ONDA

Putting Confidence in Ultrasound

Measurement Techniques to Characterize an Ultrasonic or Megasonic Cleaning System

UIA Symposium, Orlando, FL

0NDA Corporation

www.ondacorp.com

April 23, 2013

Ultrasonic Cleaning Market

- 1930’s - RCA discovers ultrasound can clean
- 1950’s - commercialization of ultrasonic cleaner
- Cleaning Tank Install Base – “hundreds of thousands”
- Market Segments
  - Precision: semiconductors, disk drives, LEDs, flat panel displays, solar, mobile, or other electronic devices, medical.
  - General: jewelry, food, aerospace, automotive, other industrial components
- Search for a reliable measurement technique has existed for decades … and continues today.

Connecting Ultrasound with Cleaning

Process Variables

Ultrasound

Gas concentration

Chemistry

Mechanical

Temperature

Flow rate

Process Time

Metrology Requirements

Acoustic Uniformity

Acoustic Amplitude

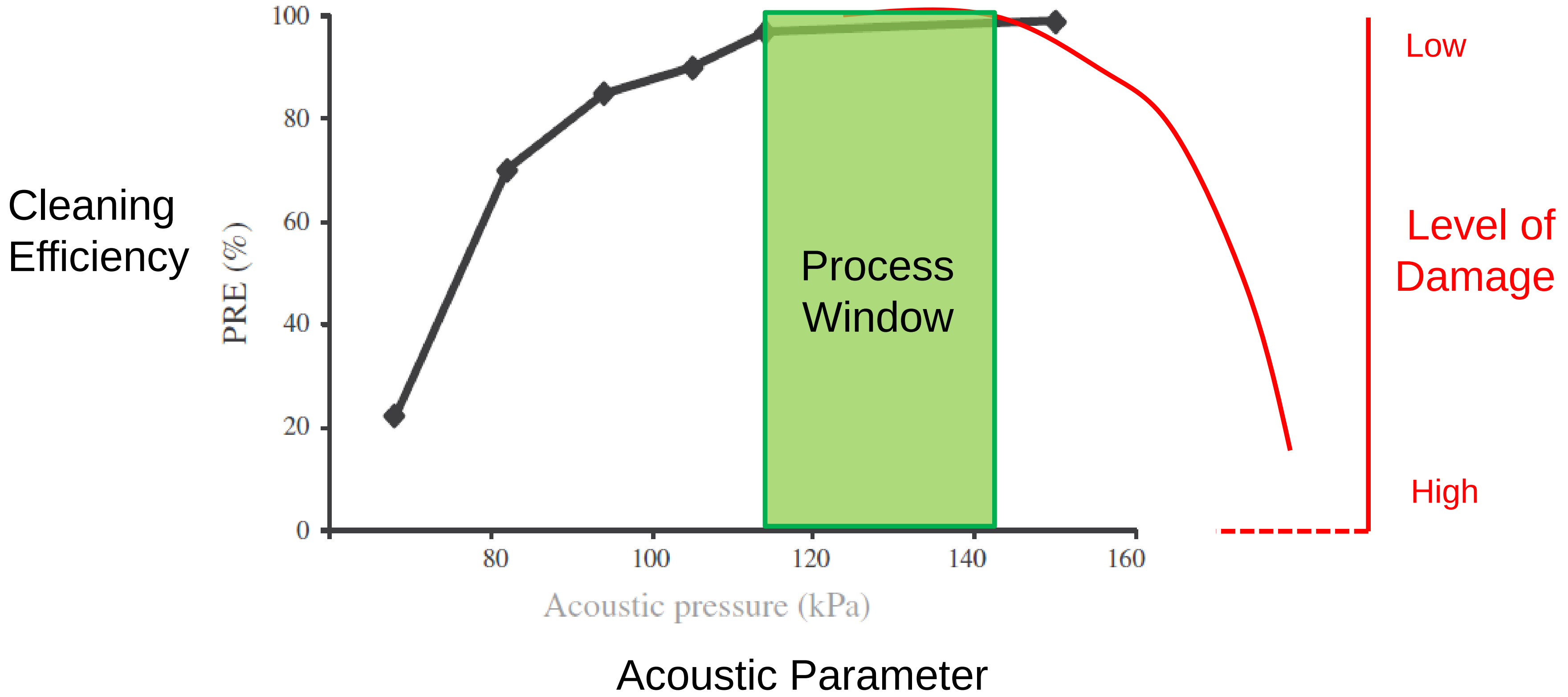
Frequency

Yield Impact

Particle Removal Efficiency

Damage Control

Developing the Process Window



Process Challenge

"The most important process parameter driving the development of megasonic technologies is the need to provide a more ***uniform acoustic field*** in which the substrate is processed."

- Prosys Systems

What is the ideal metrology?

- ❑ Meaningful
- ❑ Able to detect changes
- ❑ Trust-worthy
- ❑ Tool Matching
- ❑ Simple to Use
- ❑ Fast
- ❑ Affordable

Scorecard

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring	Sonolumniscence	Hydrophone	Hydrophone + Scanner
Correlation to Cleaning					
Sensitive					
Repeatable					
Accurate					
Ease of Use					
Throughput					
Process Compatible					
Cost of Ownership					

Optical Defect Inspection

Measurement Principle:

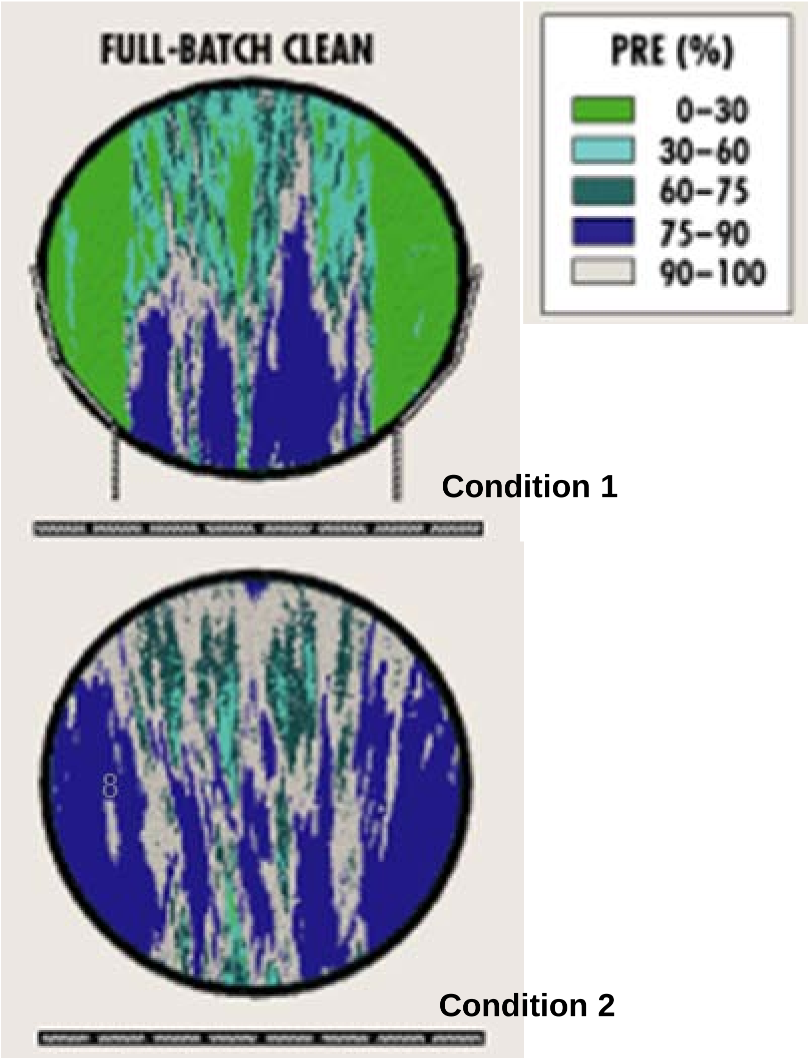
•Scattered light

Unit of Measure(s):

