# Inspection Using Model-Based Eddy Current Sensors and Analysis


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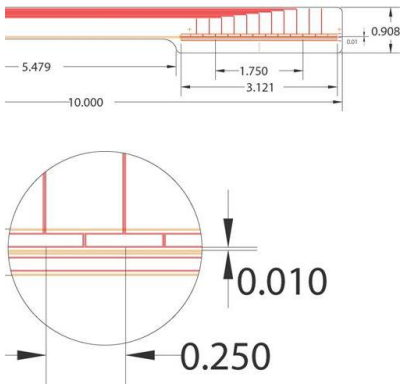
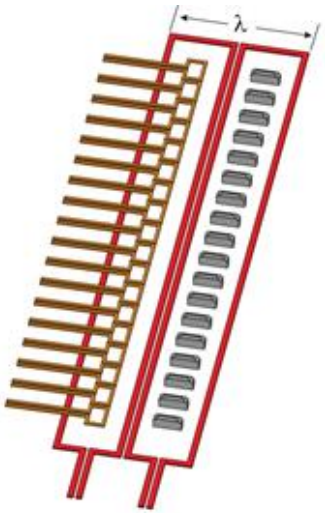
*Patents issued and pending*

# JENTEK Technology Description

## 1. Model-Based Sensors: MWM®-Arrays

- **Design the sensors to match the physics**



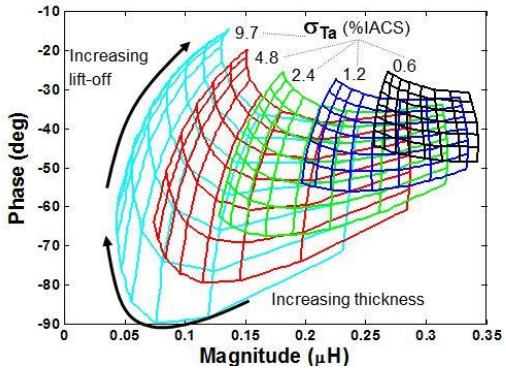

## 2. Accurate Electronics: 8200 GridStation® and jET™ Instrumentation

- **True Impedance Measurement**



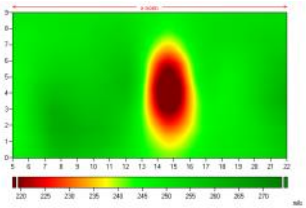

## 3. Real Property Analysis: GridStation Software using Model-Based Multivariate Inverse Methods

- **Rapid conversion of sensor data into real material properties**
  - **Electrical conductivity**
  - **Magnetic Permeability**
  - **Thickness**



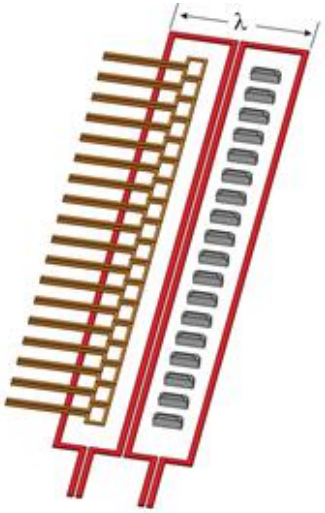

## 4. Ease of Use

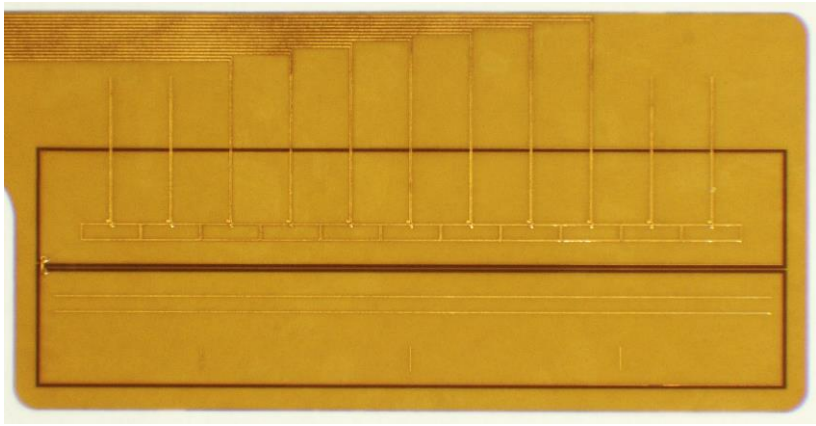
- **Air Calibration – No Ref. Std.**
- **Imaging**
- **Noise Suppression**



# Model-Based Sensor Design

- Coils of wire for the drive and sense work well, but are difficult to model accurately.
- Flat sensors can be modelled more accurately.
- Pros:
  - Enables model-based methods
  - Microfabrication techniques from the PCB industry can be used to produce thin, flexible sensors
  - Arrays using linear drive windings can be driven continuously (no switching)
  - Air Calibration: ASTM Standard E2338-11
- Cons:
  - Reduced signal levels due to smaller number of turns on the drive and sense coils

