeding in parallel with efforts at Argonne.

Discuss future plans (emphasis on coming year: schedule, go/no-go decision points, milestones)

Date	Milestone/Deliverable	Partner Activities
	Plasma R&D	
9/06	• Optimize 11-inch IPLAS system	Argonne
6/07	• Design and construct automated system	Argonne/ADT
	UNCD Materials and Processing Development	
9/05	• Demonstrate tribological benefit of UNCD	Argonne
	Pump Seal Application	
3/06	• Complete qualification tests for pump application	Crane/ADT
12/07	• Complete field tests and analyses	Crane/ADT/Argonne
	Other applications	
9/05	• Demonstrate UNCD coatings on gas seals	Argonne
3/06	• Evaluate UNCD coated gas seals (field tests)	Crane/Argonne/ADT
9/08	• Final Report	Argonne/ADT/Crane

Project Participants – Laboratory-led project

- Argonne National Laboratory
  - Energy Systems:
    - John Hryn (Project POC), Joe Libera, Jeff Elam
  - Energy Technology:
    - Ali Erdemir, Andriy Kovalchenko
  - Materials Science:
    - Orlando Auciello, John Carlisle, Dieter Gruen, Mike Pellin, Alex Zinovev

- Industry Partners:
  - Advanced Diamond Technologies, Inc. (ADT)
    - Neil Kane (Industry POC)
  - John Crane, Inc.
  - IPLAS Innovative Plasma Systems