•Defect map

•# of defects

•Particle size



Condition 1

Condition 2

Scorecard

	Optical Defect Inspection
Correlation to Cleaning	√
Sensitive	√
Repeatable	√
Accurate	√
Ease of Use	-
Throughput	√
Process Compatible	√
Cost of Ownership	

Aluminum Foil Test

Measurement Principle:

•Erosion of Aluminum

Unit of Measure(s):

•Visual erosion pattern

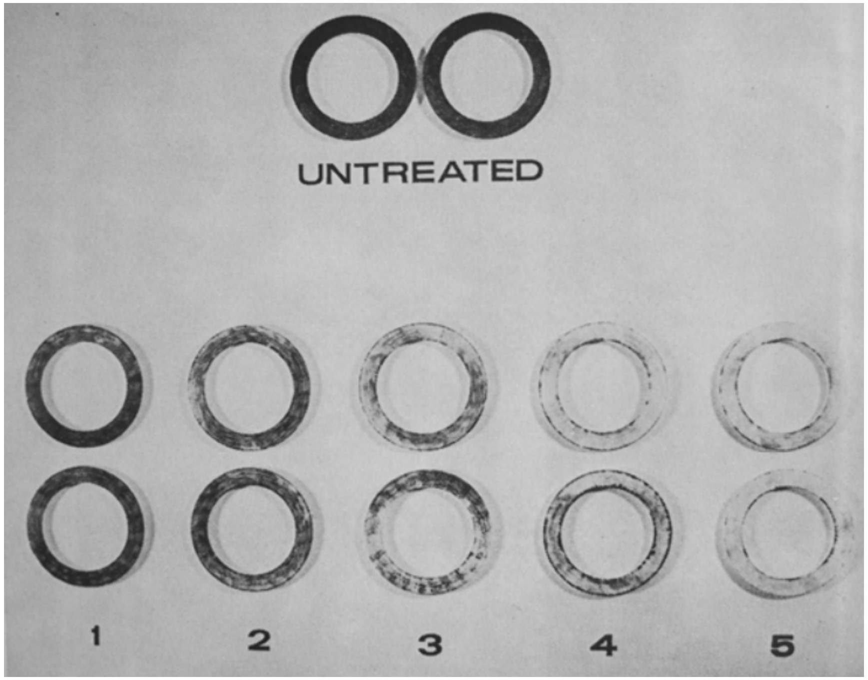
Ceramic Ring Test

Measurement Principle:

•Erosion of graphite on ceramic ring

Unit of Measure(s):

•Visual inspection of color change



Scorecard

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring
Correlation to Cleaning	√	-
Sensitive	√	-
Repeatable	√	-
Accurate	√	
Ease of Use	-	-
Throughput	√	
Process Compatible	√	
Cost of Ownership		√

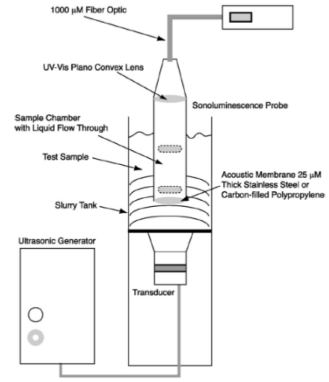
Sonoluminescence

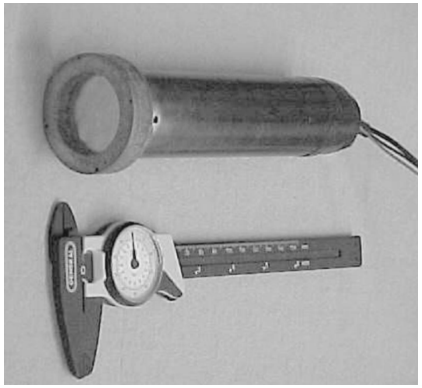
Measurement Principle:

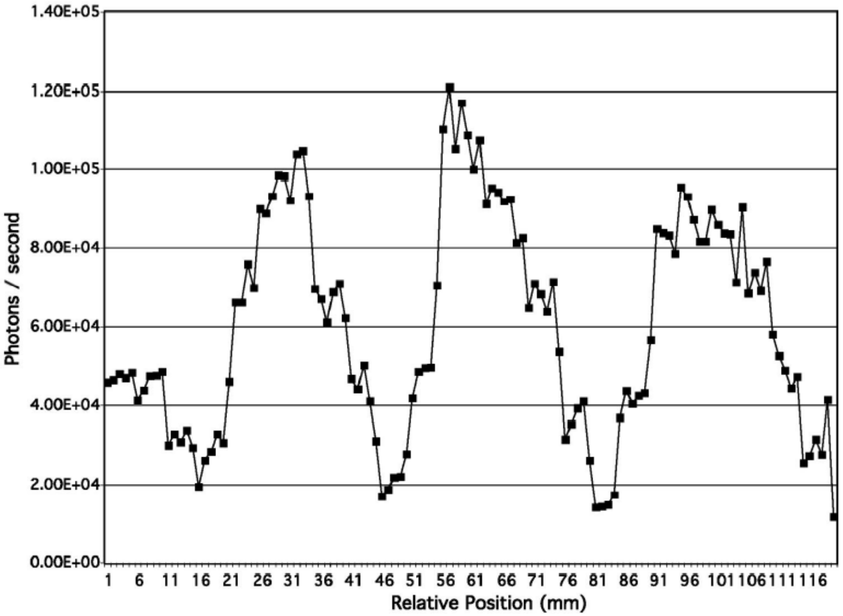
•Detecting photons as byproduct of cavitation

Unit of Measure(s):

•Photon count / seconds





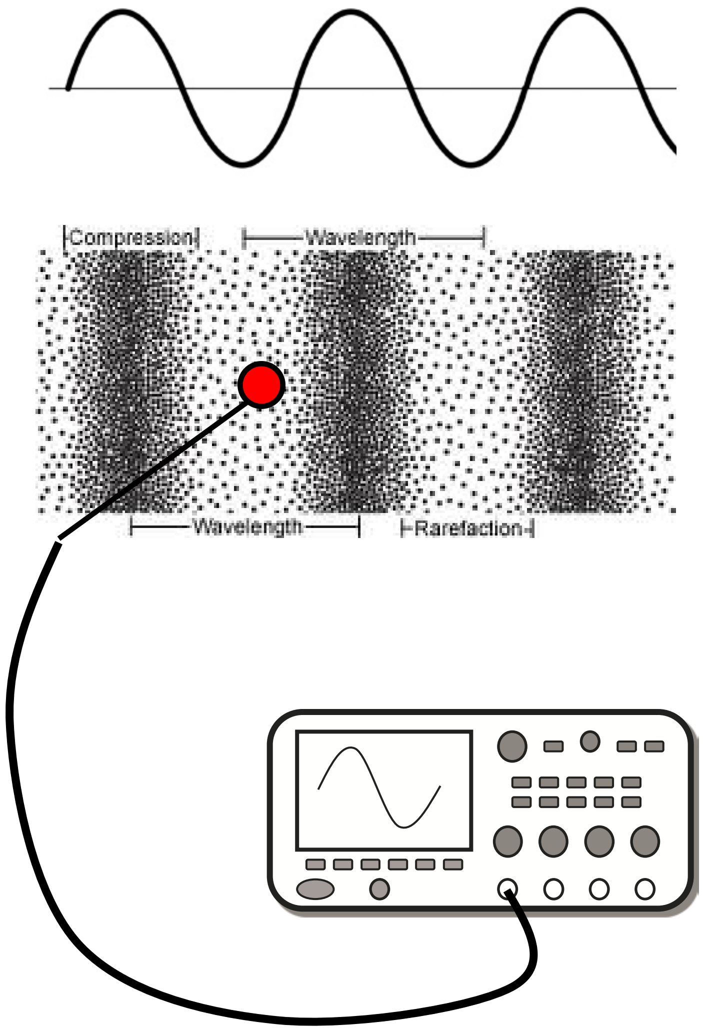


G. Ferrell and L. Crum, J. Acoustical Society June 2002

Scorecard

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring	Sonolumniscence
Correlation to Cleaning	√	-	-
Sensitive	√	-	-
Repeatable	√	-	√
Accurate	√		-
Ease of Use	-	-	-
Throughput	√		-
Process Compatible	√		
Cost of Ownership		√	-