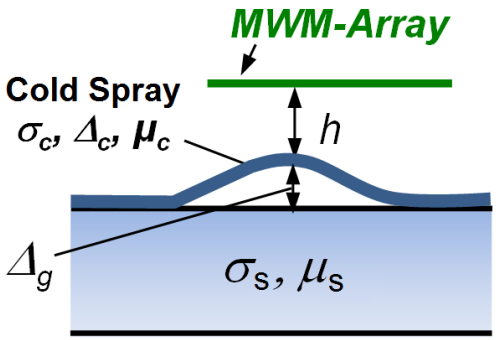


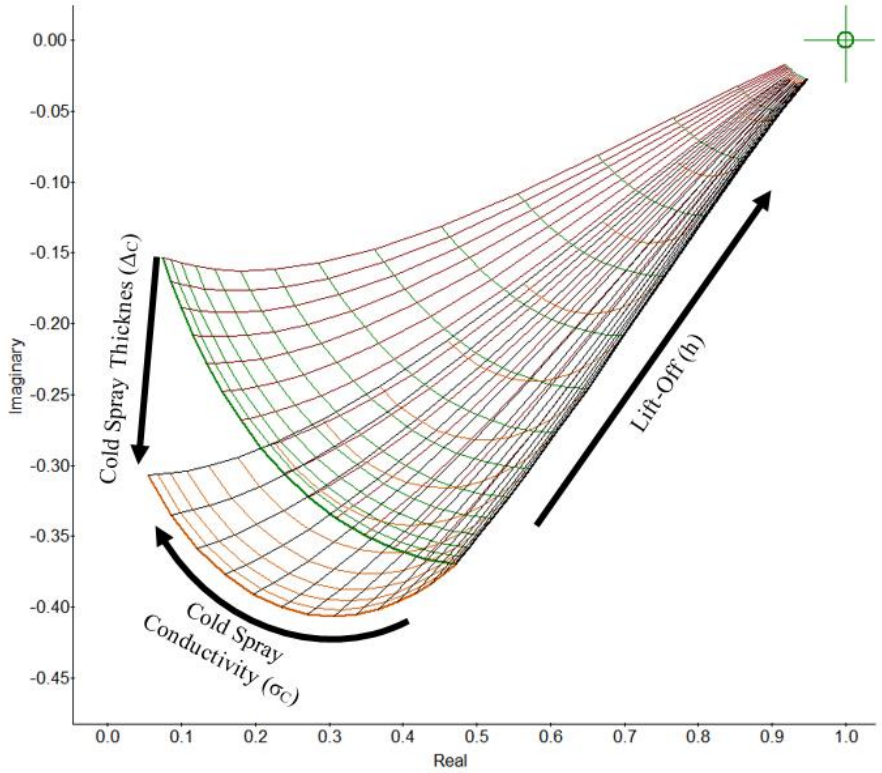



***MWM sensors and MWM-Arrays covered by issued and pending patents, including, but not limited to:*** *8,928,316, 8,803,515, 8,768,657, 8,494,810, 8,237,433, 8,222,897, 8,050,883, 7,994,781, 7,876,094, 7,812,601, 7,696,748, 7,589,526, 7,533,575, 7,528,598, 7,526,964, 7,518,360, 7,467,057, 7,451,657, 7,451,639, 7,411,390, 7,385,392, 7,348,771, 7,289,913, 7,280,940, 7,230,421, 7,188,532, 7,183,764, 7,161,351, 7,161,350, 7,106,055, 7,095,224, 7,049,811, 6,995,557, 6,992,482, 6,952,095, 6,798,198, 6,784,662, 6,781,387, 6,727,691, 6,657,429, 6,486,673, 6,433,542, 6,420,867, 6,380,747, 6,377,039, 6,351,120, 6,198,279, 6,188,218, 6,144,206, 5,966,011, 5,793,206, 5,629,621, 5,990,677 and RE39,206*

# Grid Methods: Lattices and Hyperlattices

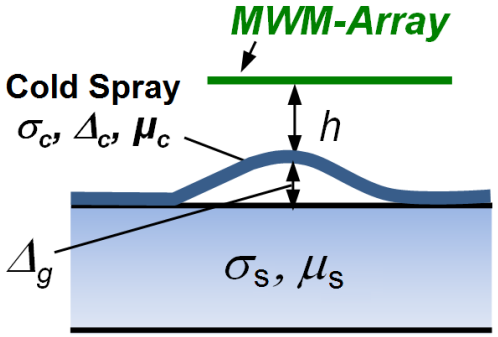
- A single frequency can be used to estimate two properties
  - Conductivity / Lift-off
  - Permeability / Lift-off
- Multiple frequencies are required to estimate three or more properties
  - Typical properties:
    - Substrate conductivity
    - Cold spray conductivity
    - Cold spray thickness
    - Lift-off
  - Other properties:
    - Substrate permeability
    - Substrate thickness
    - Gap
    - Cold spray permeability

