

**SEVENTEENTH ANNUAL**

**BiTS**

**Burn-in & Test Strategies Workshop**

TM

**March 6 - 9, 2016**

**Hilton Phoenix / Mesa Hotel  
Mesa, Arizona**

**Archive- Session 5**

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## Session 5

Ashok Kabadi  
Session Chair

BiTS Workshop 2016 Schedule

## Performance Day

Tuesday March 8 - 10:30 am

### West Meets East & Cutting Edge

#### "LPDDR4 Signal & Power Performance Optimization By Hardware"

#### "通过测试硬件的优化来提升LPDDR4信号和电源的性能"

Yuanjun Shi - Twinsolution Technology

Xiao Yao - HiSilicon Technologies Co

#### "Reliability Characterization of Unpackaged (bare) die for Silicon Photonics module"

Sujata Paul, Andrew Fong, Samir Alqadhy, Huy Nguyen, Zoe Conroy - Cisco

Tom Elliot, Jag Jassal - Evans Analytical Group

#### "Advanced High Energy CO2 Spray Cleaning Technology for Burn-In Test Substrate Cleaning Applications"

Nelson Sorbo - Cool Clean Technologies

#### "Texas Instruments Final Test Contactor Qualification Process and Low Profile Contactor Solution"

James Tong, Hisashi Ata - Texas Instruments

# Advanced High Energy CO<sub>2</sub> Spray Cleaning Technology for Burn-In Test Substrate Cleaning Applications

**Nelson W. Sorbo, Ph.D.**  
**Cool Clean Technologies LLC**



**2016 BiTS Workshop**  
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## Background

- CO<sub>2</sub> sprays have been used successfully for a wide variety of cleaning challenges in many industries.
- To meet these widely varying cleaning challenges, key spray characteristics can be modified.
  - Particle size distribution
  - Particle momentum
  - Spray temperature
  - Spray chemistry modification
- There are numerous nozzle types that can be used to achieve these varying spray characteristics.
- This presentation presents an overview of different CO<sub>2</sub> spray nozzles and their effectiveness in cleaning particles and residues from numerous substrates.

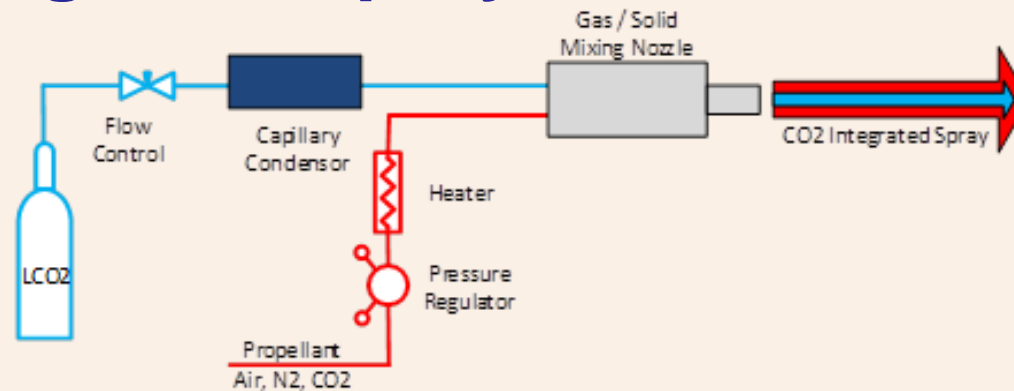
## Presentation Outline

- CO<sub>2</sub> Spray Technology
  - CO<sub>2</sub> Spray Physics
  - How to clean with CO<sub>2</sub> Spray
- CO<sub>2</sub> Spray Nozzles
  - Types
- CO<sub>2</sub> Spray Cleaning Applications
  - Electronic circuit card cleaning
  - HDD
  - Automotive
  - Residue removal
- Summary

## CO<sub>2</sub> SPRAY TECHNOLOGY



# Integrated Spray CO<sub>2</sub> Technology



- Efficient “capillary condensation” of liquid CO<sub>2</sub> to solid phase
- Metered control and introduction of solid CO<sub>2</sub> particles
- Heated inert propellant pressure control
- Various mixing nozzle designs including broad spray and brush nozzle
- Adaptable to existing assembly platforms
- No or minimal atmospheric condensation
- 1 – 15 kg/hr liquid CO<sub>2</sub>
- Variable particle size and shear stress
- Spray chemistry can optionally be modified with additive chemistries