Hydrophone Measurement



Measurement Principle:

- Piezoelectric transducer converts sound pressure into electrical signal

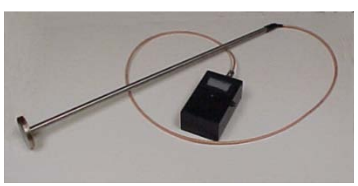
Unit of Measure(s):

- Voltage (time)

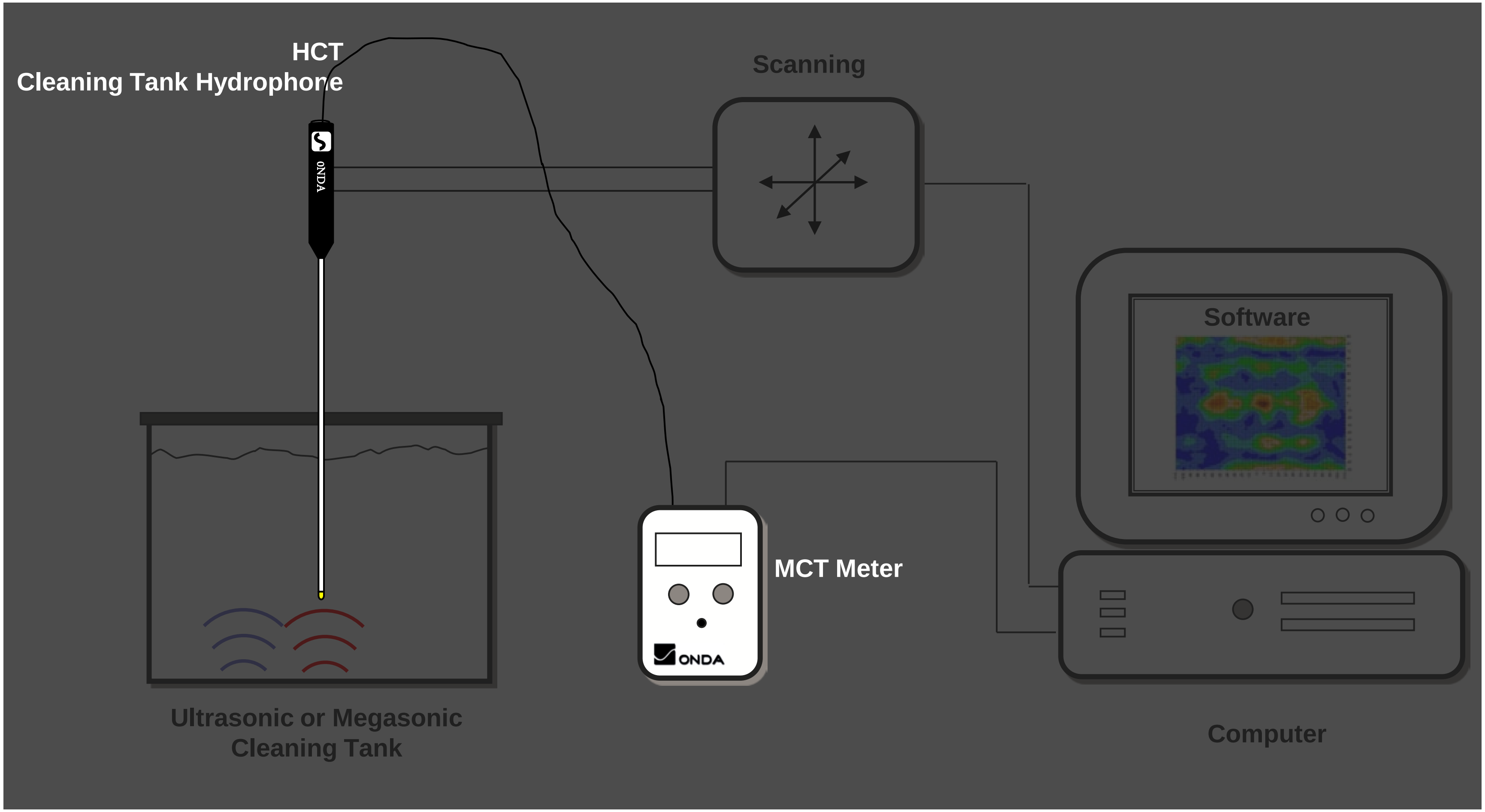
Cleaning Tank Probes

ONDA

NPL
National Physical Laboratory



Hydrophone Measurement



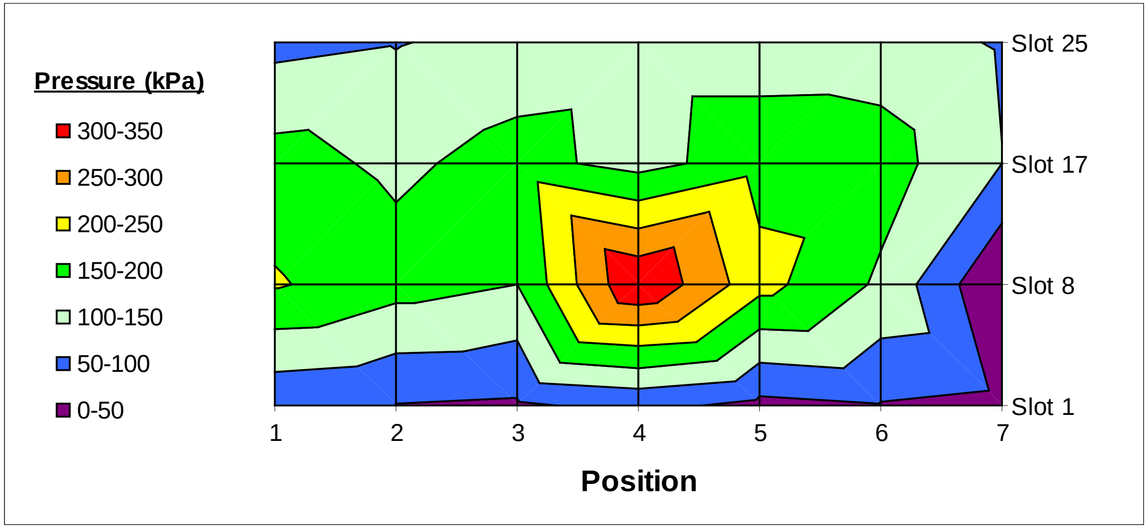
[Not to scale]