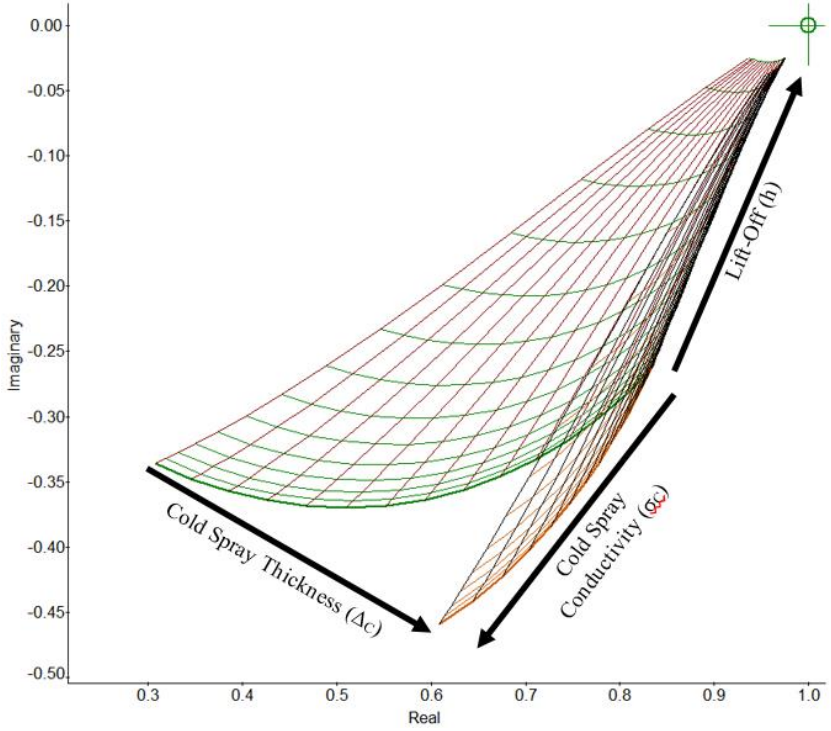


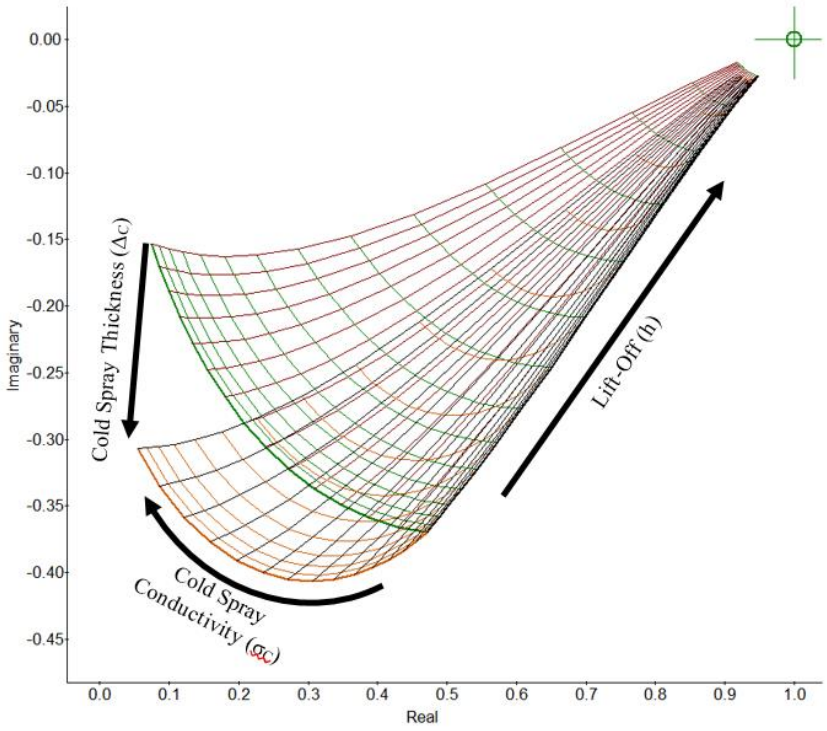



# Aluminum Cold Spray on Aluminum

- Three frequency method to estimate:
  - Substrate conductivity
  - Cold spray conductivity
  - Cold spray thickness
  - Lift-off

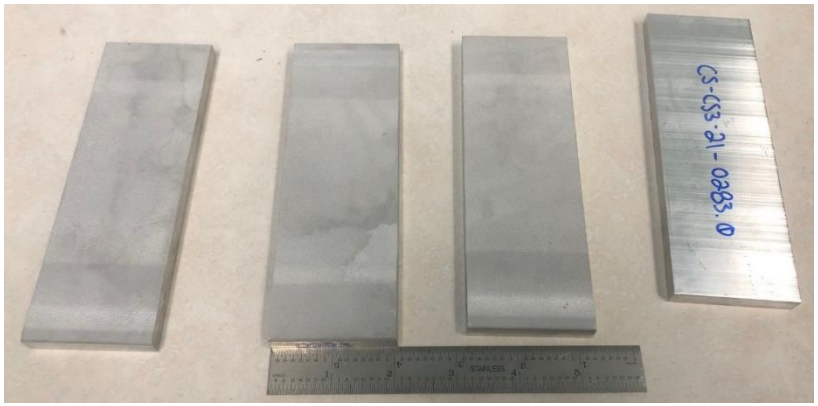


# Aluminum-on-Aluminum Cold Spray

- Samples produced by Solvus Global
- Access to samples provided by Mississippi State University
- 6061 cold spray on a 6061 substrate
- Thickness was measured to be 0.8mm by the vendor



Parameters for production:

- Travel speed: 200mm/s
- Powder feed rate: 4rpm
- Line spacing: 0.5mm
- Standoff distance: 25mm

