



CO₂ Composite Spray Technology for Probe Card Cleaning



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Cool Clean Technologies

Contributors

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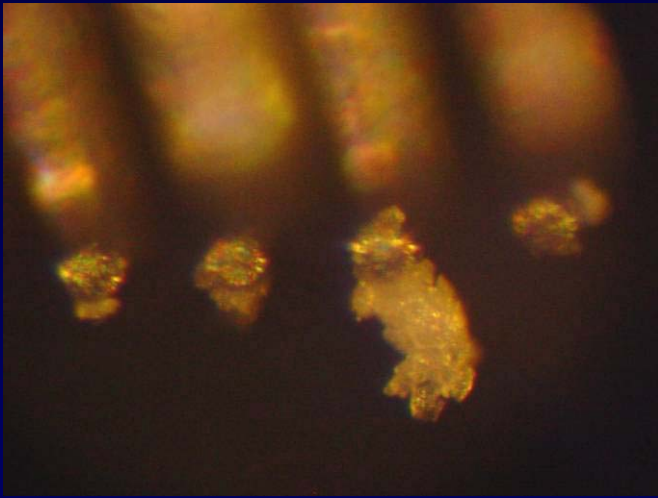
Resistive Surface Contamination



- **Metal Oxides** (Sn, Pb, Al)
- Passivation
- Silicon Nitride
- Polymers (plasticizers/fibers)
- Lapping Compounds
- Adhesive Residues
- Outgas Compounds
- Metals (solder, Al)
- Human Contaminants
- Cleaning Residues
- Solder Flux

Cleaning and Cleanliness Issues

Contamination tends to bond/adhere in cohesive layers...



Contamination generates more contamination.

Contaminations:

- A mix of transferred metals, organics, inorganics, ionics and adsorbed films
- Thin and thick layers/films

Contact Surfaces:

- Surface area (contact zone) changes over time
- Small/complex topography (curved, pointed, crowned)

Cleaning Processes:

- Incompatibilities (damage/efficacy)
- Variability/Quality
- Long cleaning times (manual methods)

Cleaning Methods (probe/socket)

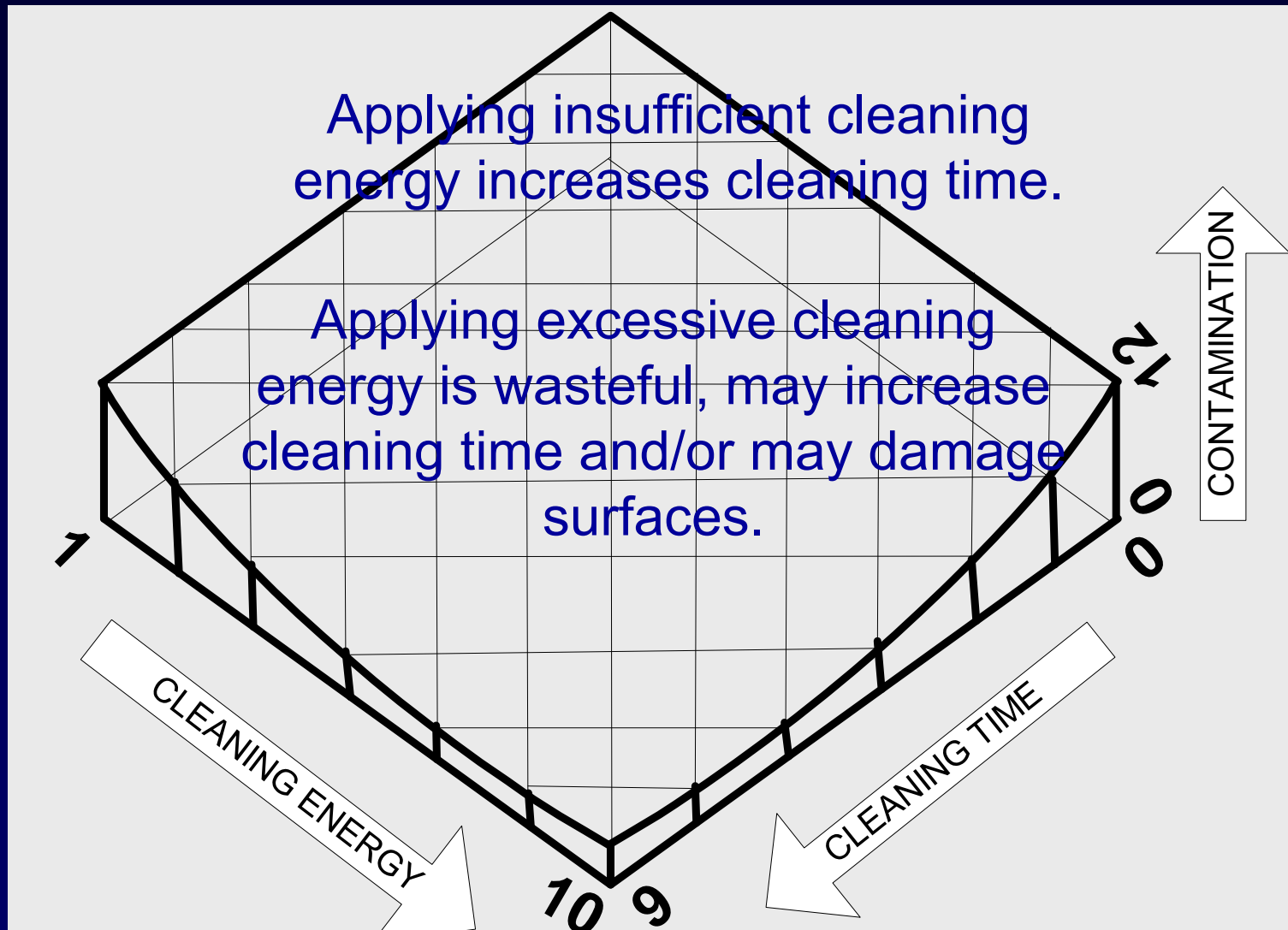
<u>Method</u>	<u>M</u>	<u>T</u>	<u>C</u>	
1. WC Plate	X			<u>Manual</u> ✓ Direct Contact ✓ Low Capital ✓ High Labor
2. Lapping Films	X			
3. Metal/Polymer Brush	X			
4. Ceramic Block	X			
5. Polymer Sheets	X			
6. Microabrasive Spray	X			
7. Camel Hair Brushing	X			
8. IPA Wet Brushing	X		X	
<hr/>				<u>Automated</u>
9. Weak Acid Cleaning	X	X	X	✓ Non-Contact ✓ High Capital ✓ Low Labor
10. Ultrasonic Cleaning	X	X	X	
11. Plasma Cleaning	X	X	X	

M – Mechanical Energy

T – Thermal Energy

C - Chemical Energy

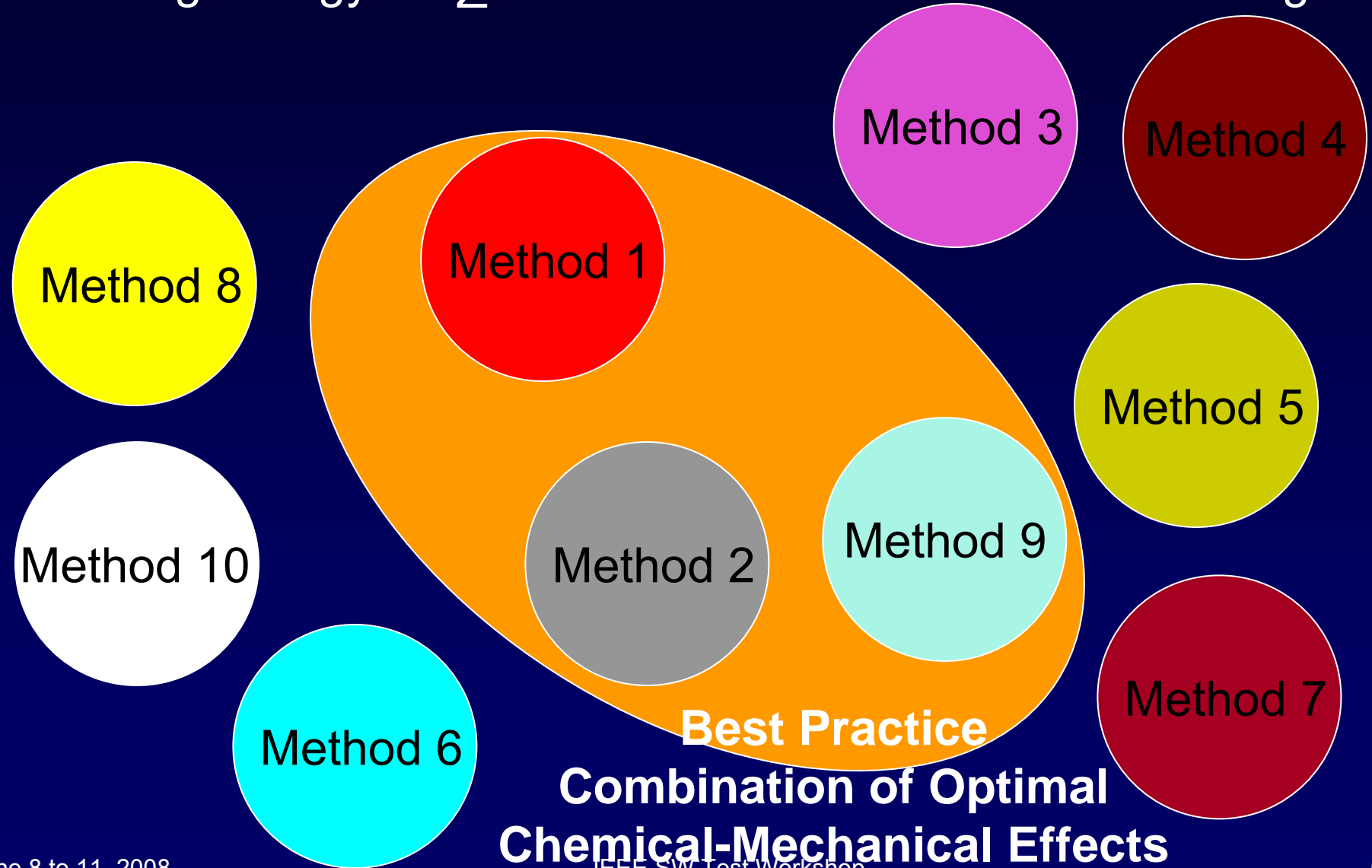
Cleaning Process Challenge



Adapted from "Theory of Cleaning", B.N.Ellis,
Circuit World, Vol.12 No.1, 1985

Cleaning Process Challenge

Cleaning Energy $\geq \sum$ Contaminant-Surface Adhesion Energies



Cleaning Process Challenge

The most desirable cleaning process:

- ✓ Non-destructive (contact surface/peripheral surfaces)
- ✓ Minimal or no human contact
- ✓ Robust (in terms of energy control)
- ✓ Both mechanical and chemical cleaning actions
- ✓ Ability to clean dense and complex surfaces
- ✓ Fast (less cleaning labor/time)
- ✓ Low cost-per-clean
- ✓ Minimal or no cleaning agent by-products
- ✓ Acceptable ROI

CO₂ Cleaning Technology

CO₂ technology has been used to produce consistently clean surfaces for high-tech products such as spacecraft devices, optical devices, sensors, lasers, disk drives, air bags, medical devices and *probe cards*...