Acoustic Maps from Hydrophones

Comparing Two Cleaning Systems, f = 850 kHz

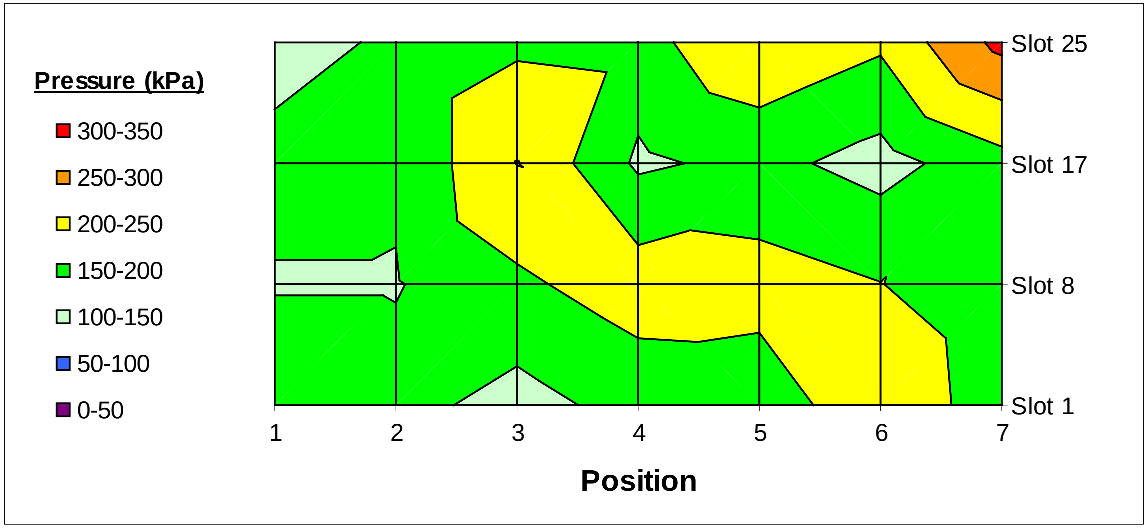
System #1

- Mean Pressure: 174 kPa
- Uniformity: 171%



System #2

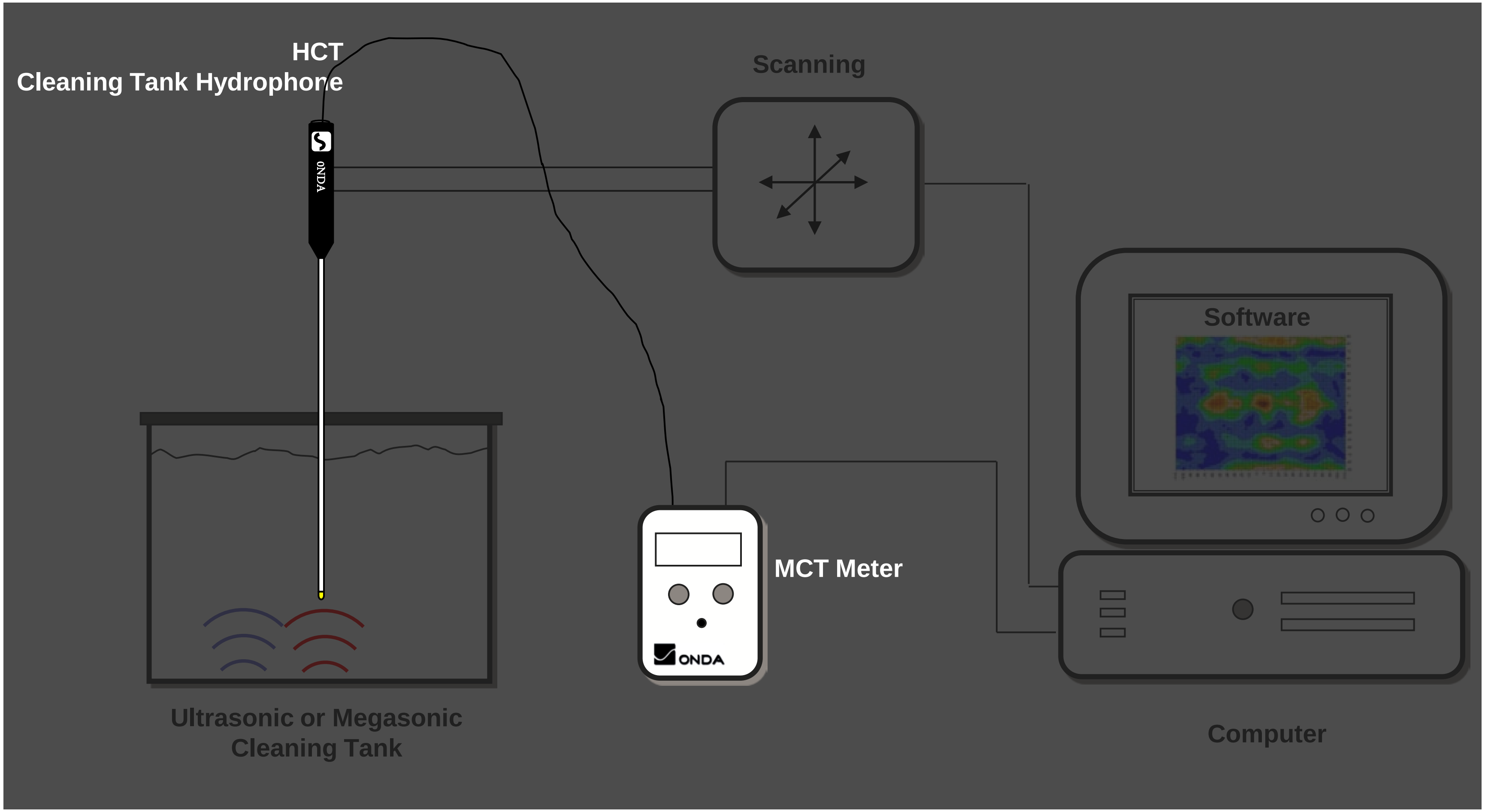
- Mean Pressure: 184 kPa
- Uniformity: 23%



Scorecard

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring	Sonolumniscence	Hydrophone
Correlation to Cleaning	√	-	-	√
Sensitive	√	-	-	√
Repeatable	√	-	√	√
Accurate	√		-	√
Ease of Use	-	-	-	-
Throughput	√		-	-
Process Compatible	√			√
Cost of Ownership		√	-	-