# Solid CO<sub>2</sub> Particle Characteristics

SEM  
Photomicrograph



- Impact phenomenon – ablation and phase change (solid->gas, solid->liquid->gas)
- Solubility parameter – can be modified with liquids, vapor-phase additives
- Density - 1.6 g/cm<sup>3</sup>
- Hardness – <2 Hm (examples: 1 – talc, 2.5 - fingernail, 5.5 – glass, 7 – quartz, 9 - AlO)
- Particle Size – < 0.5 microns to > 500 microns, range adjustable (coarse/fine)
- Impact Stress - up to 90+ MPa, pressure/particle size/distance dependent

## CO<sub>2</sub> Spray Cleaning Physics

- CO<sub>2</sub> particles formed by expansion of LCO<sub>2</sub>
  - Pressure drop results in system passing through CO<sub>2</sub> triple point
  - Liquid -> Liquid + Gas -> Liquid + Gas + Solid -> Gas + Solid
  - Approximately 40% of Liquid CO<sub>2</sub> mass converted to Solid CO<sub>2</sub> particles
- Solid CO<sub>2</sub> particles accelerated by:
  - CO<sub>2</sub> jet expansion
  - Propellant momentum

## CO<sub>2</sub> Spray Composition Control

Additive  
(Chemical/  
Physical)

Inert Gas  
(Propulsion/  
Heat)

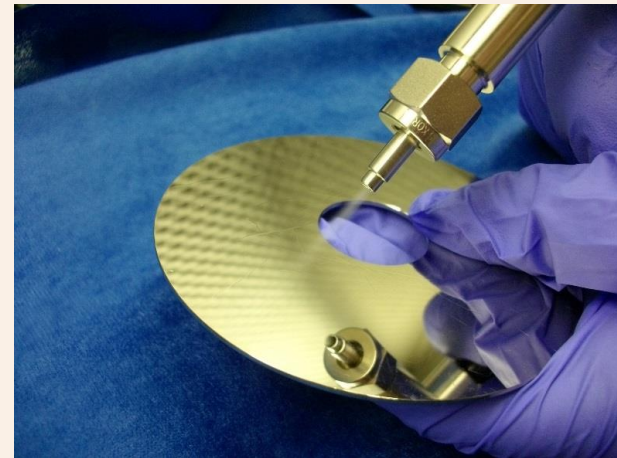
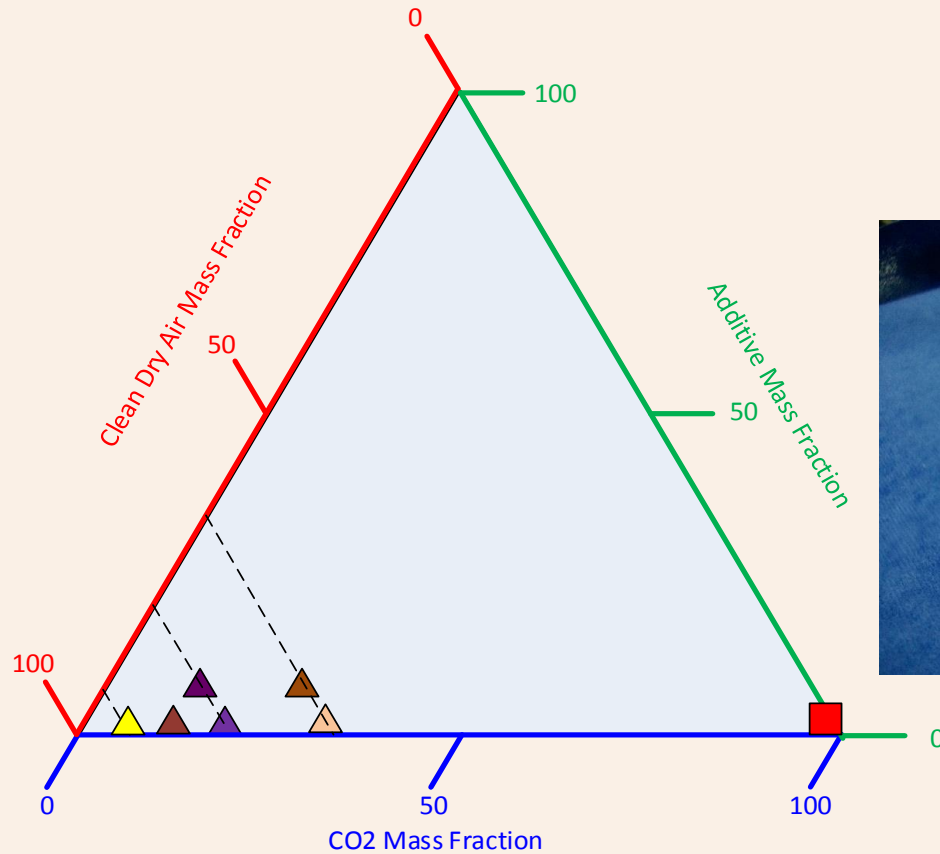
Cleaning  
Energy