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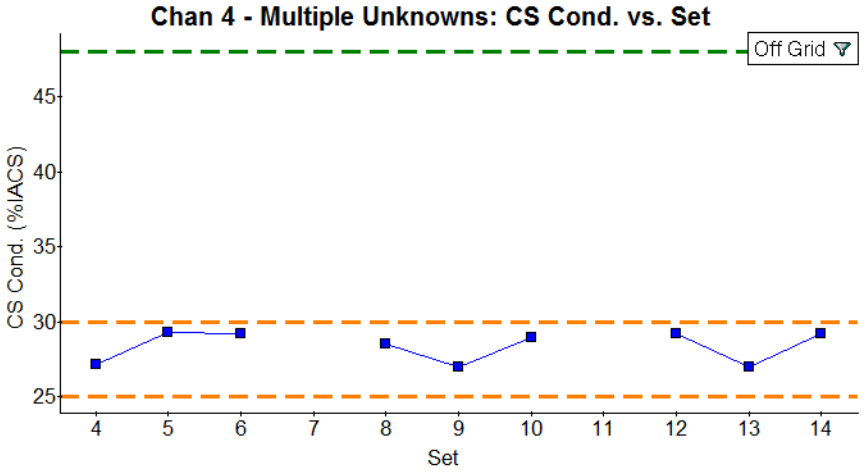
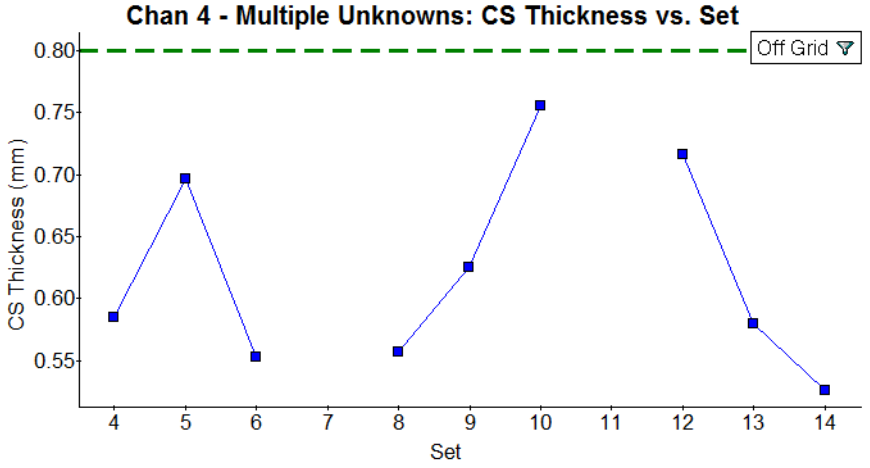
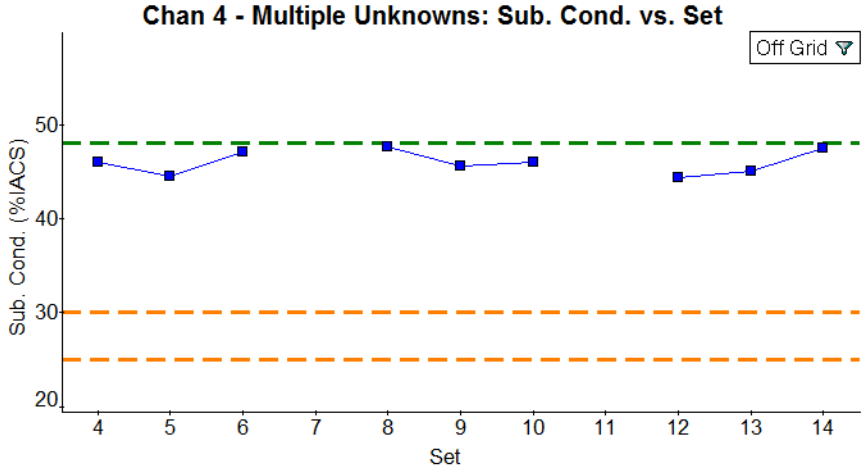
This work was supported by National Center for Manufacturing Sciences (NCMS) and United States Department of Army Research Lab (ARL); Collaboration Agreement #202031-141054 CTMA Cooperative Agreement #HQ0034-15-2-0007.

# Aluminum-on-Aluminum Cold Spray

- Conductivity of the substrate (~49% IACS) is significantly different from the conductivity of the cold spray coating (25% - 30% IACS). This difference enables independent measurement.