Hydrophone Measurement



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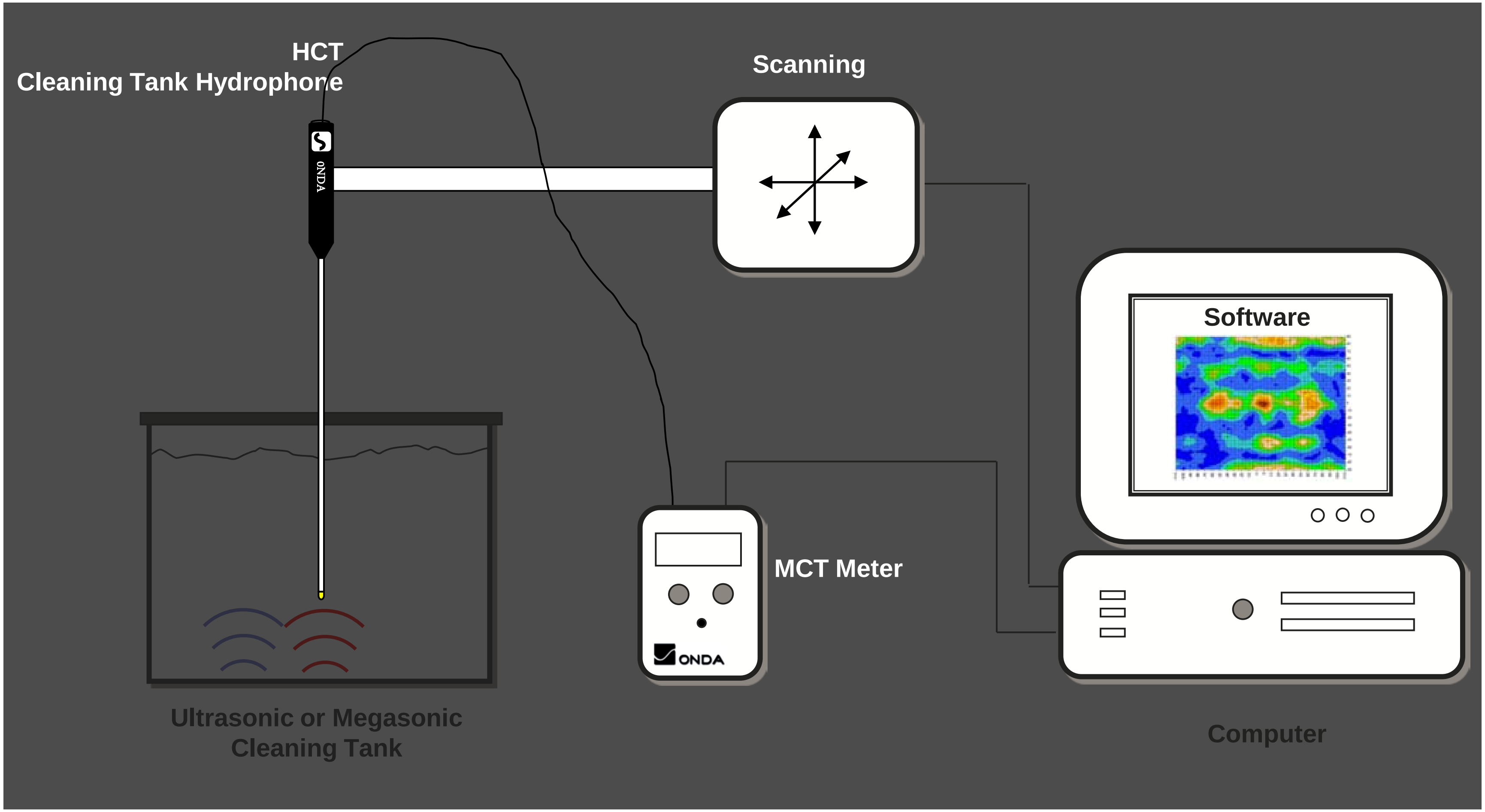
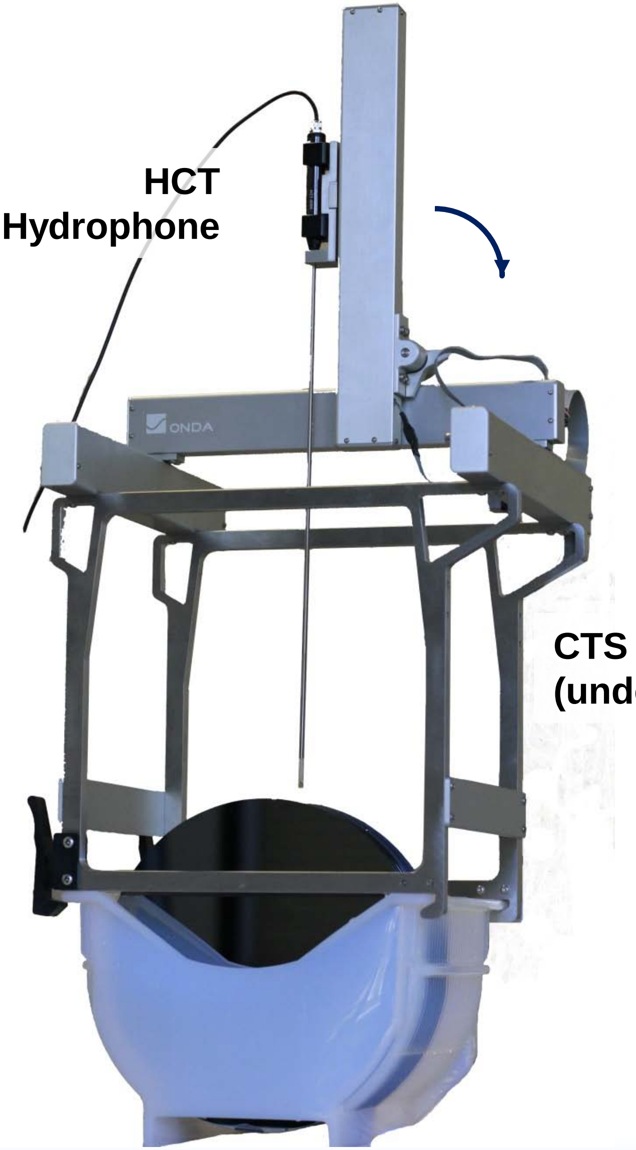
Automating Hydrophone Measurement

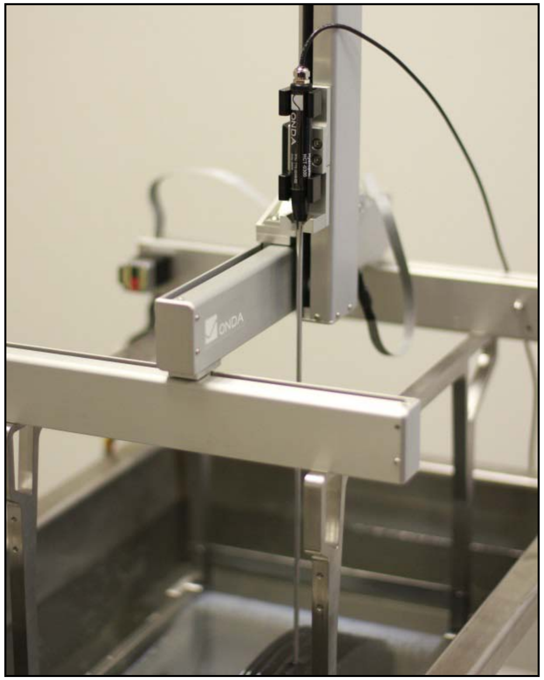


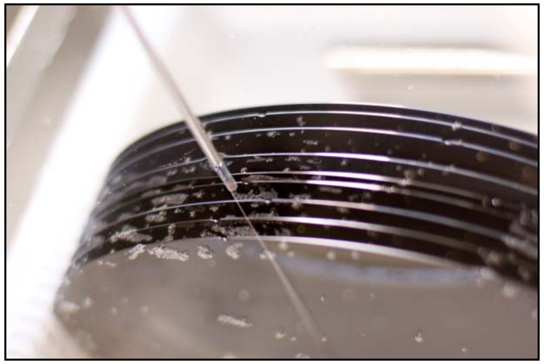
[Not to scale]