Treatment Schemes

- Composite CO₂ Spray *
- Immersion Solvent (Liquid)
- Extraction Solvent (Supercritical)
- Atmospheric Plasma *
- Low Pressure Plasma
- UV-CO₂ Treatment
- Plasma-CO₂ *
- Laser-CO₂ *
- Microabrasive-CO₂ *

Hybrid Processes

* - Probe cleaning candidates

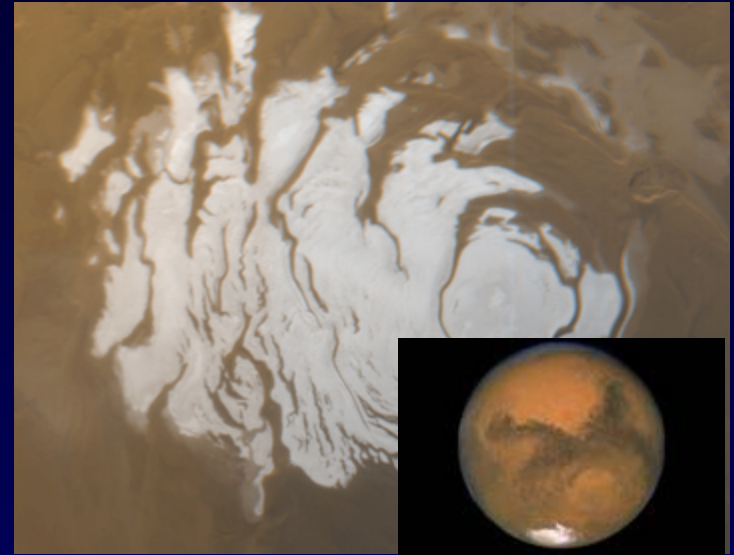
CO₂ is Abundant

A recycled by-product from industrial and natural sources such as refineries, CaCO₃ wells, and bakeries.

A recyclable and renewable resource.

Major commercial uses include beverage carbonation, fire extinguishing and welding.

South Pole - Mars



CO₂ is Safe

<u>Solvent</u>	<u>Ozone Depleting Potential (ODP)</u>	<u>OSHA PEL (ppm)</u>	<u>VOC</u>
Carbon Dioxide	None	5,000	No
Isopropyl Alcohol	~0	400	Yes
Acetone	~0	1000	No
Trichloroethylene	~0	50	Yes
1,1,1-Trichloroethane	0.15	350	Yes
n-Propyl Bromide	~0	100	Yes

CO₂ is non-toxic, non-flammable and non-corrosive. Recycled CO₂ is exempt from the EPA Global Warming legislation.

CO₂ is Inexpensive

<u>Solvent</u>	<u>Bulk Price Range</u> <u>\$/kg</u>
Carbon Dioxide	0.10 - 0.25
Acetone	0.44 - 0.49
Isopropyl Alcohol	0.75 - 0.88
Methylene Chloride	0.80 - 1.25
1,1,1-Trichloroethane	1.25 - 2.00
n-Propyl Bromide	3.00 - 5.00

Just pennies of CO₂ are used in composite spray formulations for a cleaning operation...

CO₂ Cleaning Agents

CLEANING PROCESS

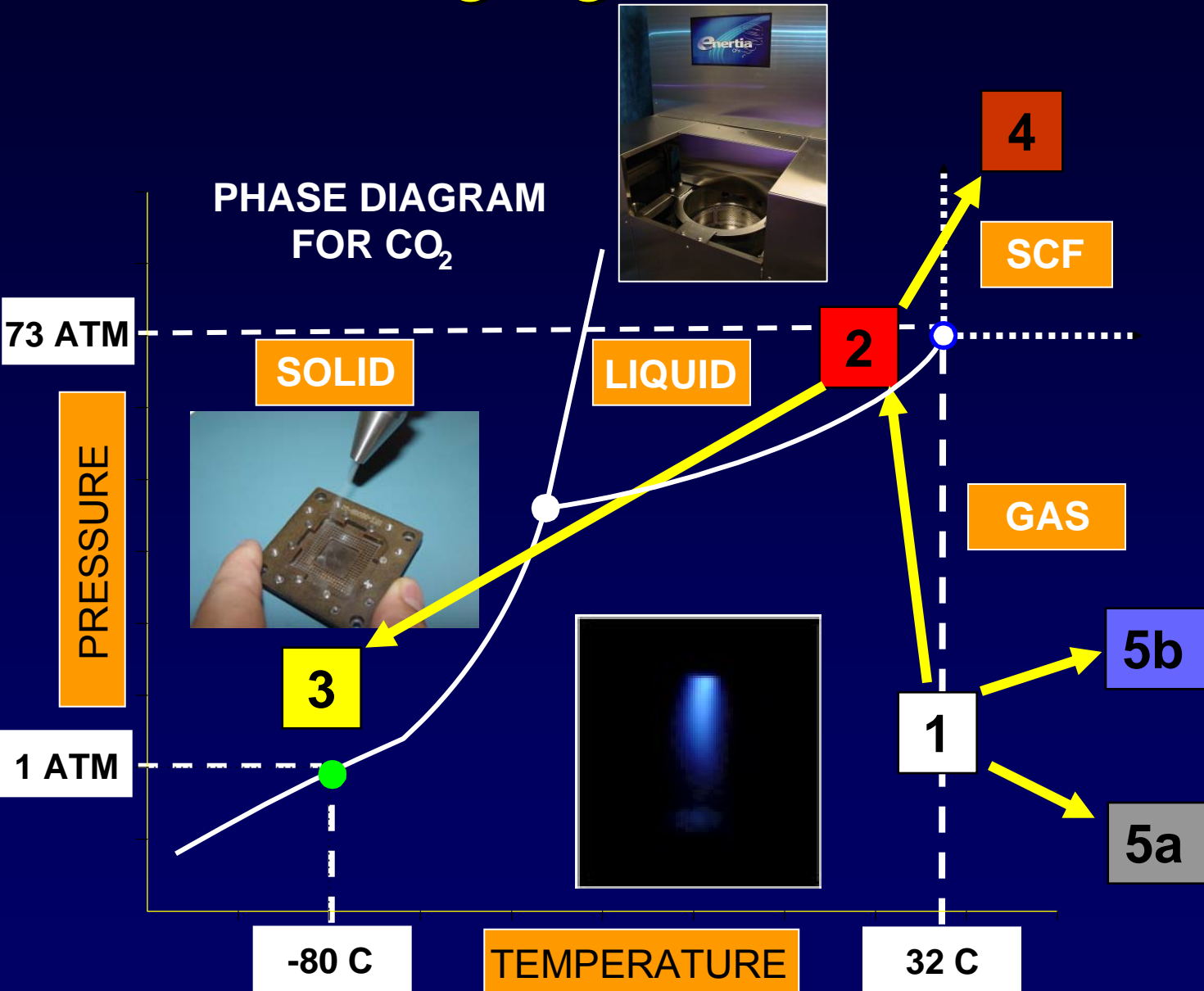
Extraction

Immersion

Spray

H.P. PLASMA

L.P. PLASMA



CO₂ Solvent Properties

Carbon Dioxide

Acetone

DENSITY

g/ml

Solid

1.6

Liquid

0.8

Supercritical

0.5

0.8

VISCOSITY

mN-s/m²

-

0.07

0.03

0.32

SURFACE

TENSION

dynes/cm

5-10

5

0

24

SOLUBILITY

MPa^{1/2}

22

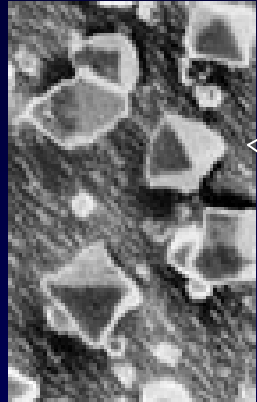
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14

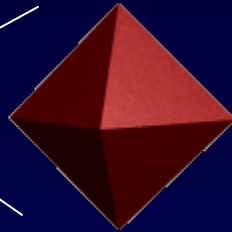
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Solid Carbon Dioxide

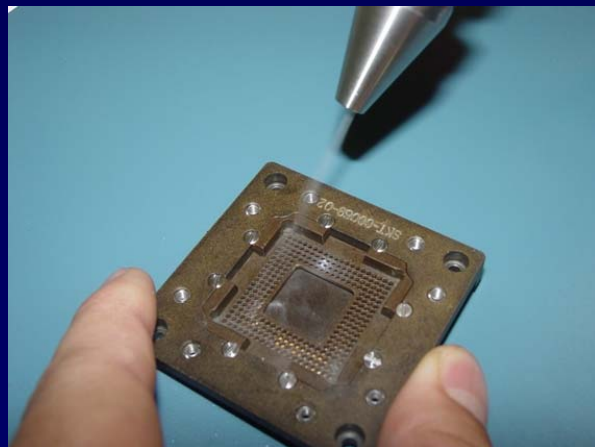
SEM
Photomicrograph



1 μm



- **Structure** - molecular crystal, angular, octahedron
- **Solvency** – hydrocarbon-like, $22 \text{ MPa}^{1/2}$
- **Impact Phenomenon** – ablation and phase change (solid->gas, solid->liquid->gas)
- **Chemistry** – can be modified with plasmas, liquids, solids, vapor-phase additives
- **Compressibility** - incompressible
- **Density** - 1.6 g/cm^3
- **Hardness** – 0.3 Hm (8 Hv)
- **Particle Size** – $< 0.5 \text{ microns}$ to $> 500 \text{ microns}$, range adjustable (coarse/fine)
- **Impact Stress** - up to 60 MPa ($8,700 \text{ psi}$)