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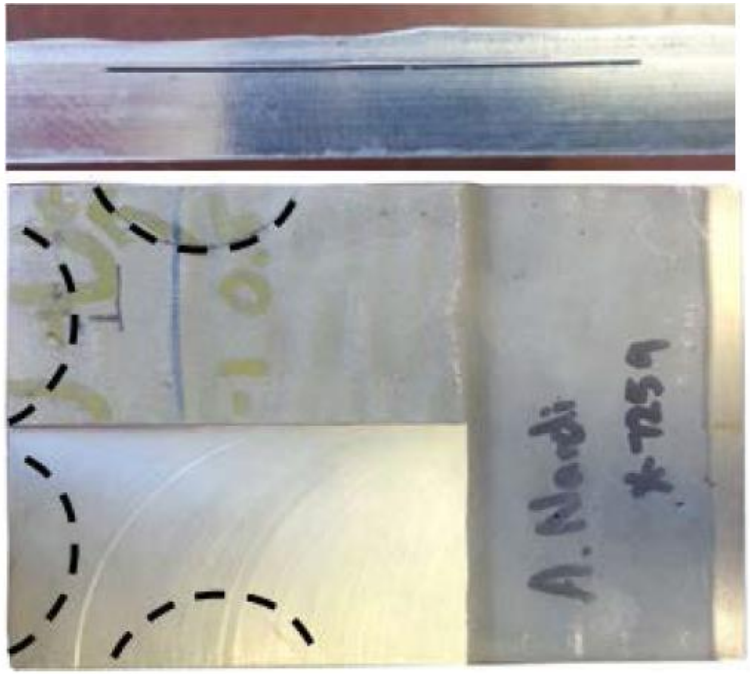
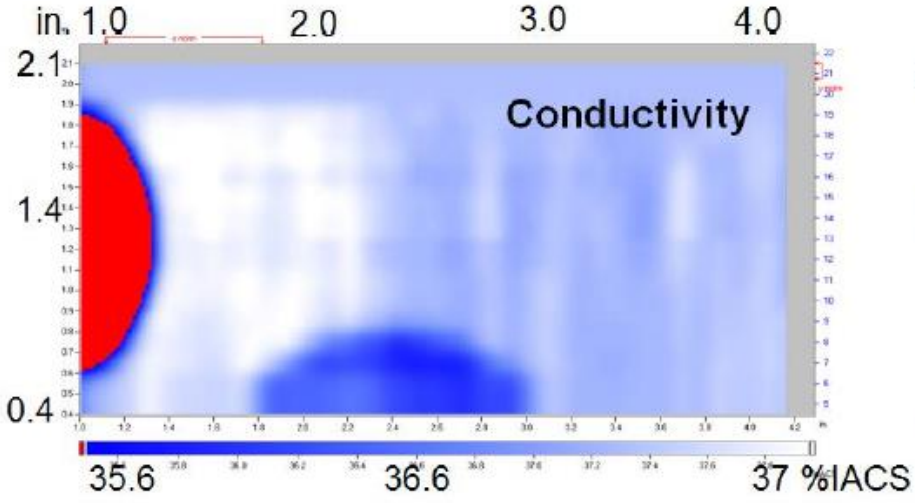
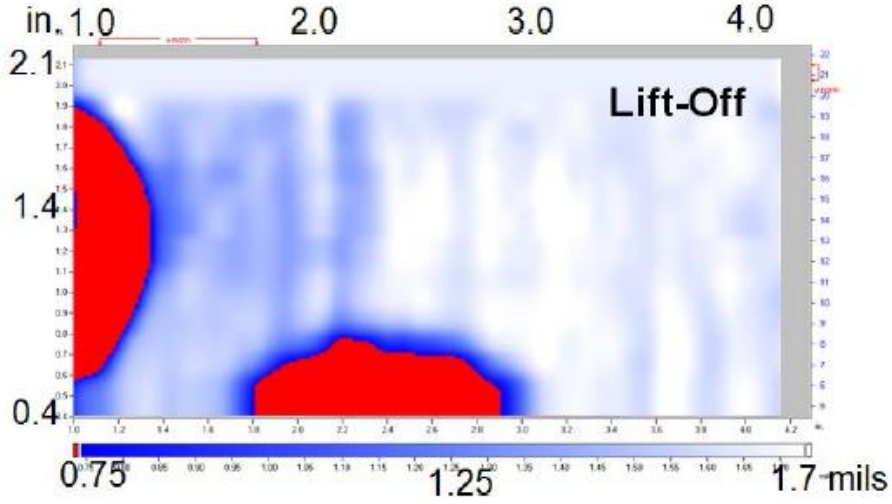
# Disbonds

- Data from 2013
- Shows sensitivity to simulated disbonds
- Note: In this case, material was removed to simulate the disbond. Tight disbonds with no gap will be difficult to detect.