Automated Scanning for Precision Cleaning



CTS Scanner

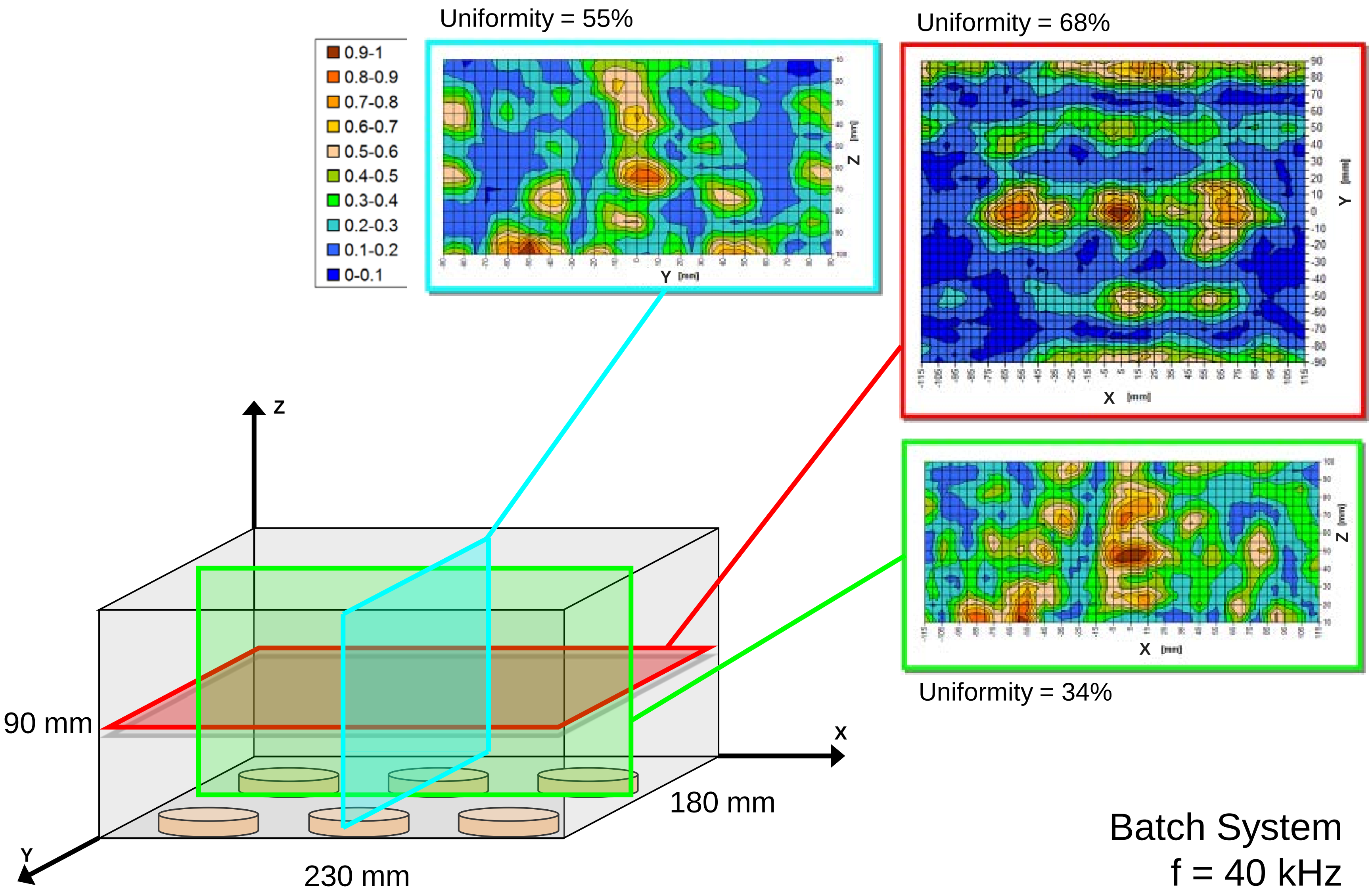




- X, Y, Z scanner mounted onto wafer carrier
- Scanner compatible with HCT hydrophone and MCT meter
- Full software control
- Designed to be able to measure “loaded” systems

A short demonstration…

Mapping Acoustic Distribution



Batch System
f = 40 kHz

Scorecard

	Optical Defect Inspection	Aluminum Foil / Ceramic Ring	Sonolumniscence	Hydrophone	Hydrophone + Scanner
Correlation to Cleaning	√	-	-	√	√
Sensitive	√	-	-	√	√
Repeatable	√	-	√	√	√
Accurate	√		-	√	√
Ease of Use	-	-	-	-	-
Throughput	√		-	-	-
Process Compatible	√			√	√
Cost of Ownership		√	-	-	-

Closing Remarks

- Connection between ultrasound and cleaning performance continues to be explored
- Complexity in wet clean processes requires acoustic control to maximize cleaning efficiency and limit damage
- Various measurement techniques available; still, the need for standardization exists
- Hydrophone measurements with automated scanning offers a quantitative and systematic approach

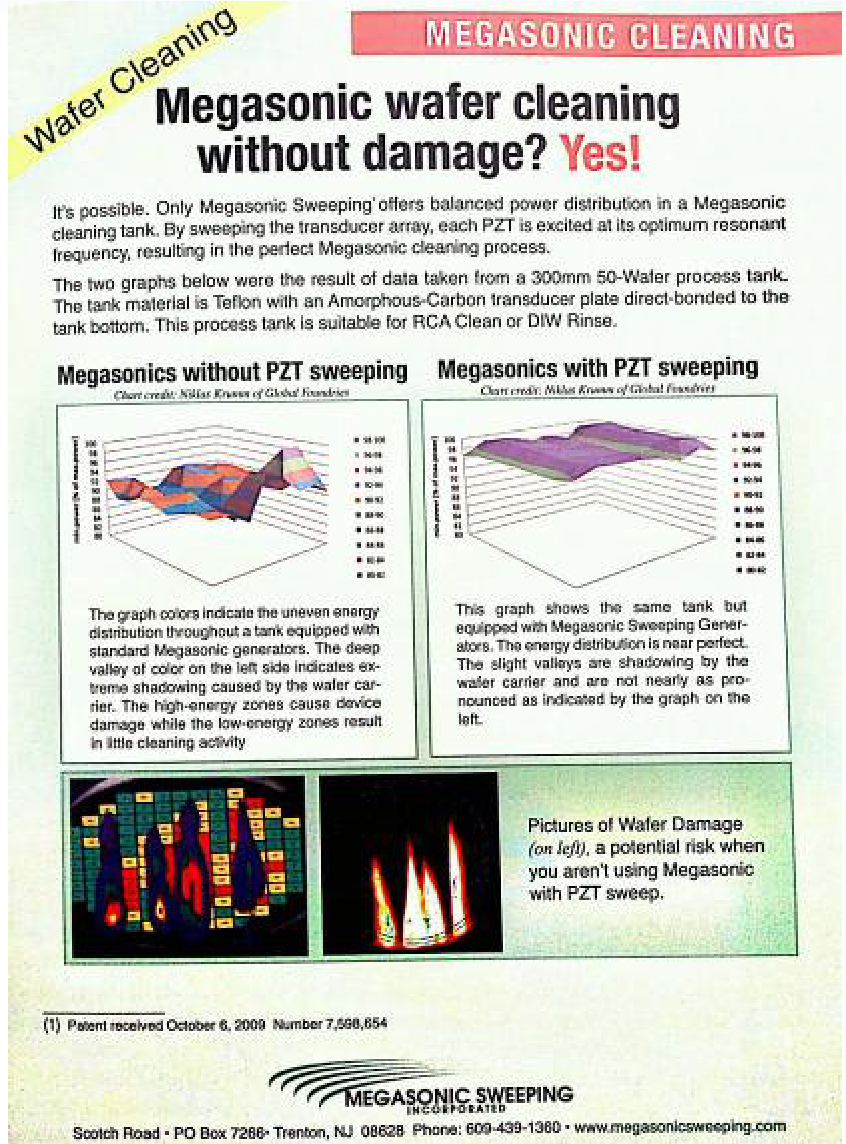
Putting Confidence in
Ultrasound

BACKUP

Megasonic Sweeping (Crest Subsidiary)

Hydrophone Results

Defect Maps


Wafer Cleaning

MEGASONIC CLEANING

Megasonic wafer cleaning without damage? Yes!

It's possible. Only Megasonic Sweeping[1] offers balanced power distribution in a Megasonic cleaning tank. By sweeping the transducer array, each PZT is excited at its optimum resonant frequency, resulting in the perfect Megasonic cleaning process.

The two graphs below were the result of data taken from a 300mm 50-Wafer process tank. The tank material is Teflon with an Amorphous-Carbon transducer plate direct-bonded to the tank bottom. This process tank is suitable for RCA Clean or DIW Rinse.

Megasonics without PZT sweeping

Chart credit: Niklas Krauss of Global Foundries

The graph colors indicate the uneven energy distribution throughout a tank equipped with standard Megasonic generators. The deep valley of color on the left side indicates extreme shadowing caused by the wafer carrier. The high-energy zones cause device damage while the low-energy zones result in little cleaning activity

Megasonics with PZT sweeping

Chart credit: Niklas Krauss of Global Foundries

This graph shows the same tank but equipped with Megasonic Sweeping Generators. The energy distribution is near perfect. The slight valleys are shadowing by the wafer carrier and are not nearly as pronounced as indicated by the graph on the left.