CO<sub>2</sub>



- Particle Size
- Chemistry
- Spray Density
- Temperature
- Pressure
- Distance/Angle
- Time

## Efficient Use of CO<sub>2</sub>

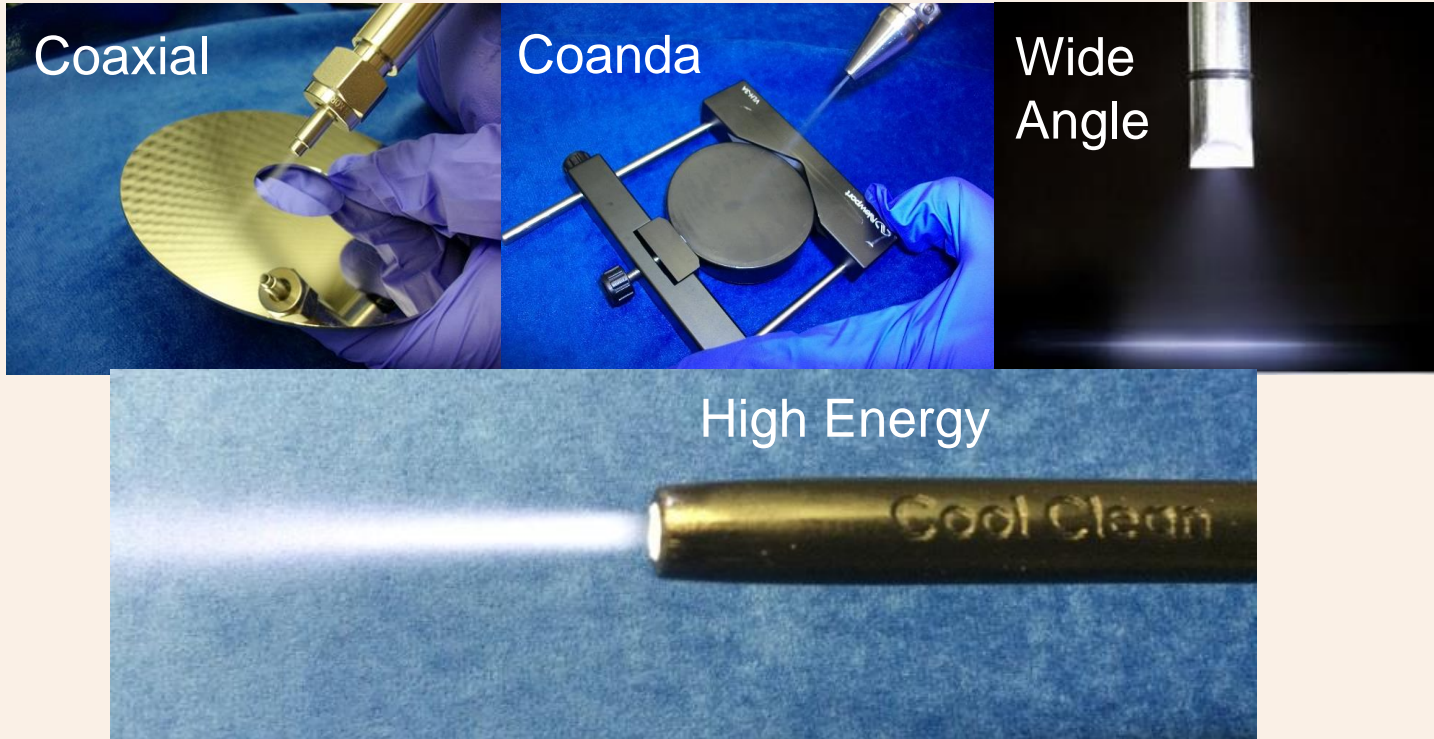


## CO<sub>2</sub> Spray Cleaning Physics

- Particles removed by momentum exchange:
  - $\Sigma m_p * \Delta V_p > F_{\text{adhesion}}$
  - $F_{\text{adhesion}} \approx \text{dia}_p$
- Residues solubilized by chemistry:
  - CO<sub>2</sub> particles change upon impact
  - Solid -> Liquid -> Gas
  - Liquid CO<sub>2</sub>
    - Hexane like chemistry:
    - HSP: 9 – 18 MPa<sup>0.5</sup>
    - HSP @ triple point: 0.52 MPa, -56.6°C =  $\delta_T = 18.4 \text{ MPa}^{0.5}$ 
      - $\delta_D = 16.3 \text{ MPa}^{0.5}$
      - $\delta_P = 5.3 \text{ MPa}^{0.5}$
      - $\delta_P = 6.5 \text{ MPa}^{0.5}$

## CO<sub>2</sub> SPRAY NOZZLES

## Types of CO<sub>2</sub> Spray Nozzles



All Remove: Particulate Matter, Thin Films, Residues



## Different Nozzle Types for Different Applications

Type	Principal Use	Effective Cleaning Width, mm	Working Distance, mm	Cleaning Energy, MPa