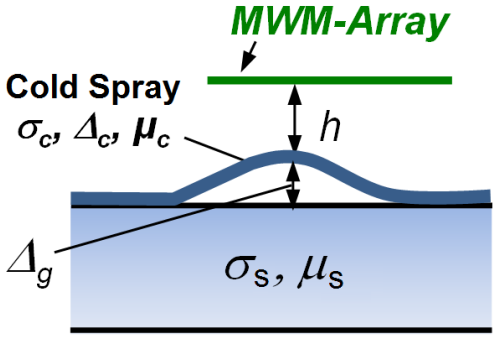


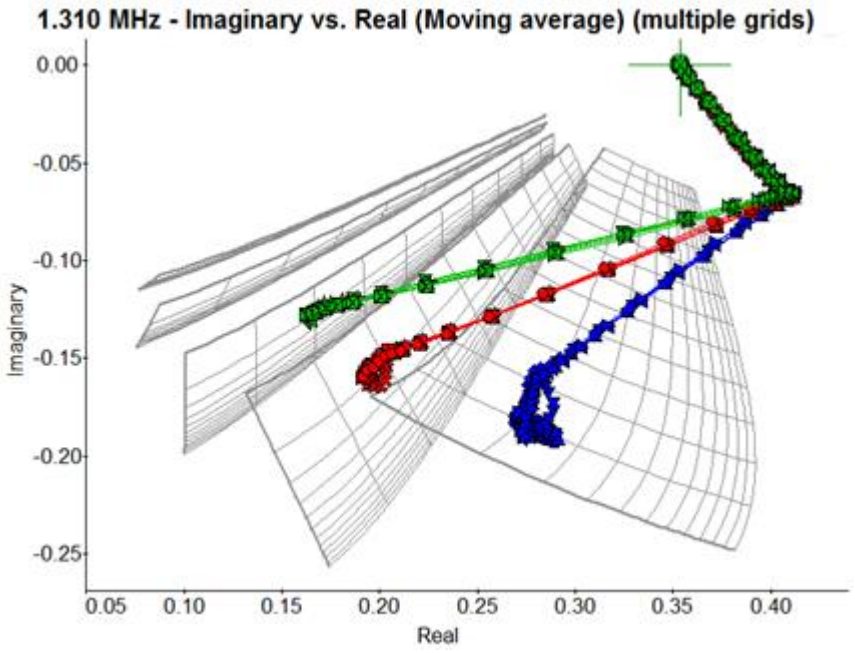


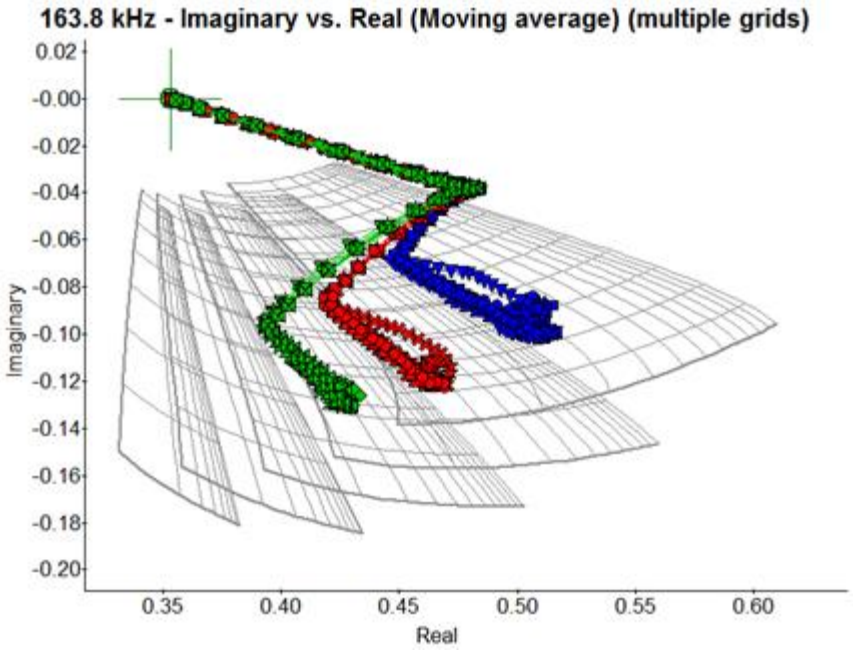



# Non-ferrous Metal Cold Spray on Steel

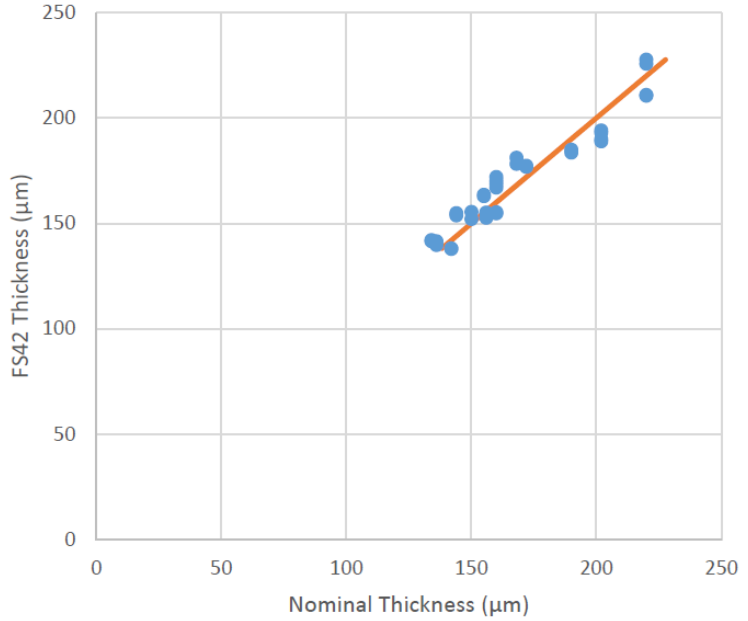
- Three frequency method to estimate:
  - Substrate permeability (assumed conductivity value)
  - Cold spray conductivity
  - Cold spray thickness
  - Lift-off