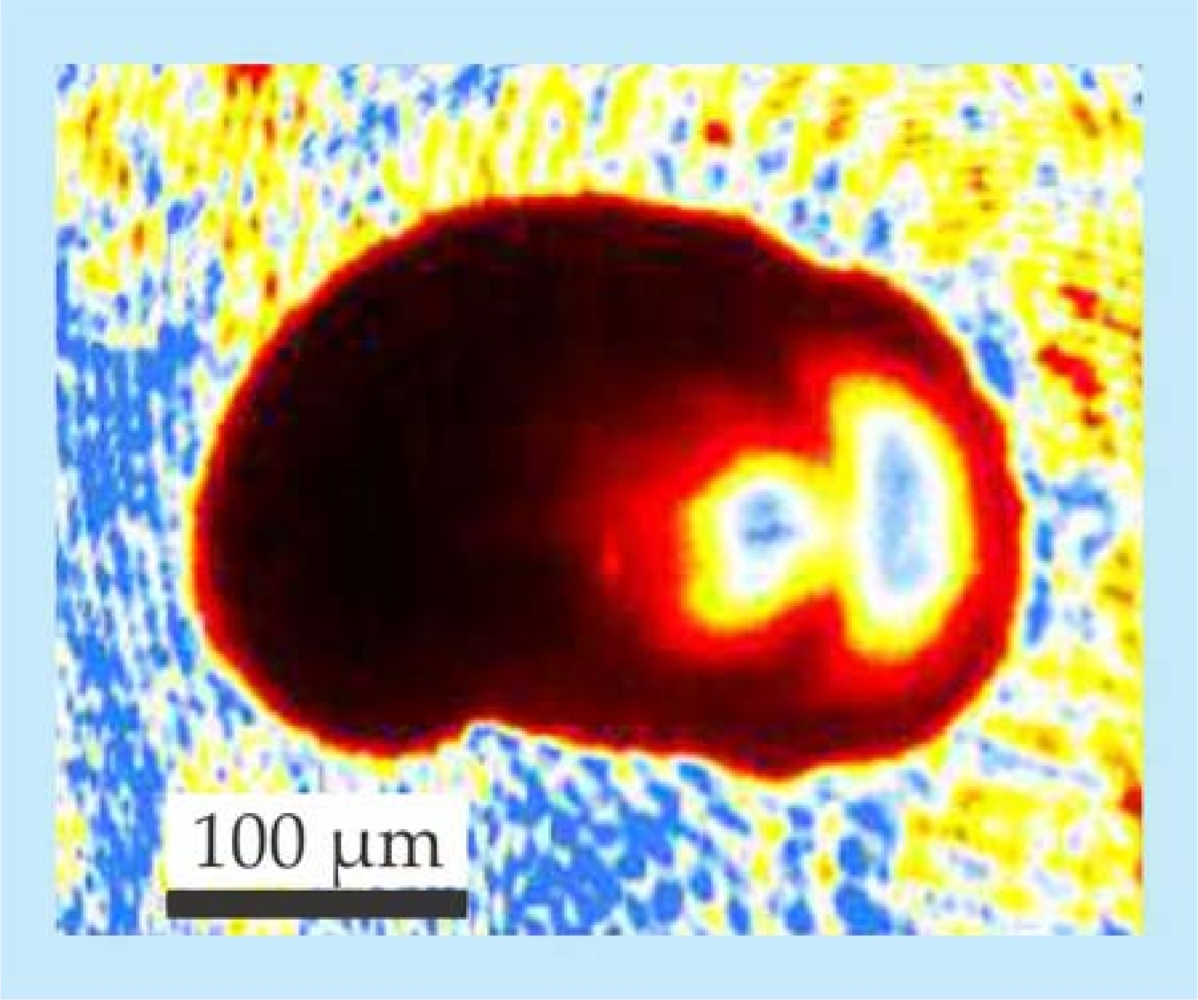
Pictures of Wafer Damage *(on left)*, a potential risk when you aren't using Megasonic with PZT sweep.

(1) Patent received October 6, 2009 Number 7,598,654

MEGASONIC SWEEPING INCORPORATED

Scotch Road • PO Box 7266• Trenton, NJ 08628 Phone: 609-439-1360 • www.megasonicsweeping.com

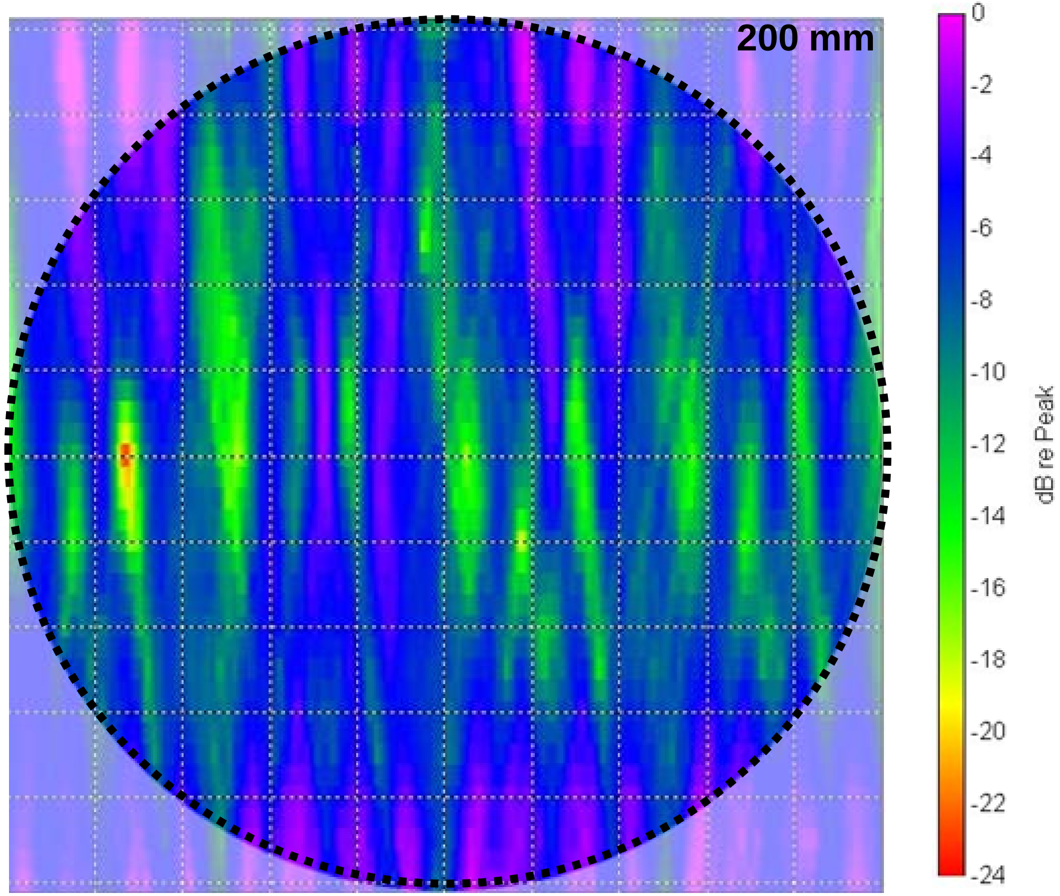
Sonoluminescence



Physics Today: Mar. 12, 2012, Seth Putterman UCLA

Acoustic Pressure Uniformity

f = 970 kHz



HCT Accessories

Wireless Data Logger

Apple iPad with
Redfish App

Data Logger (Redfish)