Coaxial	<ul style="list-style-type: none"> <li>Fine particle and thin film removal,</li> <li>Delicate feature substrates</li> </ul>	3 - 10	10 - 25	10 - 30
Coanda	<ul style="list-style-type: none"> <li>General cleaning for particles, residues and thin films</li> <li>Industrial cleaning apps,</li> </ul>	5 - 50	25 - 200	20 - 60
Wide Angle	<ul style="list-style-type: none"> <li>Fine particle removal</li> <li>Planar surfaces</li> </ul>	50	25	10 - 30
High Energy	<ul style="list-style-type: none"> <li>General cleaning</li> <li>Tough residue removal</li> </ul>	10 - 50	25 - 100	40 - 90+
Coanda Assy (4)	<ul style="list-style-type: none"> <li>General cleaning</li> <li>Large surface area</li> </ul>	100 - 250	100 - 250	20 - 60

Application / substrate / contaminant determine nozzle used.

## Fingerprint Removal from Plastic Surface (Video)



## Removal of Adhesive from Glass Surface (Video)



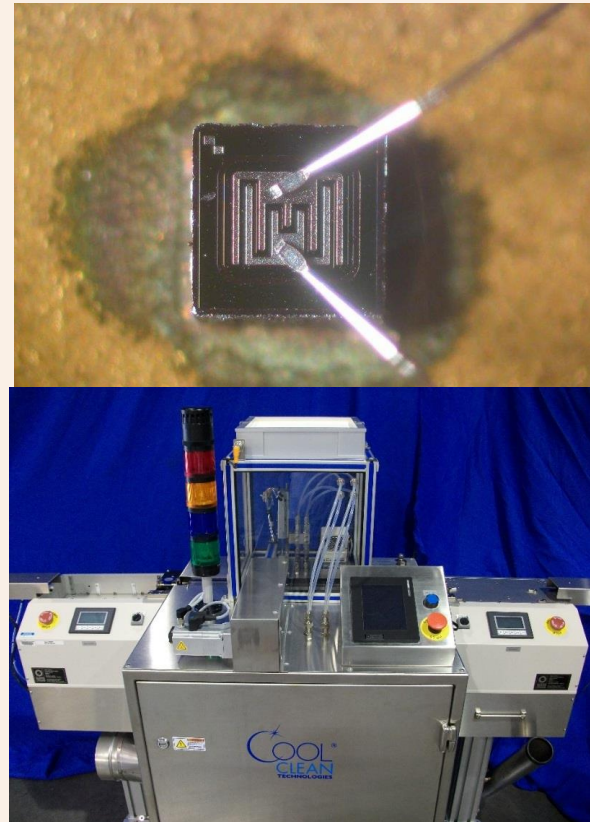
## Removal of Oily Grime from Metal Surface (Video)