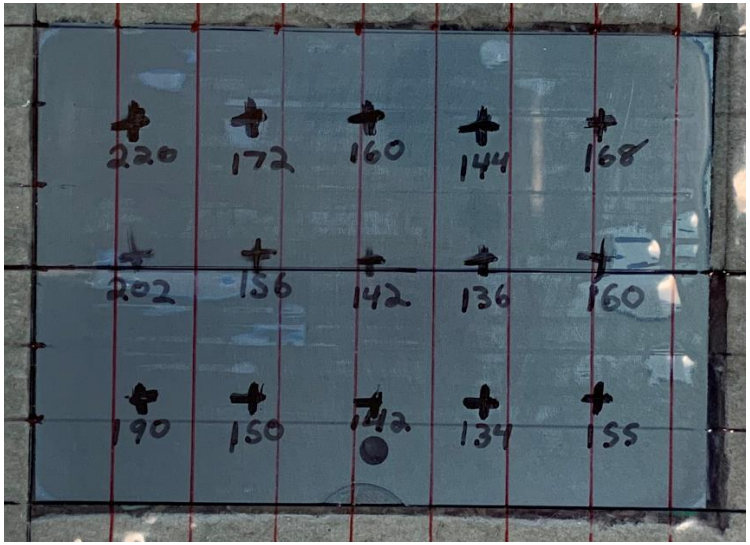


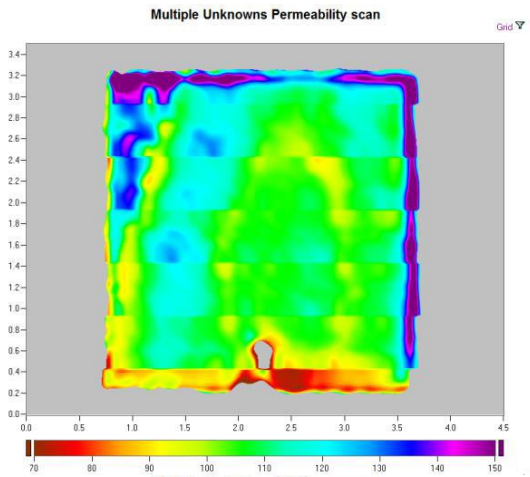



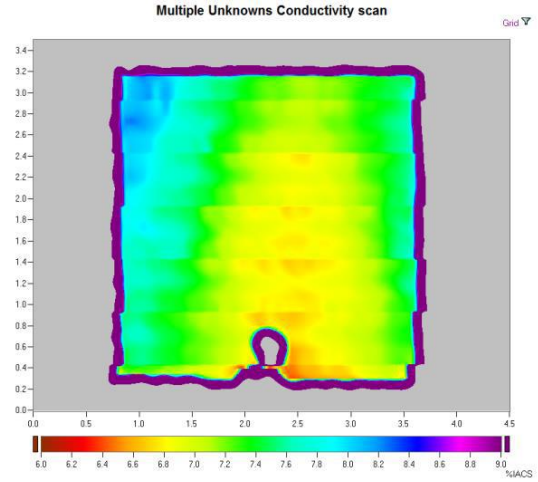



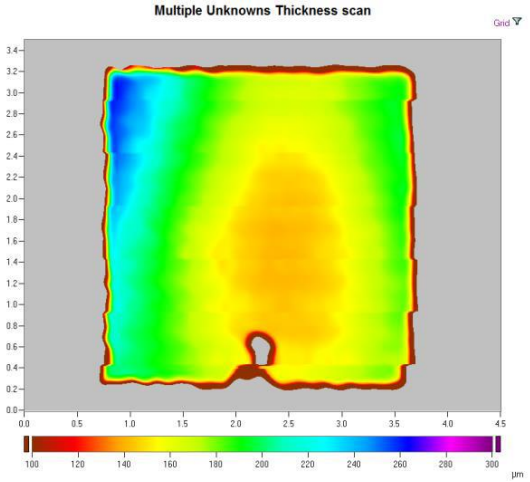
# Non-ferrous Metal Cold Spray on Steel

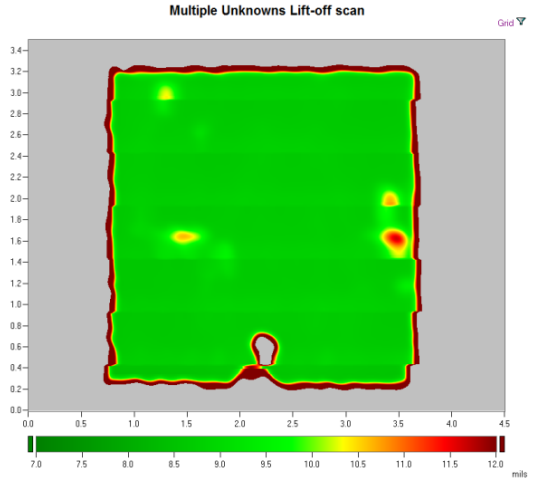


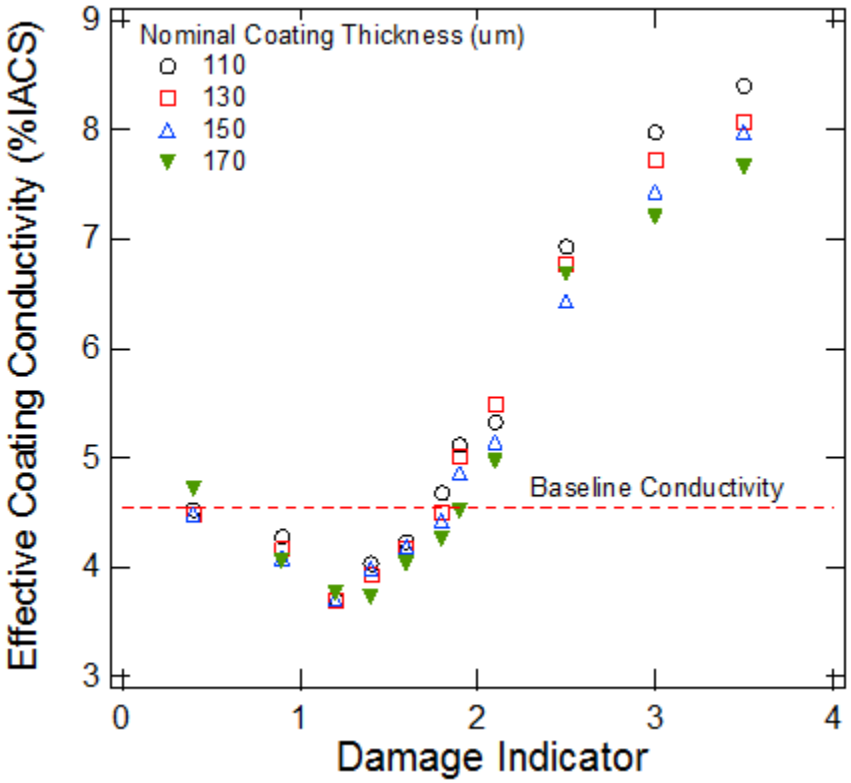



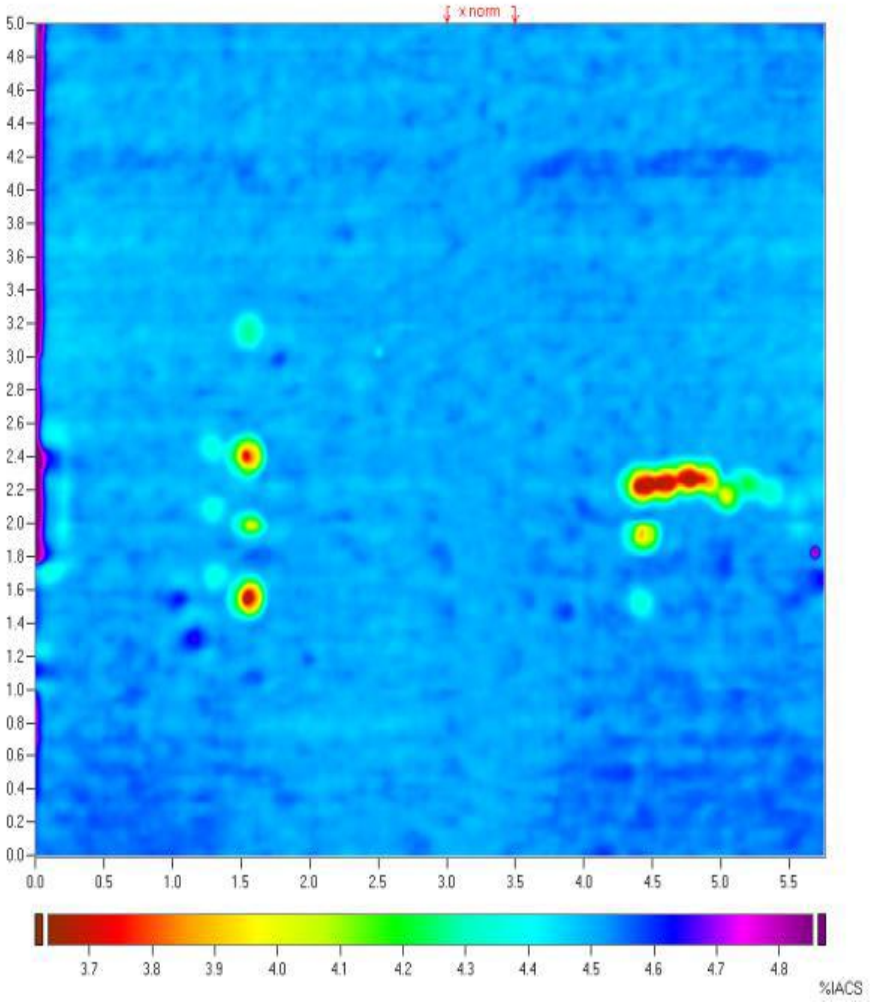



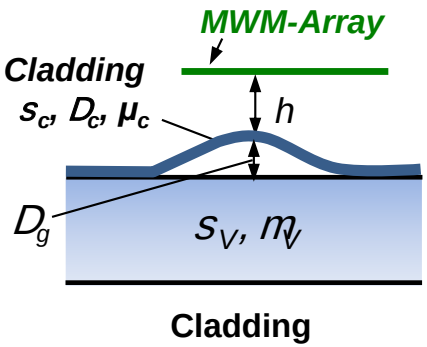