Conventional Snow Cleaning

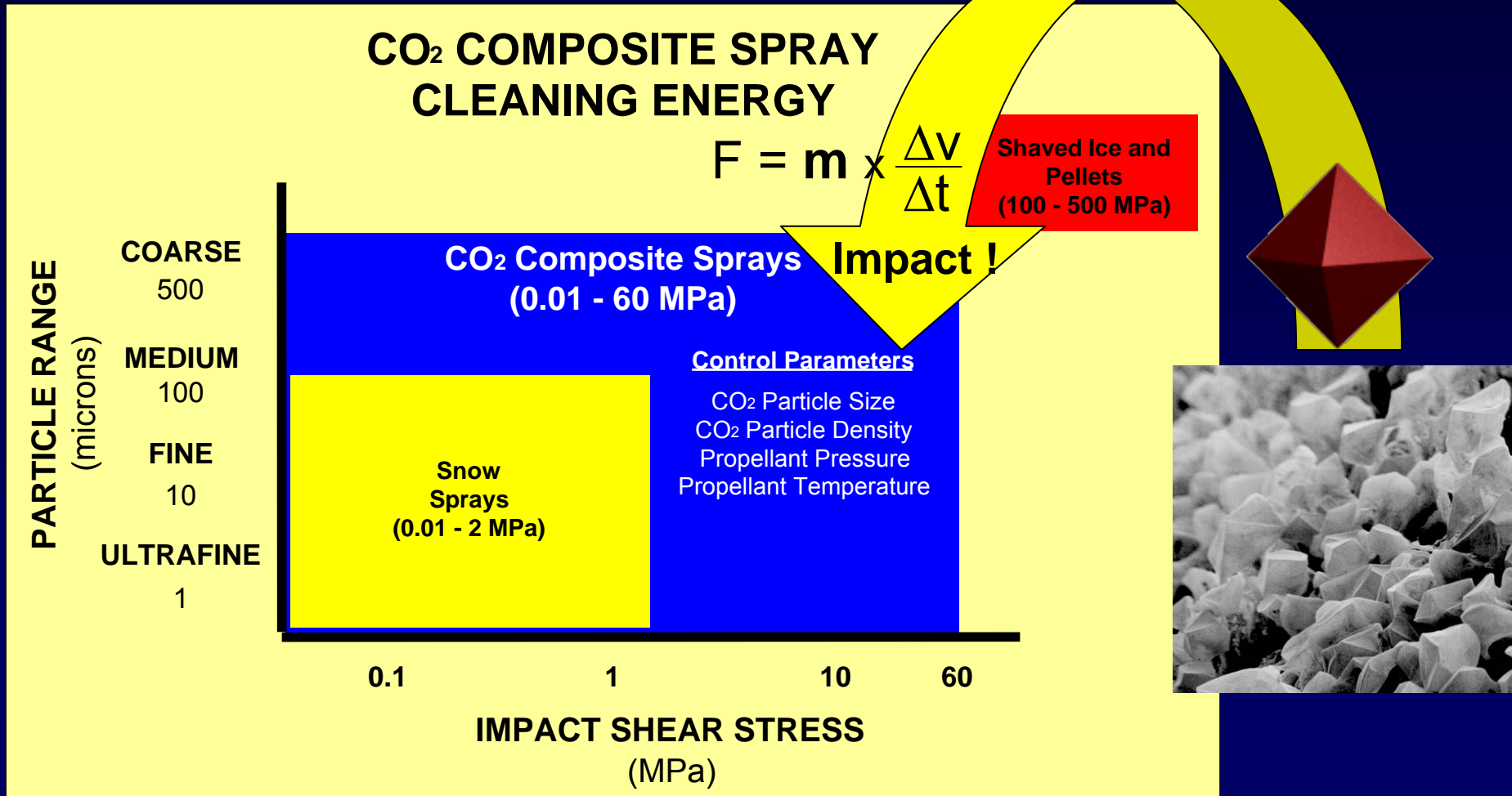
- ✓ CO₂ “snow” particles are *too small* and can't deliver the shear stress required to dislodge resistive contaminants.
- ✓ CO₂ snow sprays are *too dense and cold (- 80 F)*, which tends to shield/freeze surface contamination (“Igloo Effect”).
- ✓ CO₂ snow sprays discharge at a *high pressure* (800+ psi) that can damage structures at close proximity (needed for cleaning effectiveness with small particles).



CO₂ composite spray technology is better suited to the contact cleaning task... Why ?

First... Variable Particle Size and Density

Adjustable compositions of lean (high freq. impacts) energetic CO₂ particles (size control) and heated propellant gas...at low spray pressures (10 -120 psi).



Second... Spray Composition Control

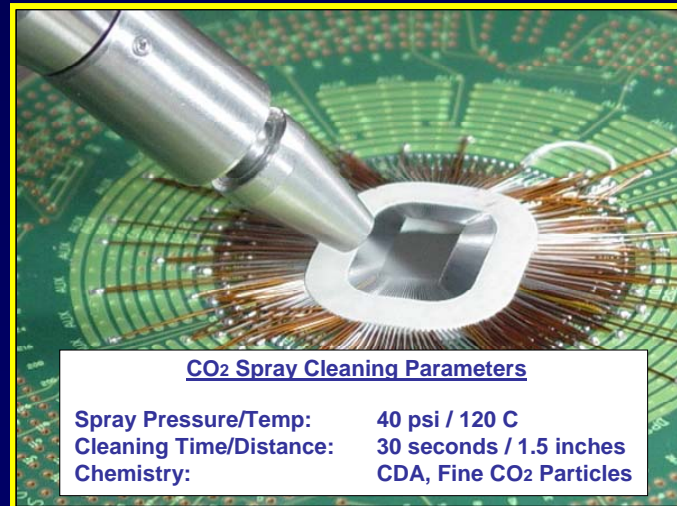
Additive(s)
(Chemical/
Physical)

Gas
(Propulsion/
Heating)



Chemical
Thermal
Mechanical

CO₂
→



Particle Size
Chemistry
Spray Density
Temperature
Pressure
Distance/Angle
Time

Third...Process Enhancement Tool



CO₂ composite sprays easily adapt to and augment an existing probe maintenance program to increase overall cleaning process efficiency and effectiveness

Existing Cleaning and Inspection Process

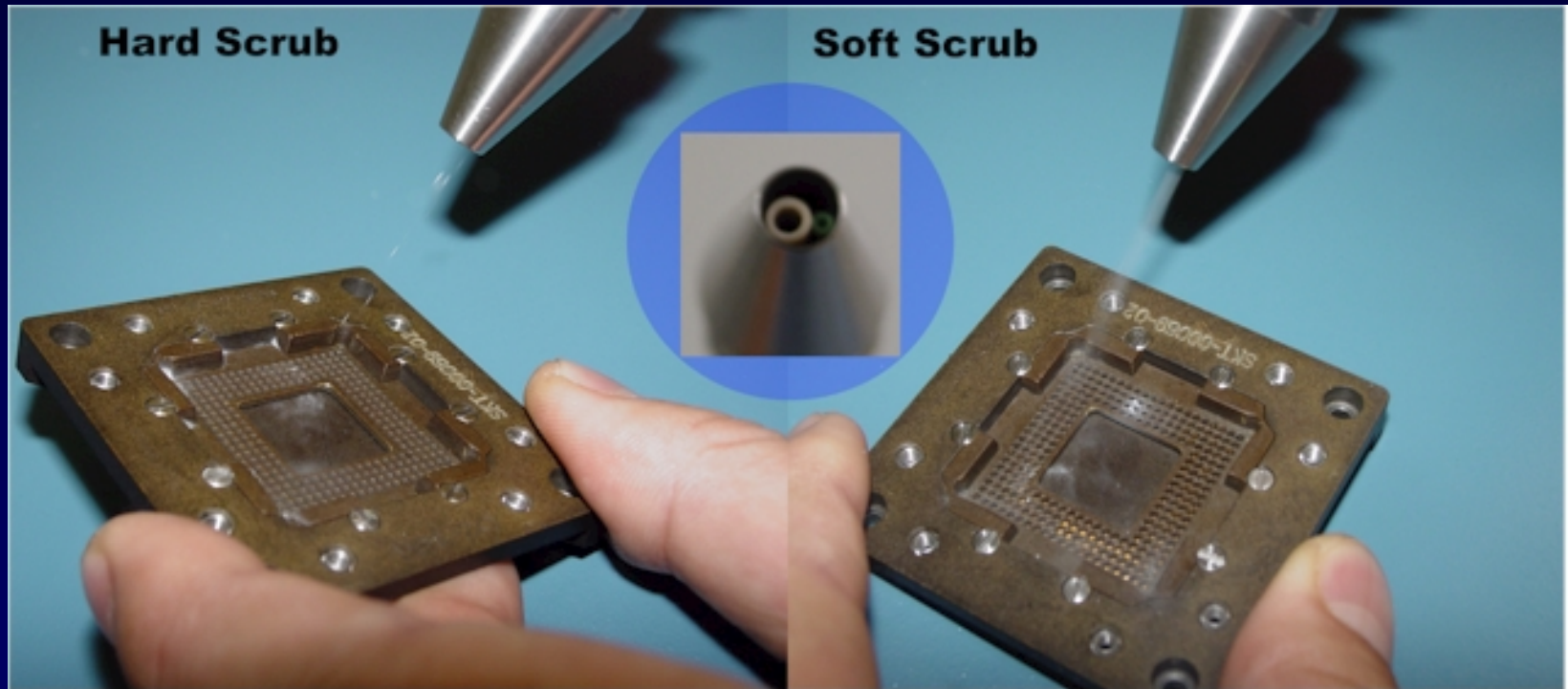
Composite sprays are additive without being mechanically destructive (energy control)...

CO₂ Composite Spray Technology



- Capillary condensation for particle size control
- Micro-metered mass flow for precise spray density control
- Clean hot propellant gas for pressure and temperature control
- Coaxial and Coanda composite spray nozzles
- Chemical co-solvents easily employed
- Hybrid CO₂ composite spray treatments - Microabrasives, Laser, Atmospheric Plasma, Chemical Adjuncts, **Brush**

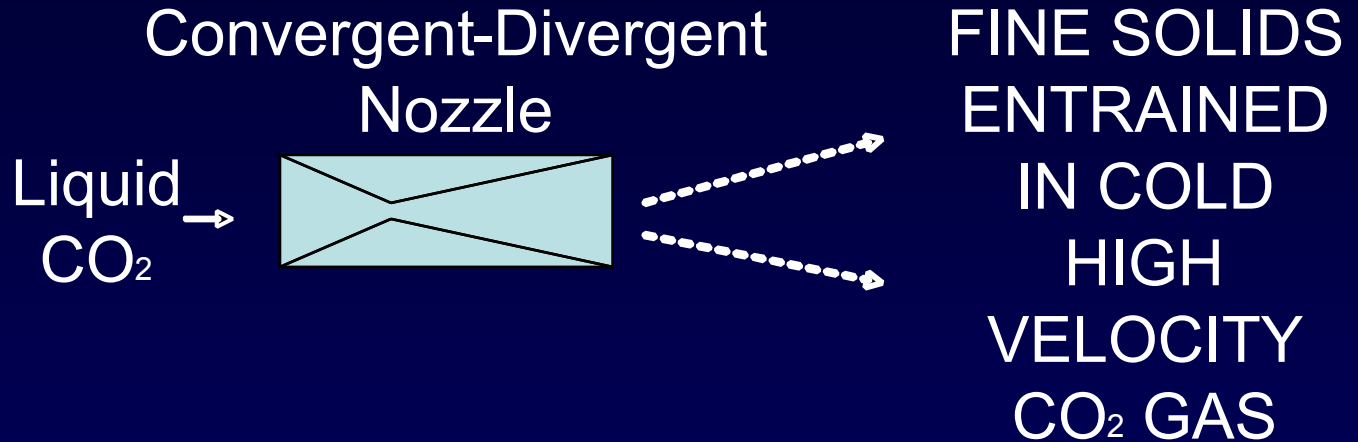
CO₂ Composite Spray Technology



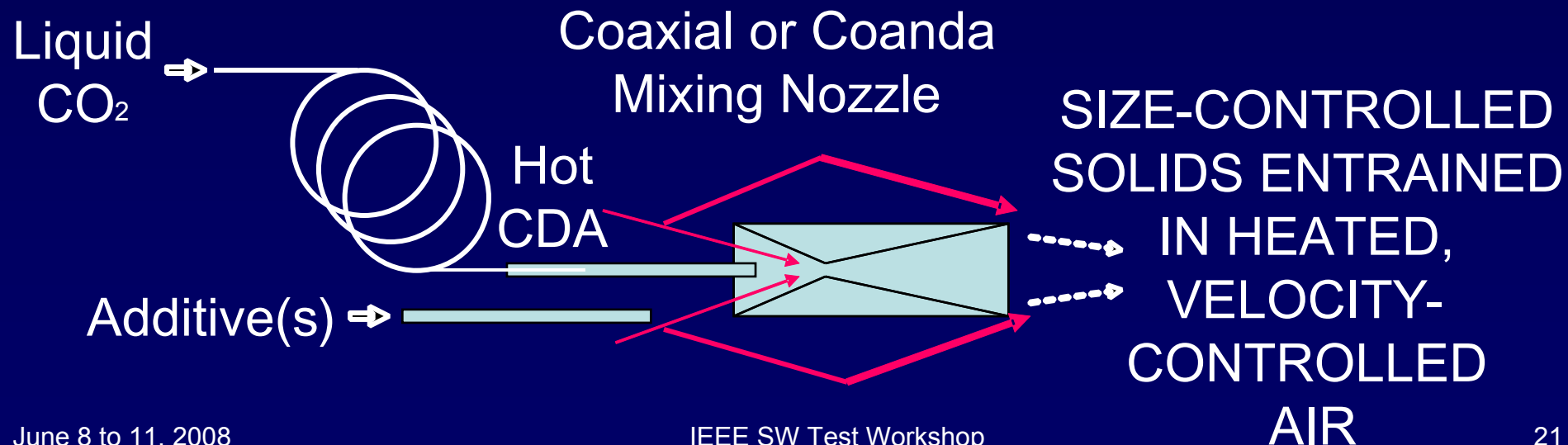
Lean Composite CO₂ Sprays, used in cooperation.