## CO<sub>2</sub> SPRAY CLEANING APPLICATIONS

# Automated In-Line Circuit Card Cleaning System

- Requirement:
  - Achieve equivalent or better cleaning method than alcohol/Q-tip or tape cleaning of pockets in electronic circuit
  - No damage to fine wires
  - Cleaning system must accept customer specified feed trays
- Result:
  - Cleaner developed that exceeds customer expectations.



## Particle Removal from HDD Components

- Particle Removal: 0.2 – 0.5  $\mu\text{m}$
- Analytical Verification:
  - LPC
  - Particle Count Standard
  - Verification – visual
- Processing Time:
  - 2.5 – 10 Seconds / drive





## CO<sub>2</sub> Spray Cleaning for Automotive Component Painting

- No Water Consumption or Treatment
- No Touch Cleaning
- Small Footprint
- Low Energy Usage – No Drying Required
- Easily Retrofitted



## Cleaning of Automotive Parts (Video)



# Automotive Component Parts Cleaning

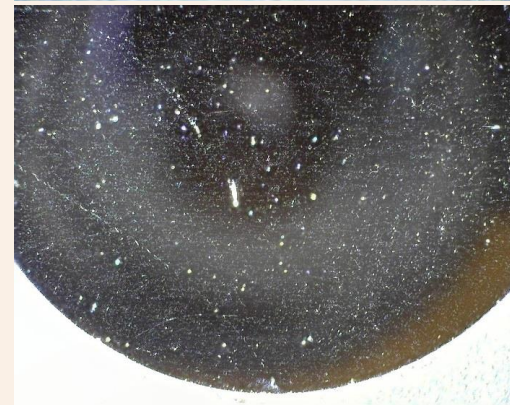
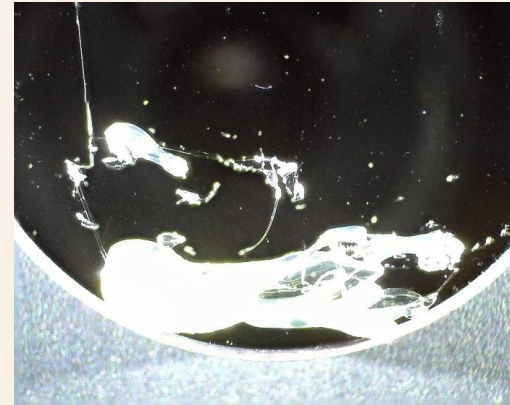
- Objective:
  - Remove manufacturing residues from precision pistons for sizing.
  - Interface with Production line and automatic sizing tool
- Residues:
  - Machining coolant
  - Residues
- Solution:
  - CO<sub>2</sub> Automated Spray Cleaning Tool
  - Interfaces with production line 6 axis robot.
  - Self-contained cleaning system.