# Damaged in Cold Spray Layers

- Properties such as cold spray conductivity can be correlated with damage conditions



# Inspection through Cold Spray: Cracks

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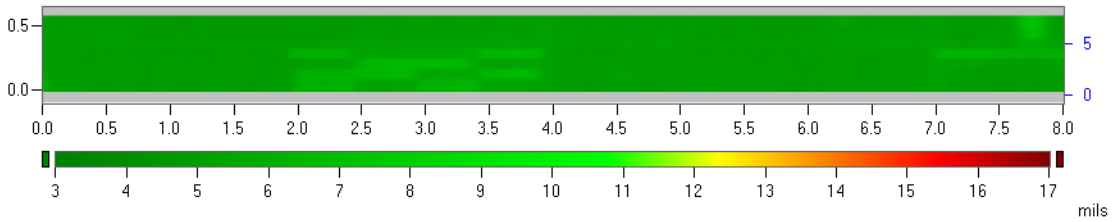
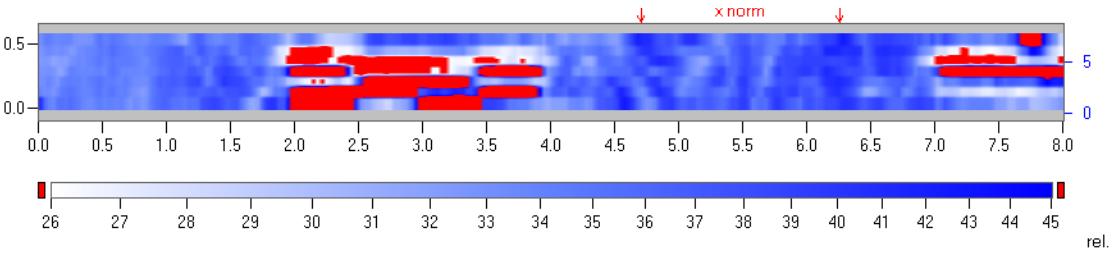
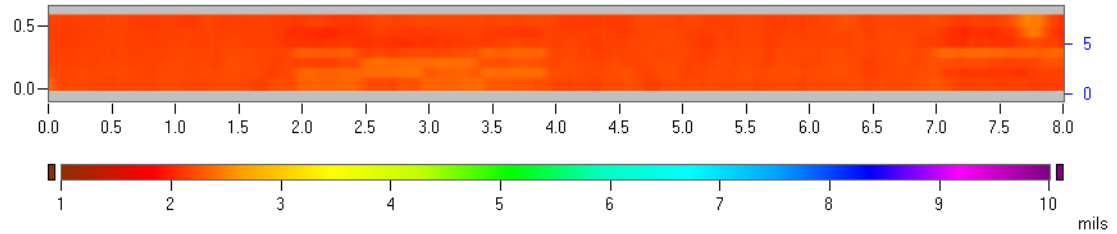
Lift-off




Permeability (rel)




Thickness (mil)



# Thank You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