HCT Hydrophone

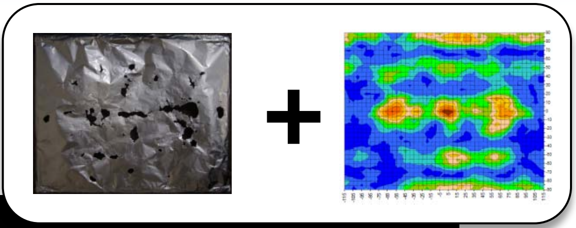
MCT Acoustic Meter

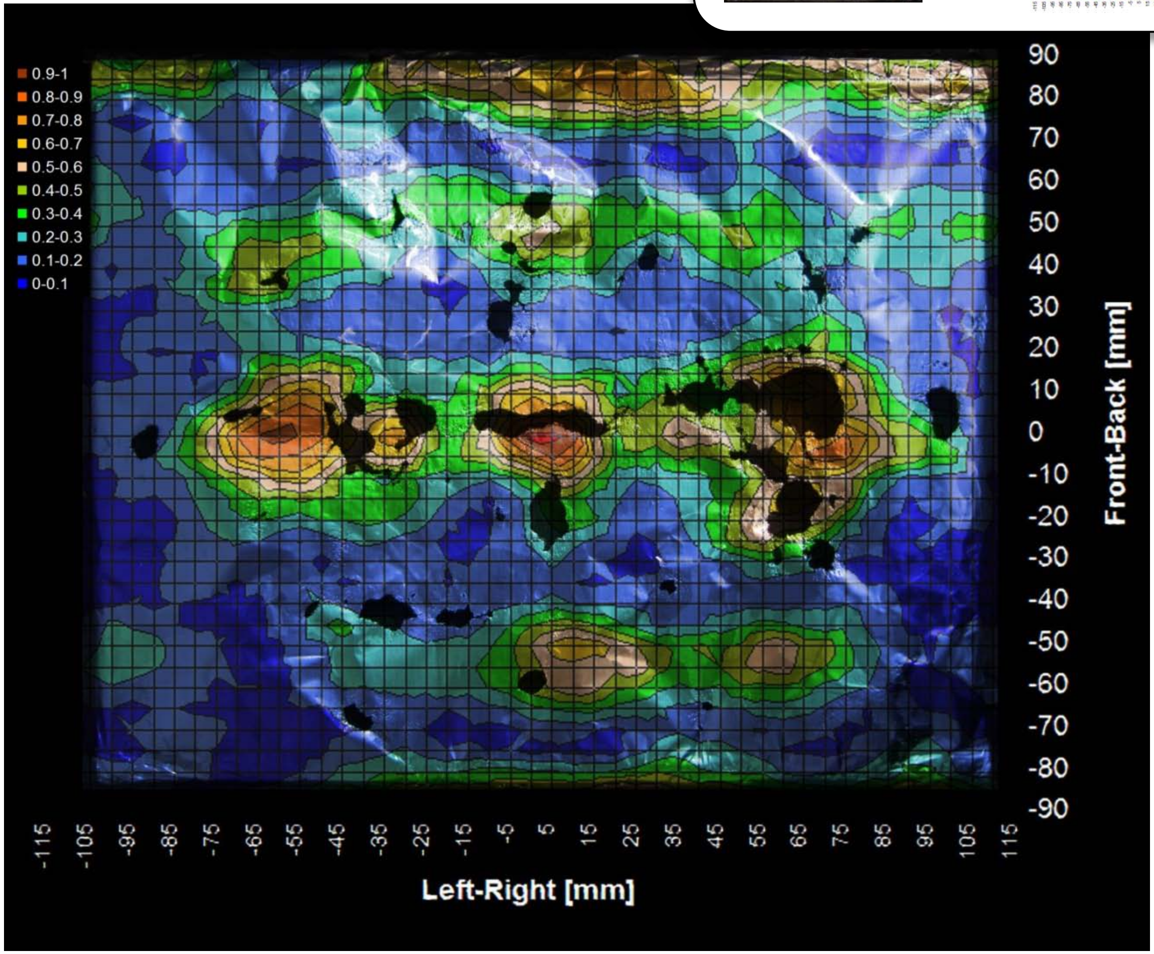
Healthmark Sonocheck

Neat, but not quantitative…

Good Correlation:

Al Foil Erosion and HCT Acoustic Plot

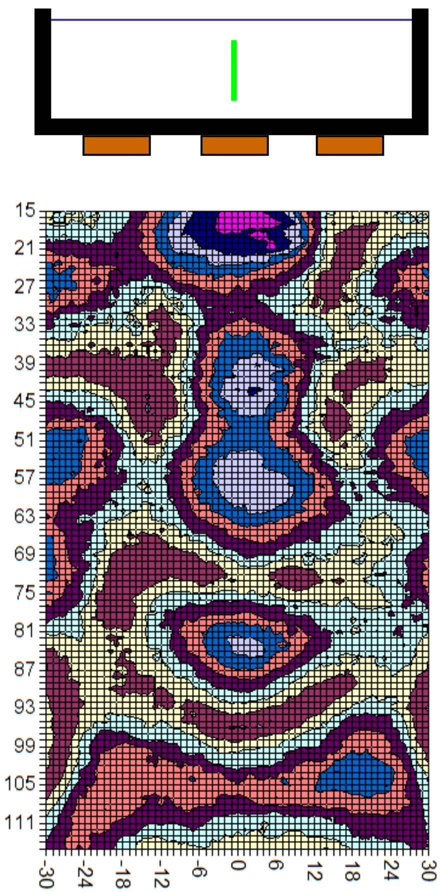




Comparing Various Configurations

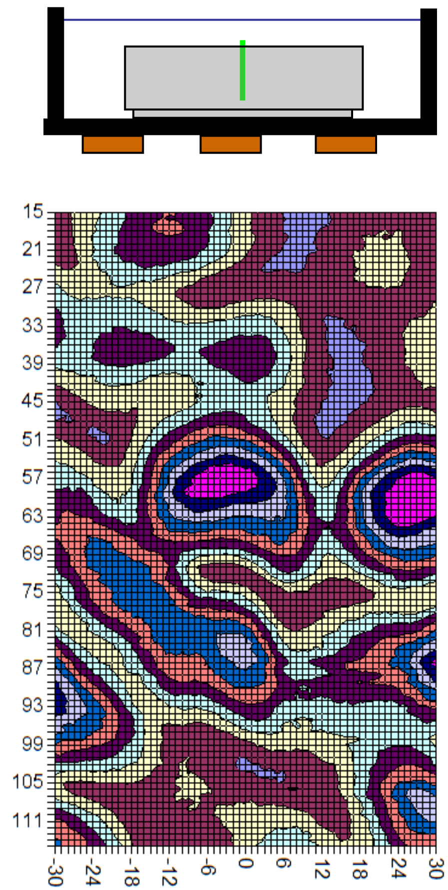
40 kHz Batch System

(1) Tank Empty



% Std Dev = 43.5%

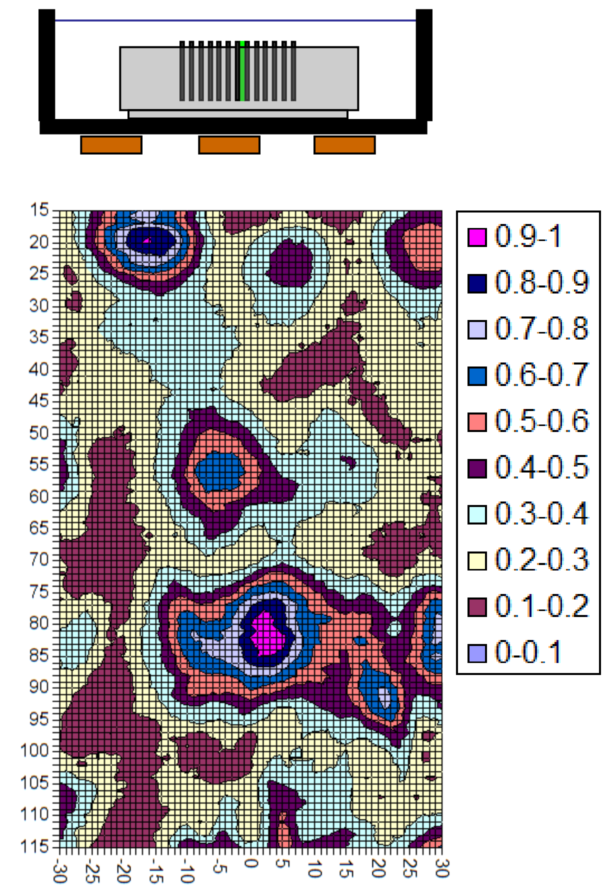
(2) Empty Cassette



% Std Dev = 55.0%

$\Sigma P_{rms\ (2)} = 0.7 \times \Sigma P_{rms\ (1)}$

(3) Cassette with 14 Disks



% Std Dev = 46.1%

$\Sigma P_{rms\ (3)} = 0.3 \times \Sigma P_{rms\ (1)}$