## Surface Residue Removal – Hot Glue

- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

Before



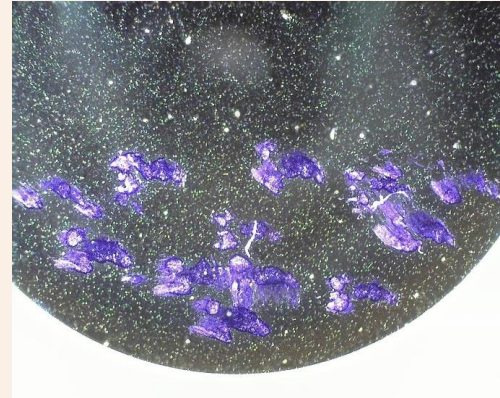
After



# Surface Residue Removal – Marker Ink & Particulate Matter

- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

Before



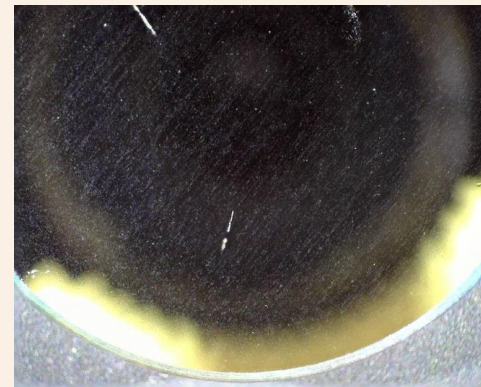
After



# Surface Residue Removal – Metal Particles

- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN
- Results:
  - Effective

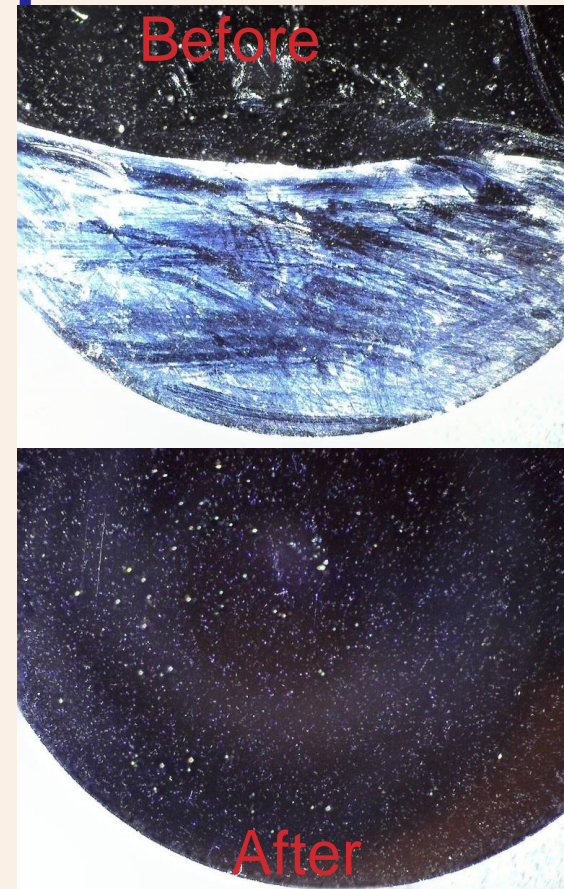
Before



After

## Surface Residue Removal – Polishing Compound

- Objective:
  - Removal of surface residues from polished Al surface
- Residues:
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective





## Surface Residue Removal – Soap Residue

- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

Before



After

# Surface Residue Removal – Water Spots

- Objective:
  - Removal of surface residues from polished Al surface
- Residues:
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