CO₂ Composite Spray Technology

SNOW SPRAYS (Conventional)



COMPOSITE SPRAYS



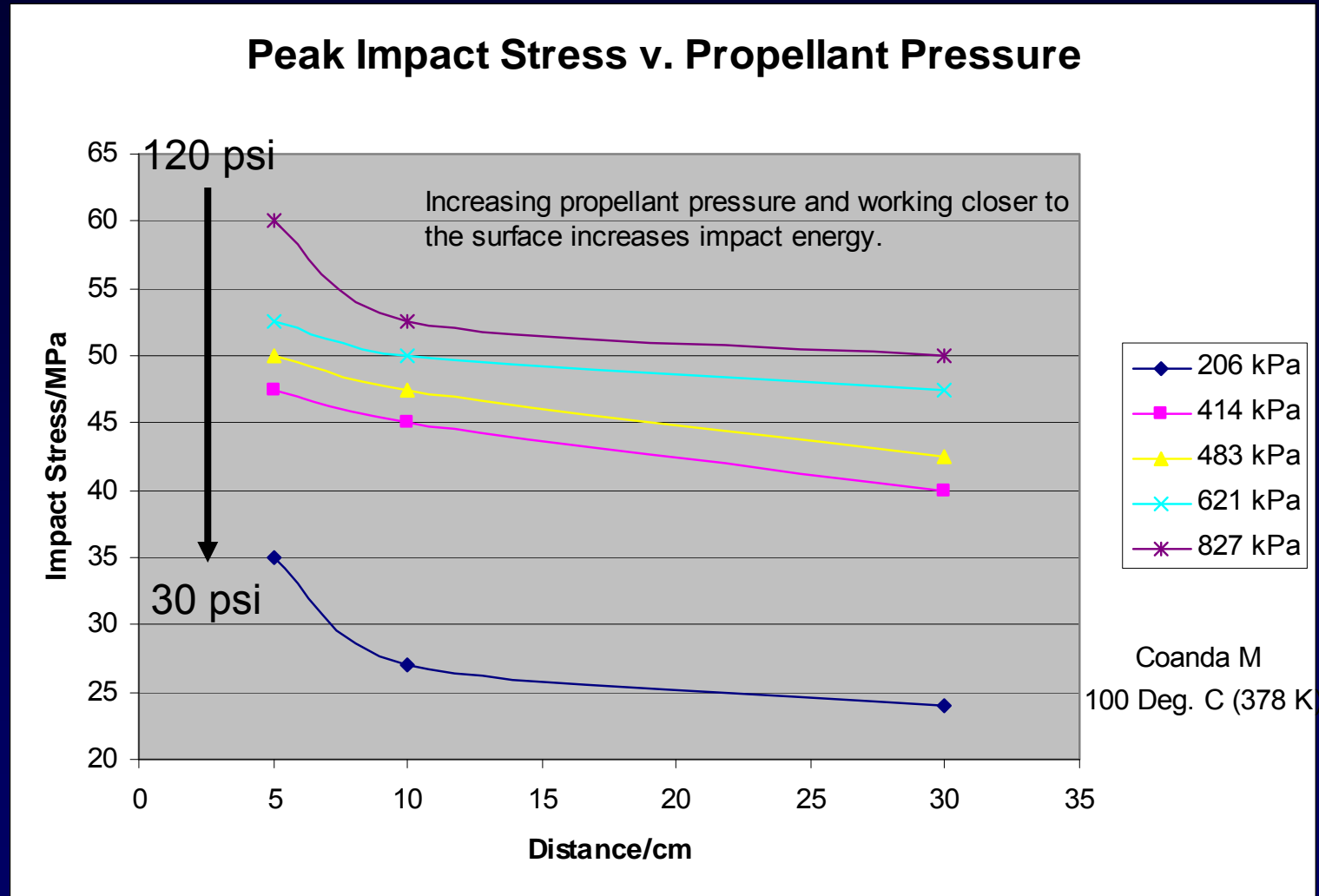
CO₂ Composite Spray Technology

Mechanical and Tribo-Chemical Cleaning Actions

CO₂ composite spray cleaning process effectiveness and efficiency is controlled by:

- ✓ Particle velocity
- ✓ Particle mass/size
- ✓ Spray chemistry
- ✓ Particle hardness (fine → coarse)
- ✓ Particle shape (angular is better (stress conc.))
- ✓ Impact frequency
- ✓ Spray distance
- ✓ Time

CO₂ Composite Spray Technology



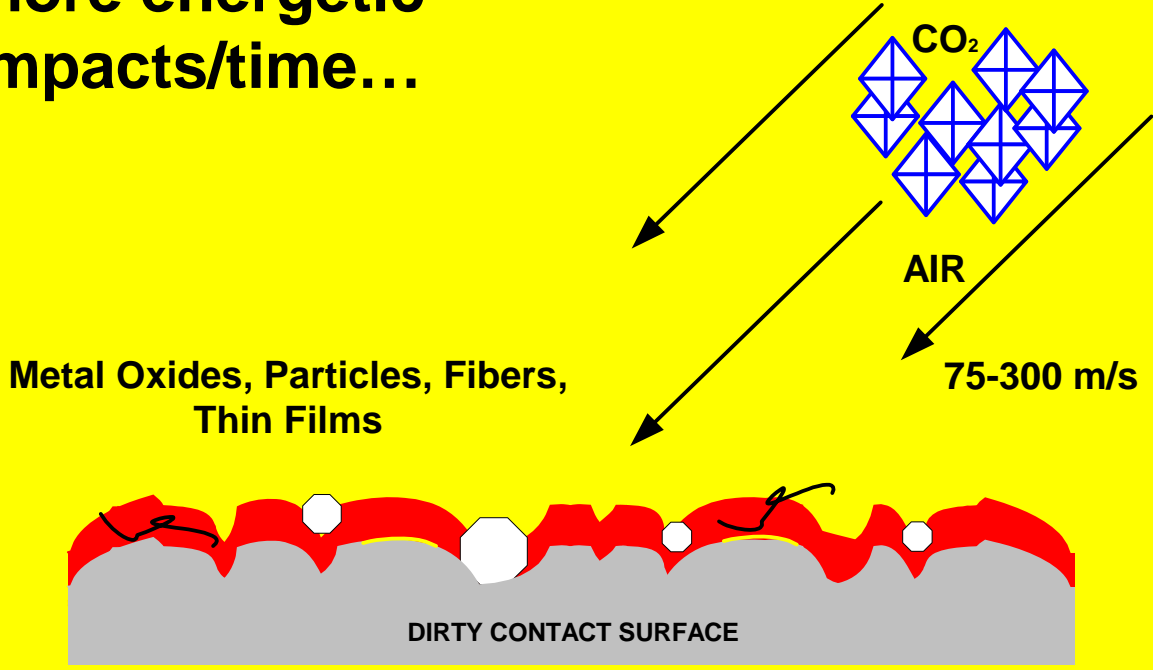
CO₂ composite spray cleaning energy varies with pressure, temperature, particle size and additive energy...

CO₂ Composite Spray Technology

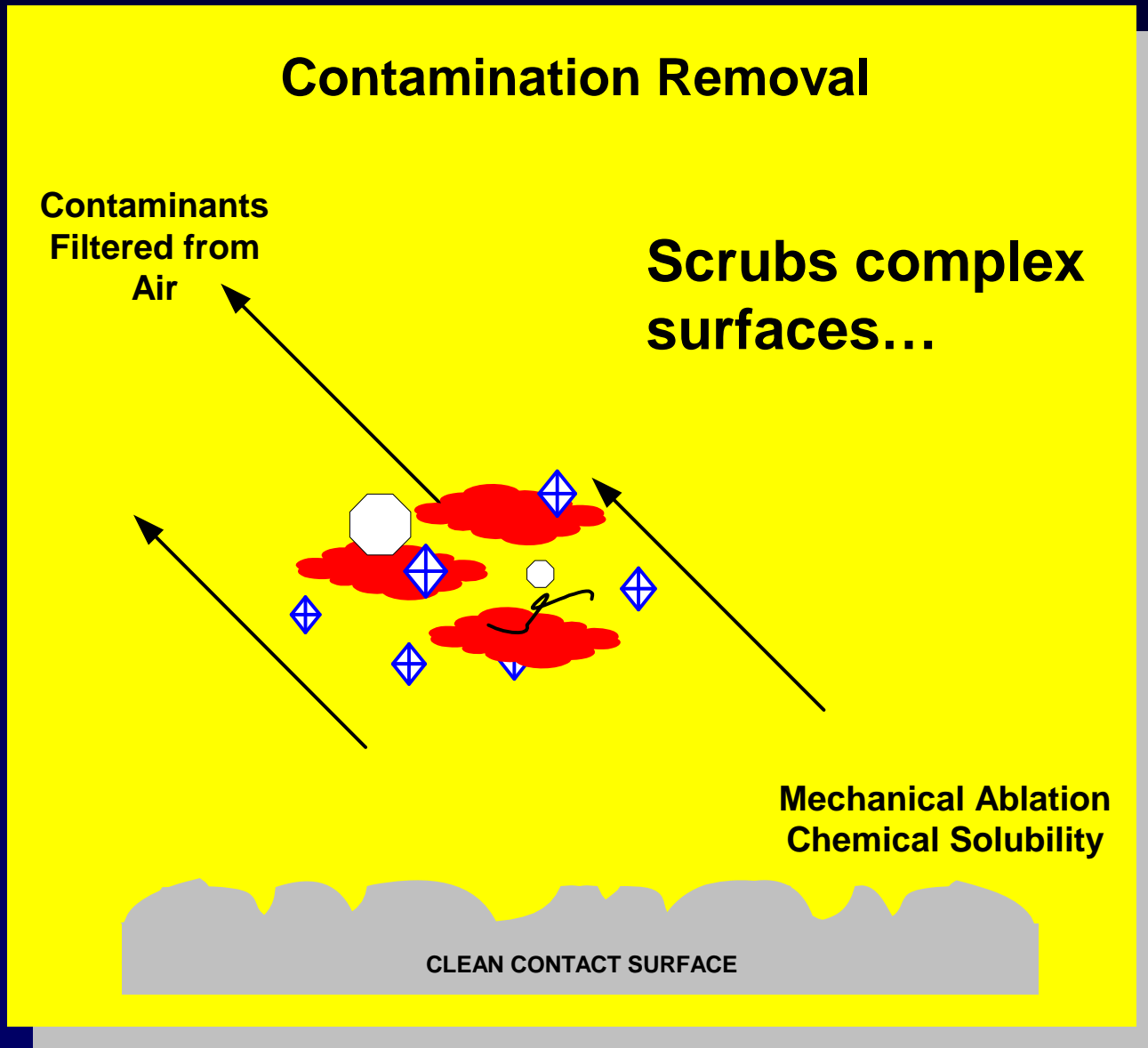
Surface Impact

Lean sprays create more energetic impacts/time...

Adjustable Particle Size, Velocity, and Spray Density
(2-Phase Flow)



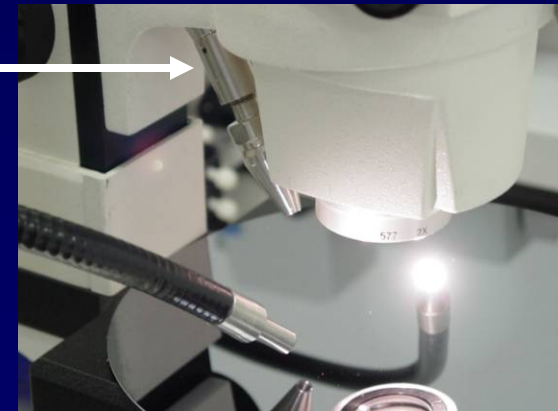
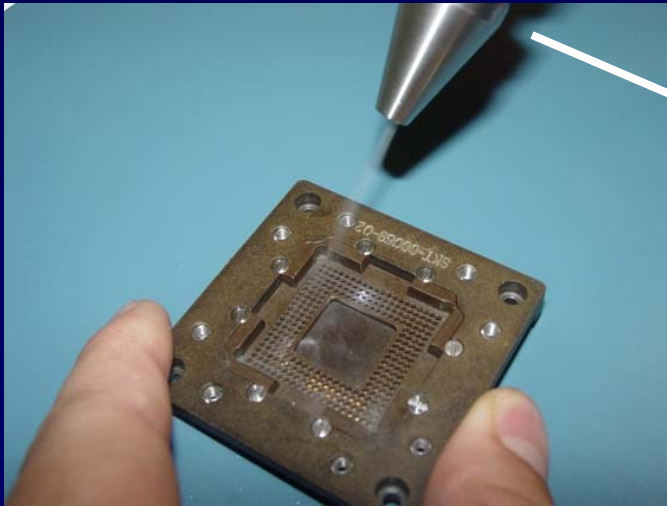
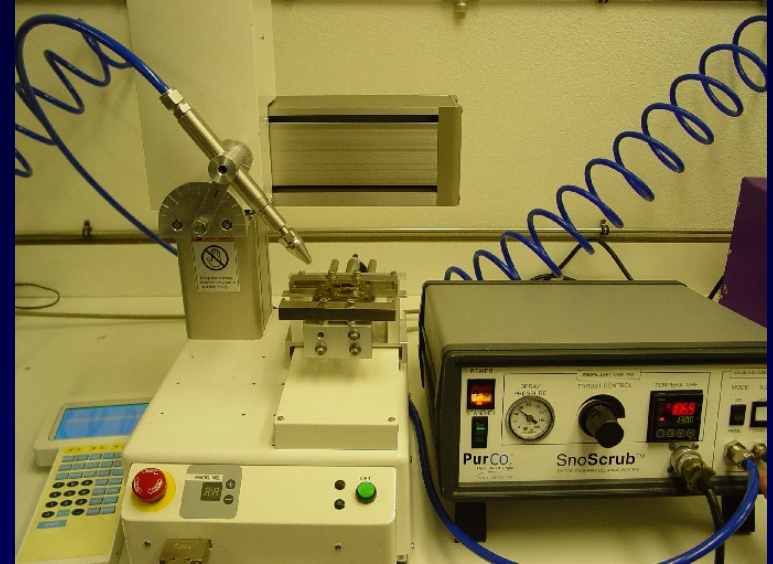
CO₂ Composite Spray Technology



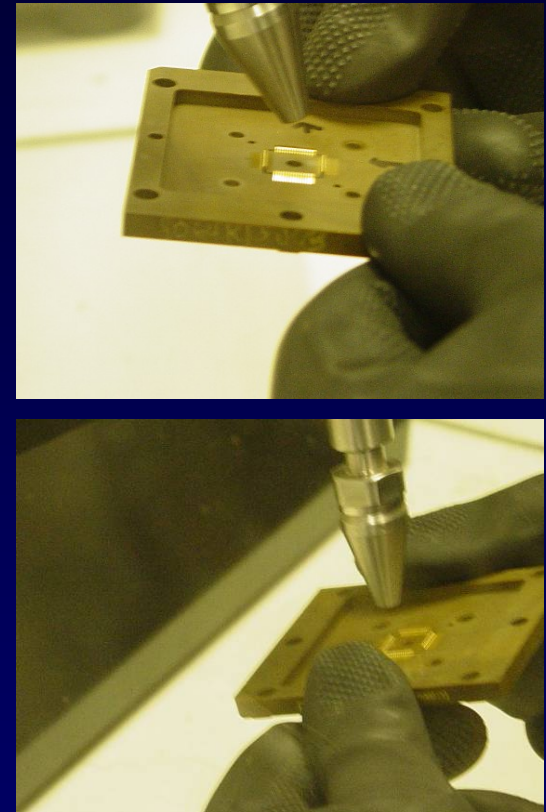
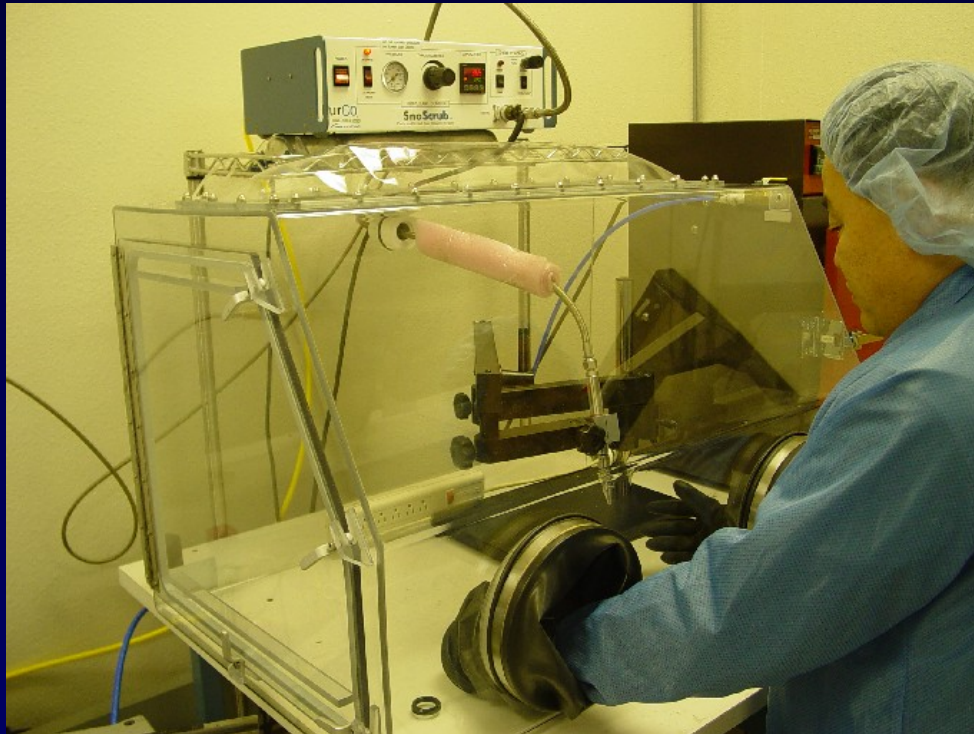
CO₂ Composite Spray Cleaning System

Several CO₂ composite spray cleaning methods and processes under development for probe cards (and test sockets)...

Manual – Automated - Hybrids



Cleaning Process Development

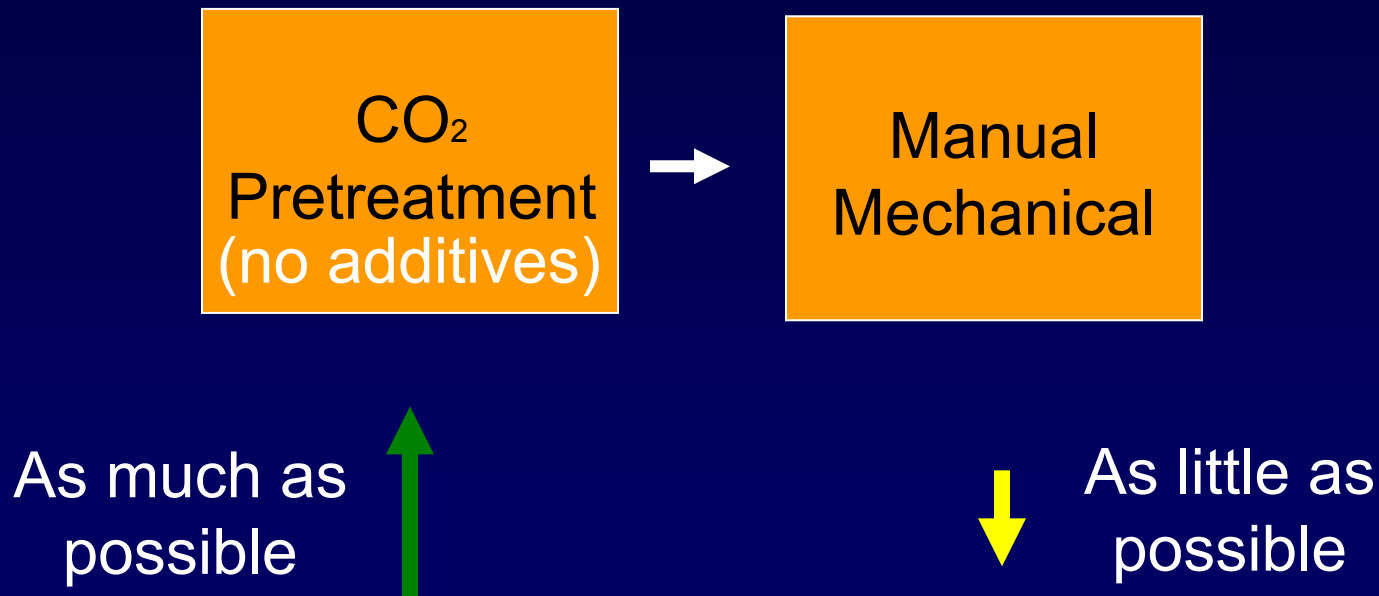


R&D System at customer site

Cleaning Process Development

Goal: Minimize or eliminate direct contact cleaning.