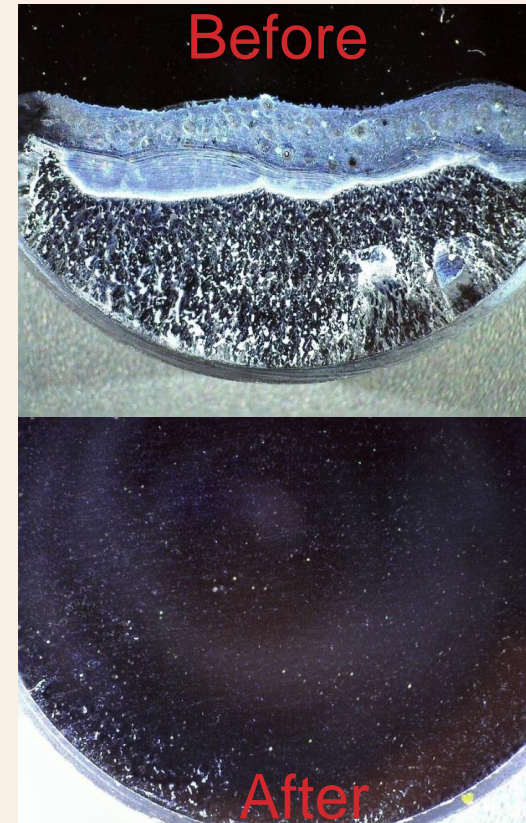
Before



After

## Surface Residue Removal – Water Soluble Spray Lubricant

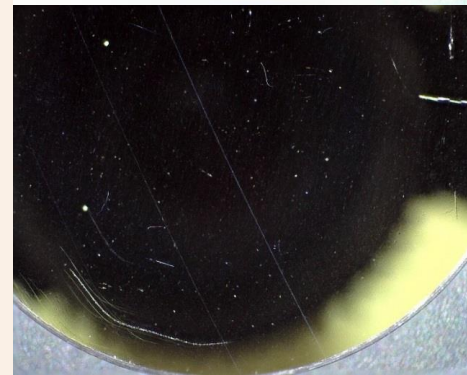
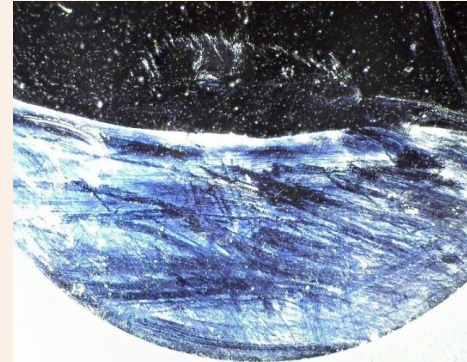
- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective



# Surface Residue Removal – Silicon Carbide Slurry

- Objective:
  - Removal of surface residues from polished Al surface
- Residues:
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

Before



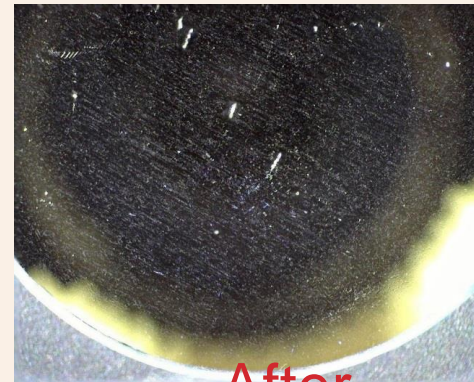
After



# Surface Residue Removal – Spray Coating

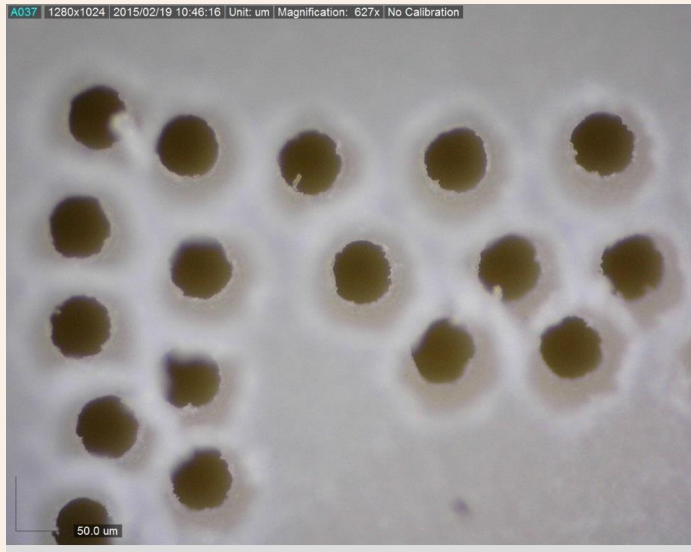
- Objective:
  - Removal of surface residues from polished Al surface
- Cleaning Method:
  - HEN with Additive Injection
- Results:
  - Effective

Before



After

## Deburring of Holes Drilled in PEEK



Before



After

## Summary

- CO<sub>2</sub> Sprays have been adapted to meet a wide range of cleaning applications.
- Many nozzle types have been developed to deliver effective no-touch cleaning to these substrates.
- This spray technology can be adapted to meet cleaning challenges of burn-in test substrate cleaning applications:
  - Delicate features
  - Sophisticated chemistries
- New nozzle technologies will provide enhanced cleaning capabilities.