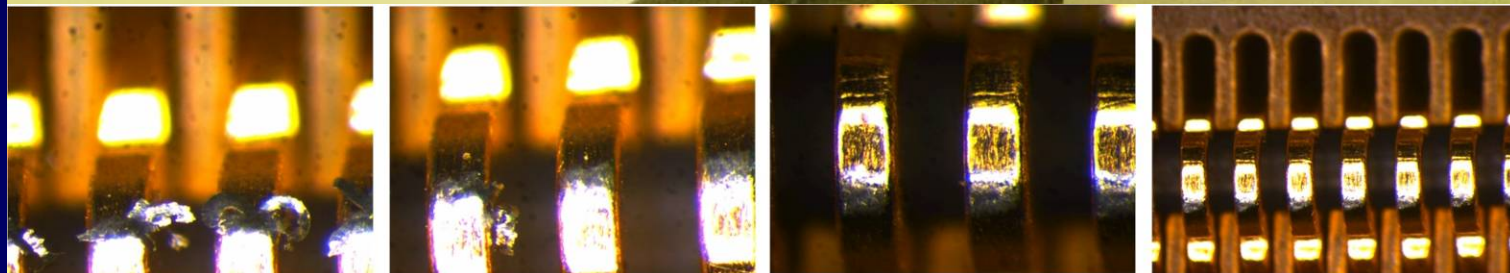
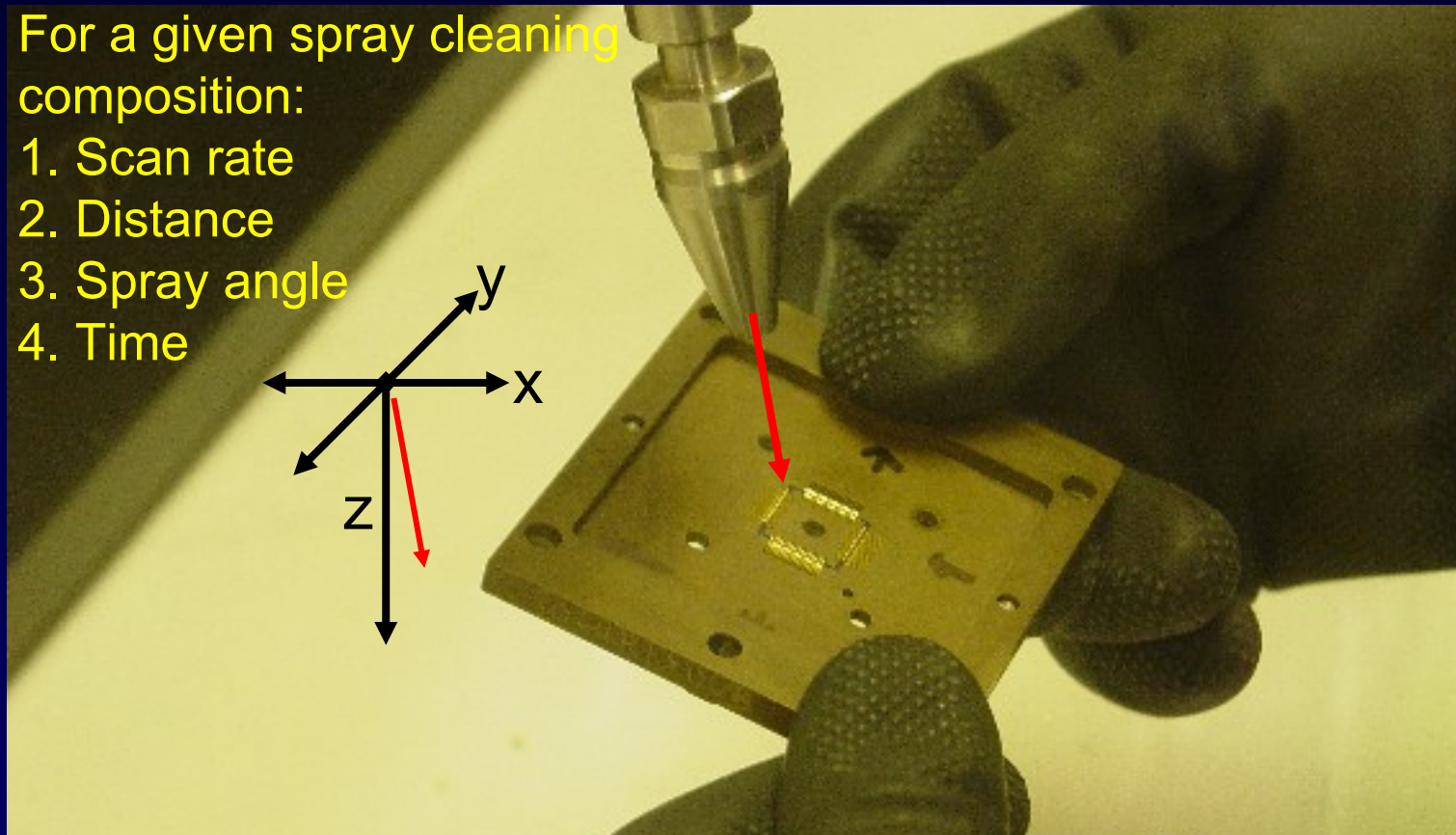
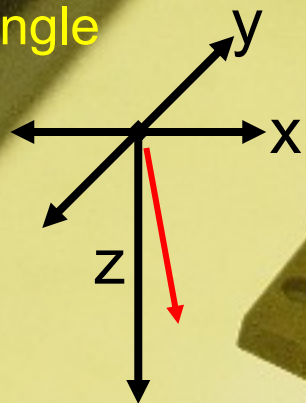
Clean-during-Inspection



Cleaning Process Development

For a given spray cleaning composition:

1. Scan rate
2. Distance
3. Spray angle
4. Time



Cleaning Process Development

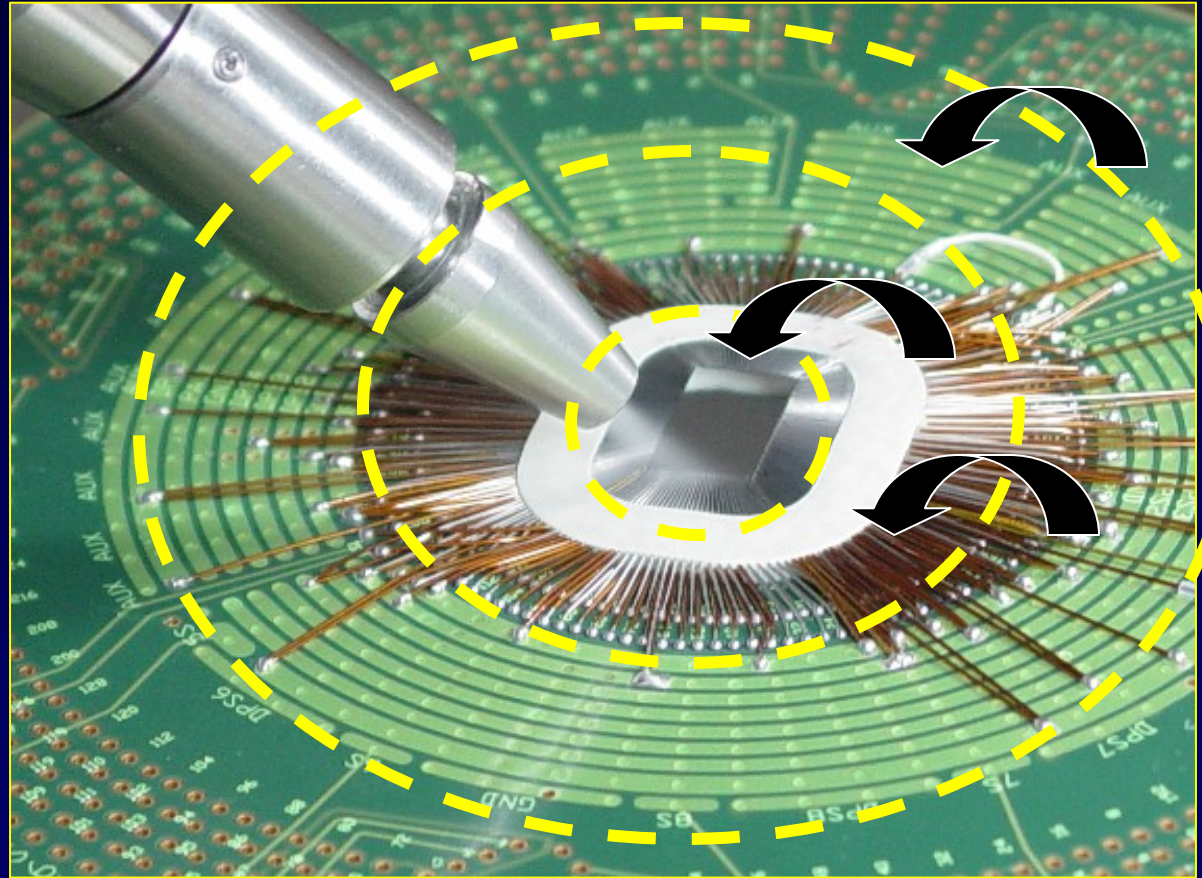
What should be cleaned ?

Best Practice:

Contacts plus
Peripheral Surfaces

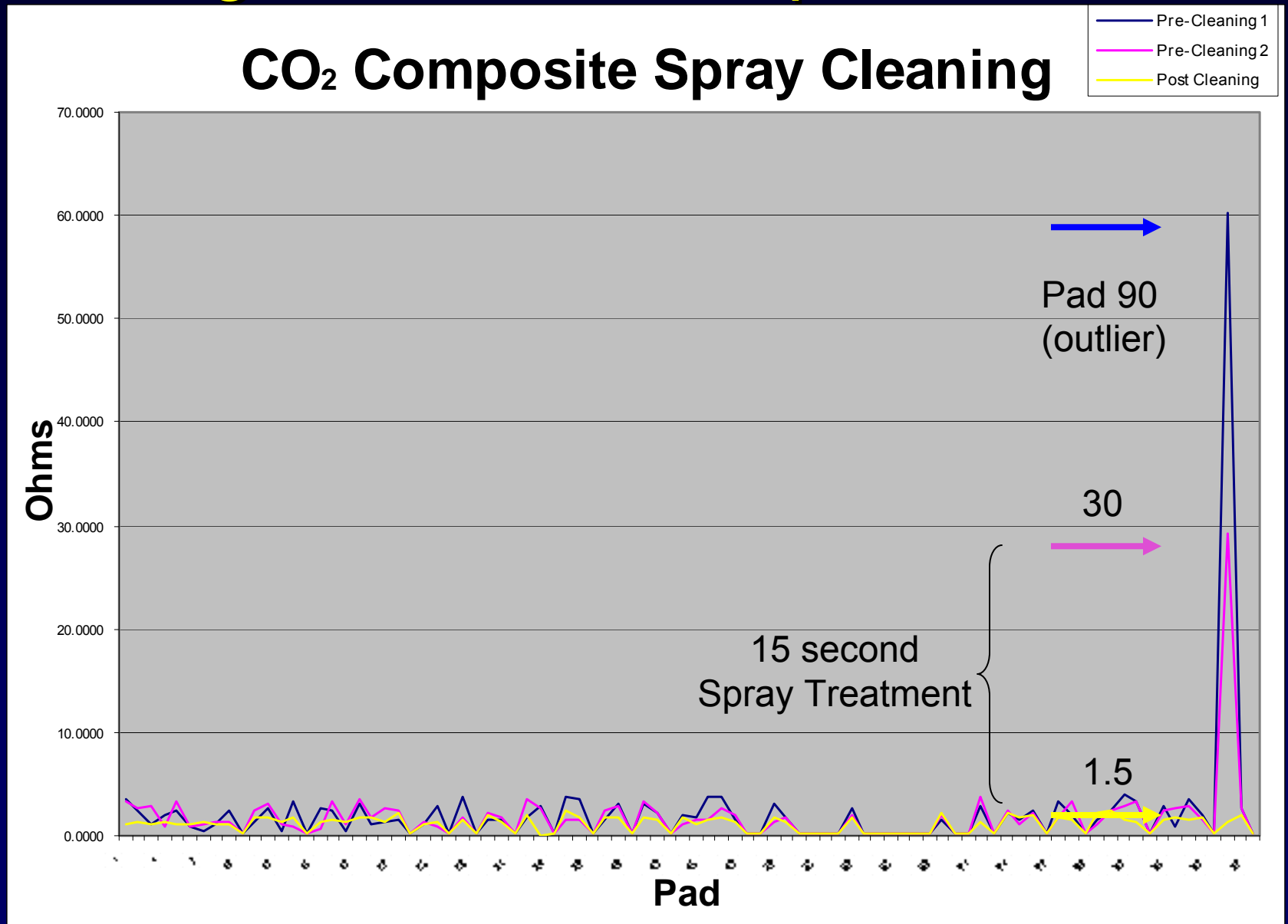
Contamination

migrates through
ES-Fields, thermal
gradients, physical
transfer modes...



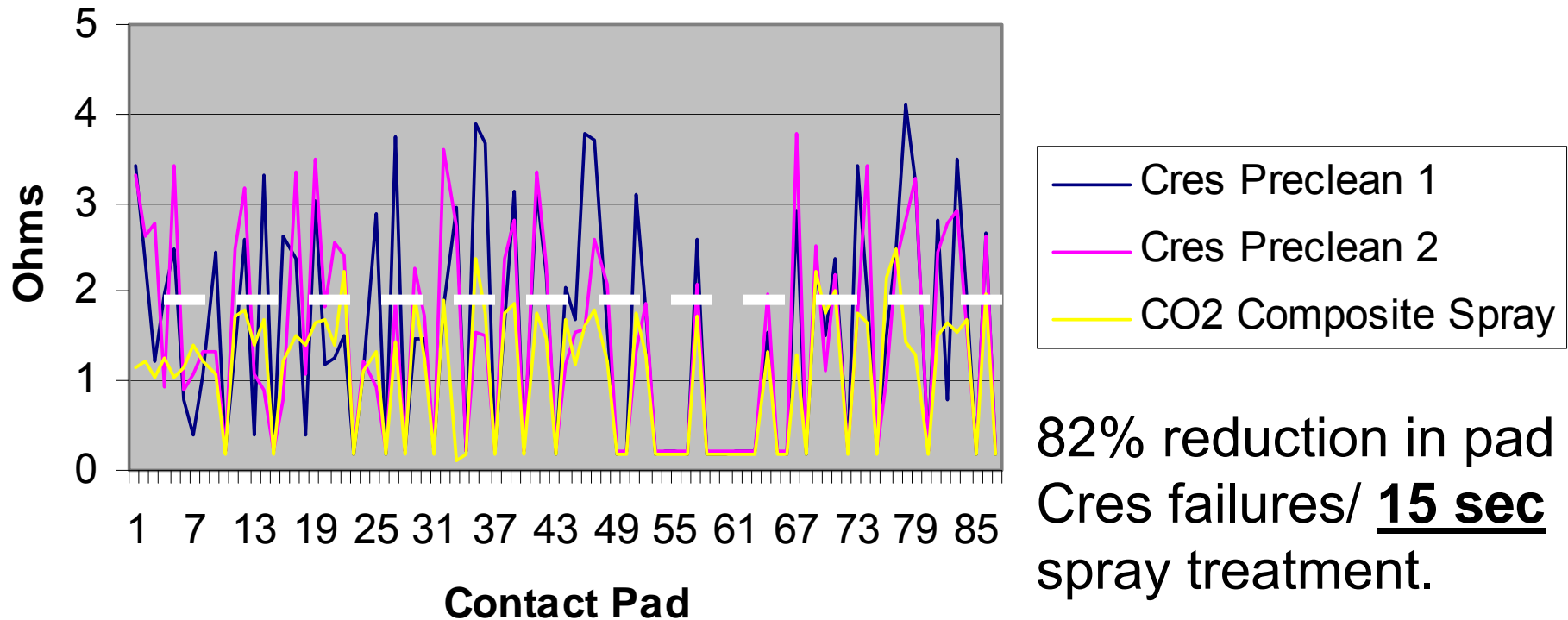
Not cleaning the entire surface creates the
potential for cross-contamination...

Cleaning Process Development



Cleaning Process Development

Pad Cres

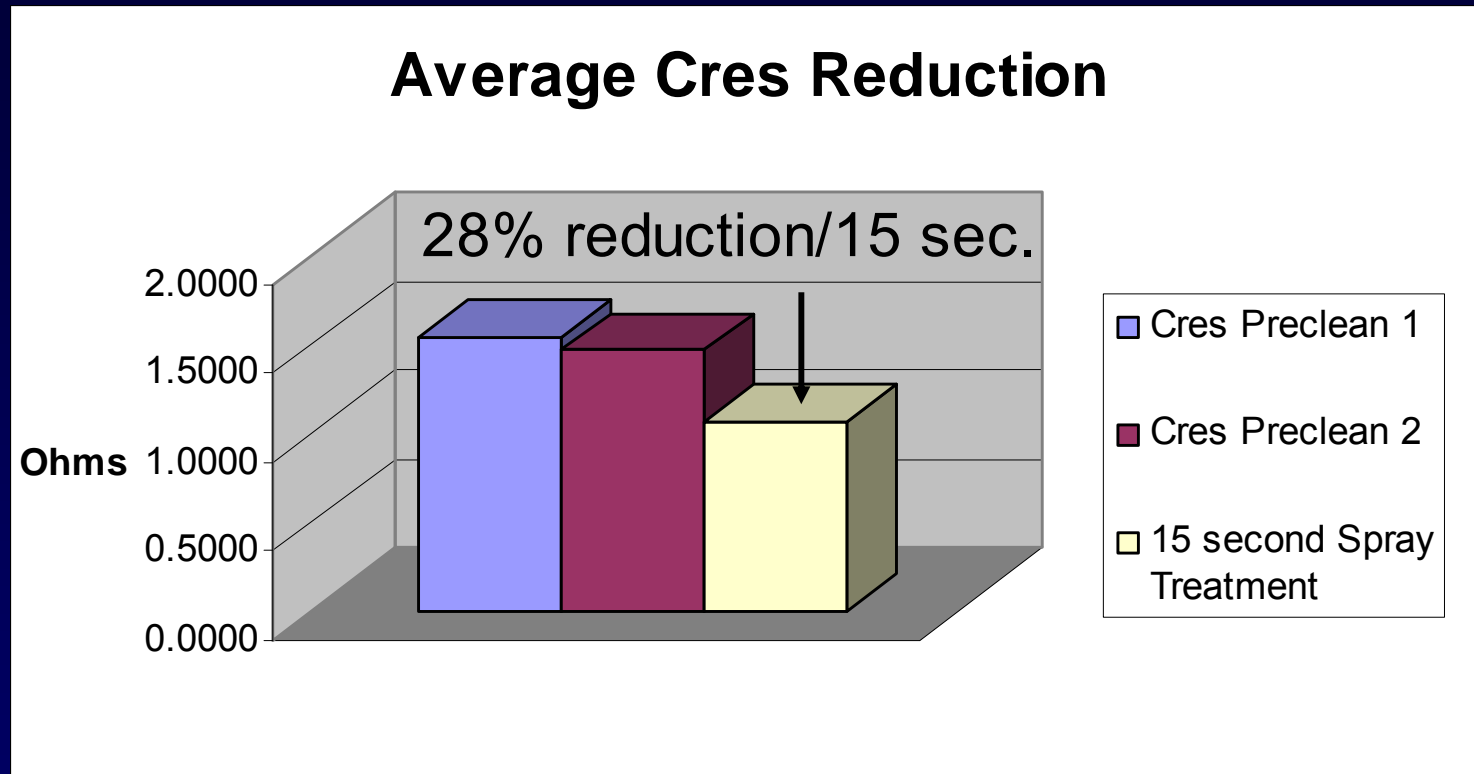


82% reduction in pad
Cres failures/ **15 sec**
spray treatment.

33→6

Outlier data (Pad 90) removed from data set

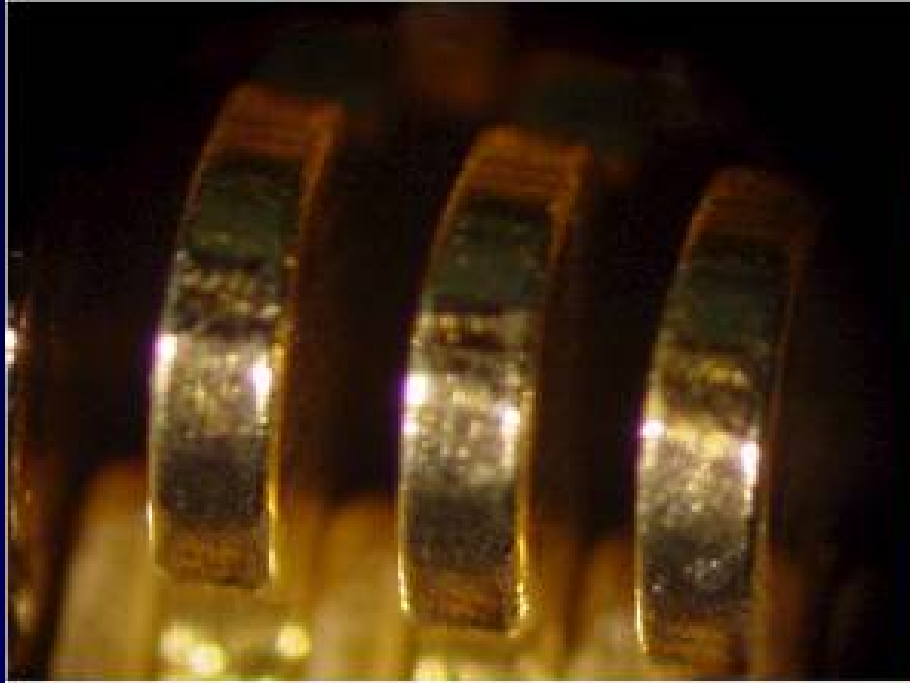
Cleaning Process Development



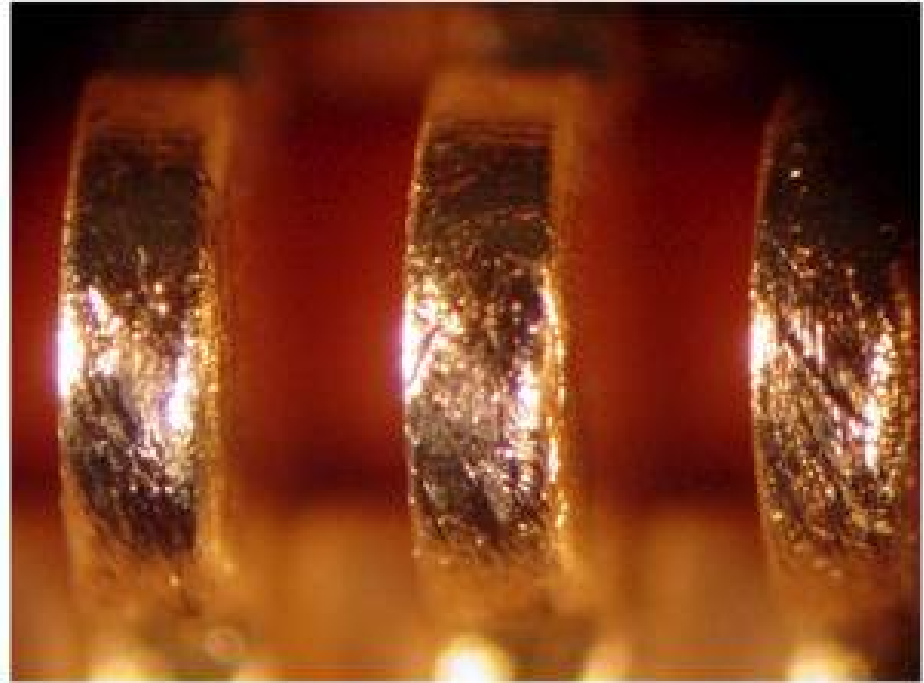
Outlier data (Pad 90) removed from data set.

Cleaning Action

Before



After



Metal Oxides/Solder

Cleaning Spray Parameters:

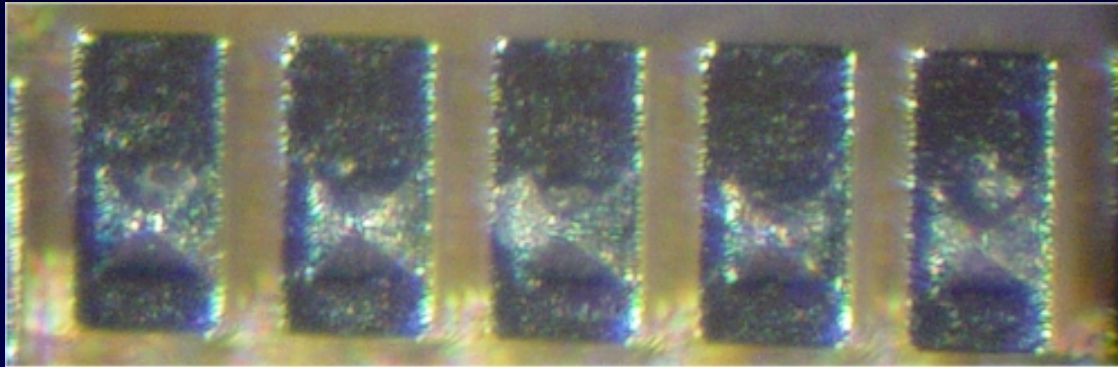
Spray Pressure/Temp: 80 psi/120 C

Cleaning Time/Distance: 1 minute/1 inch

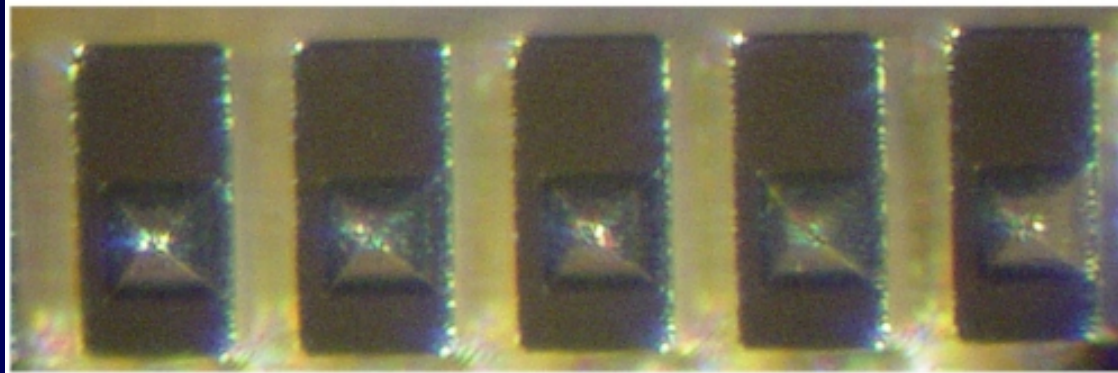
Chemistry: CDA, Coarse CO₂ Particles

Cleaning Action

Before



After



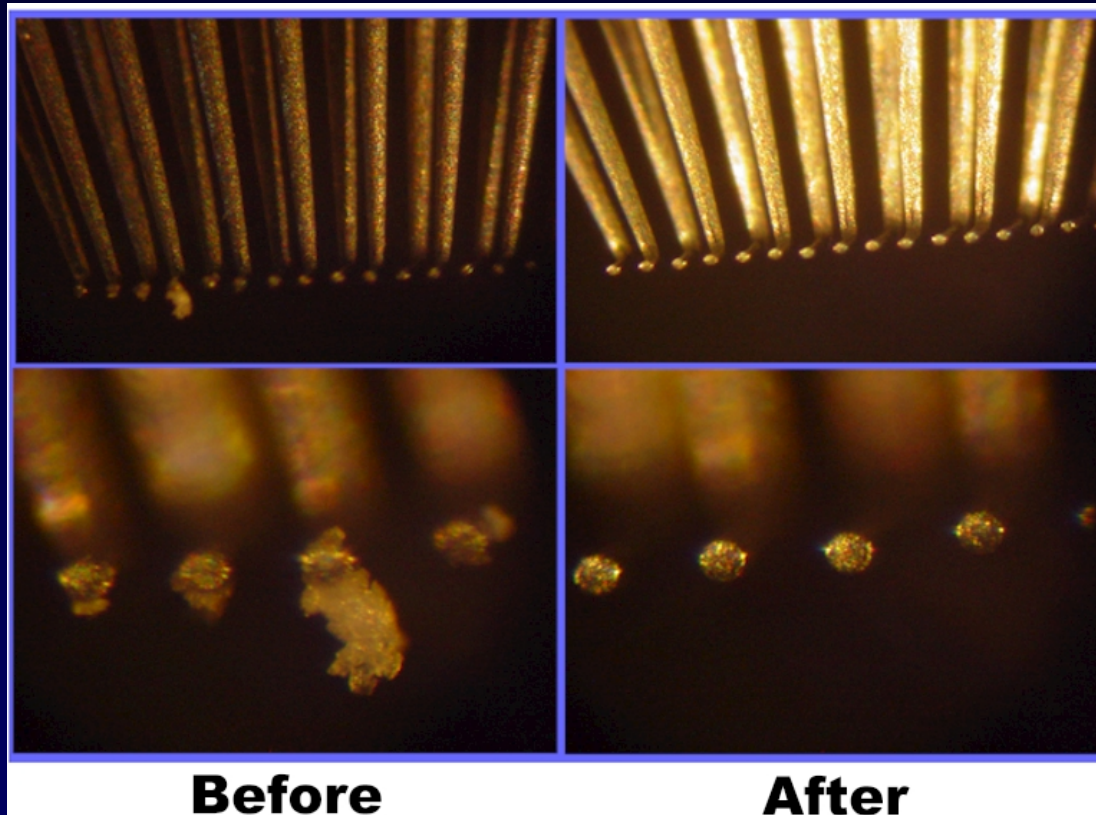
Aluminum/ Al_2O_3

Cleaning Spray Parameters:

Spray Pressure/Temp: 70 psi/120 C
Cleaning Time/Distance: 3 minutes/2 inches (robotic process)
Chemistry: CDA, Fine CO_2 Particles

Cleaning Action

Metal Oxides
and Solder
Flux



Cleaning Spray Parameters:

Spray Pressure/Temp: 40 psi/120 C
Cleaning Time/Distance: 30 seconds/1.5 inches
Chemistry: CDA, Fine CO₂ Particles

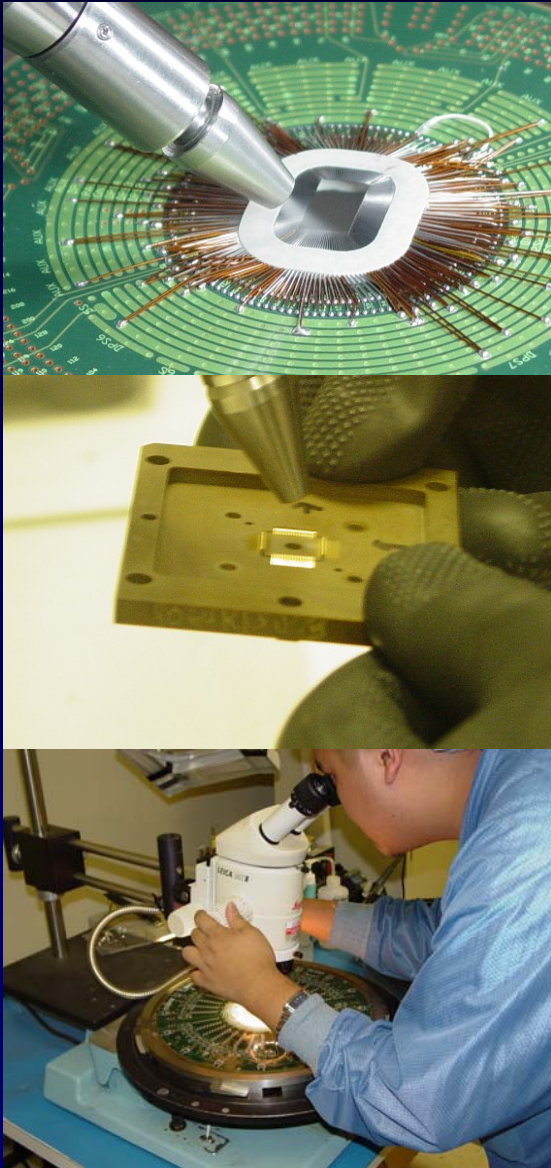
Cleaning Cost Reduction



Existing Process:

- Easy to get lost under scope
- Surface contamination remains in complex topography (crevices)
- Potential physical damage to surfaces with brush
- Time intensive

Cleaning Cost Reduction



New Process:

In combination with CO₂ pretreatment:

- ✓ Significant reduction in maintenance labor
- ✓ Cleaner surfaces... *faster*
- ✓ Much less direct contact
- ✓ Much less physical damage

Wrap-up

- Composite CO₂ sprays are fully adjustable and provide quick, clean, and non-destructive contact cleaning.
- Worker- and equipment-safe cleaning process.
- Adaptable to existing cleaning processes. Minimizes manual cleaning, potential to replace mechanical contact treatments.
- Low cost-per-clean with a significant contact maintenance labor (time) reduction potential.

Questions ?

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<http://www.purco2.com>