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Differential Imaging Microscopy of Physically Complex Surfaces Undergoing Atmospheric Corrosion

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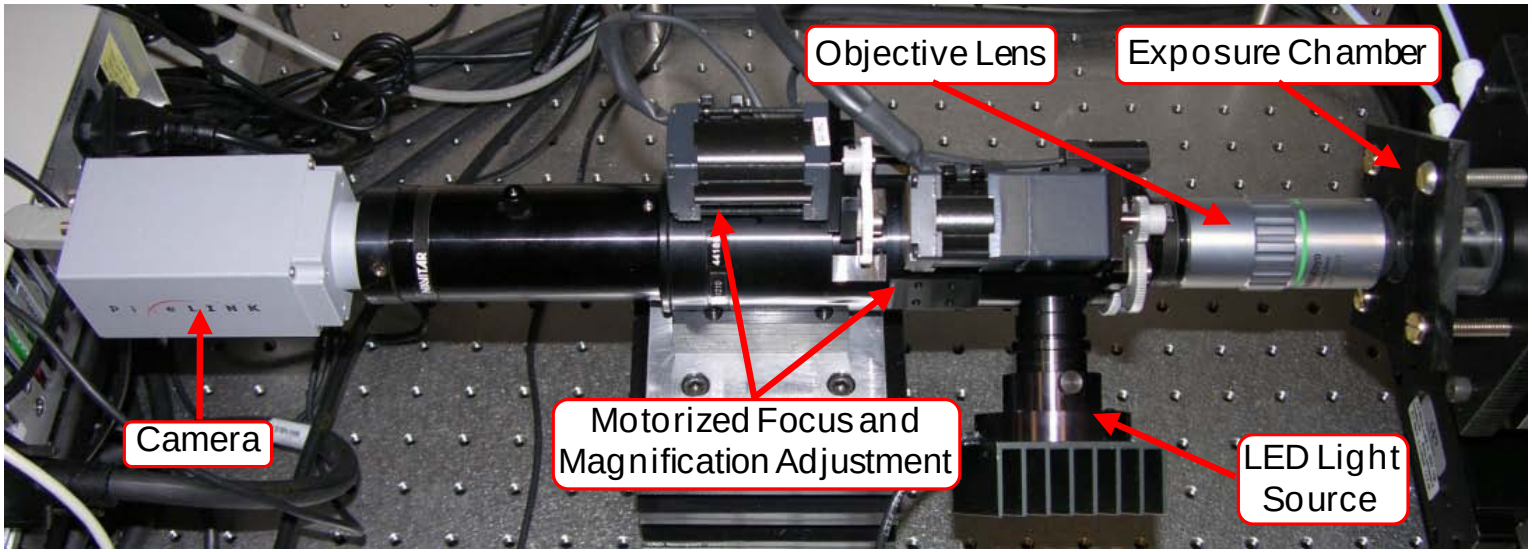
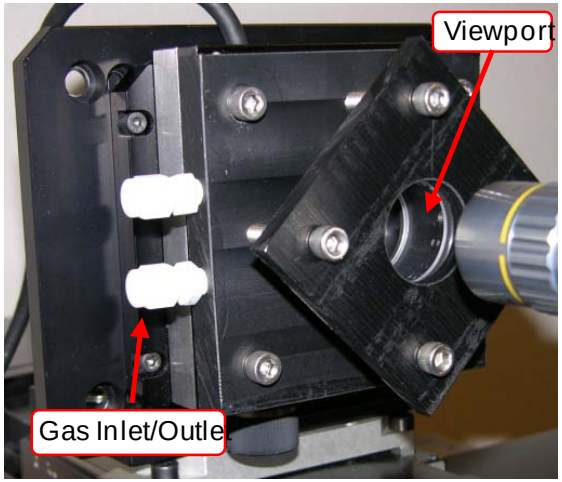
Background

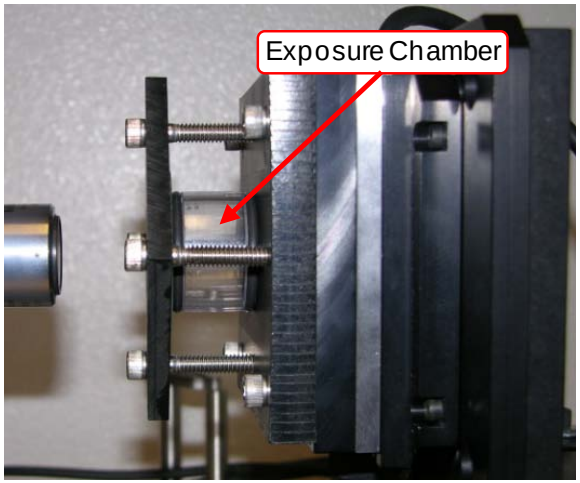
- **Differential imaging technique for in-situ observation of atmospheric corrosion**
  - Similar to work of Isaacs, et. al (2006) for aqueous samples
  - System consists of imaging hardware/optics along with data acquisition and image analysis software

- **Demonstration of system capabilities performed on noble metal plated copper specimens, simulating metallurgies commonly used in microelectronic connectors**

Differential Imaging System Hardware Configuration







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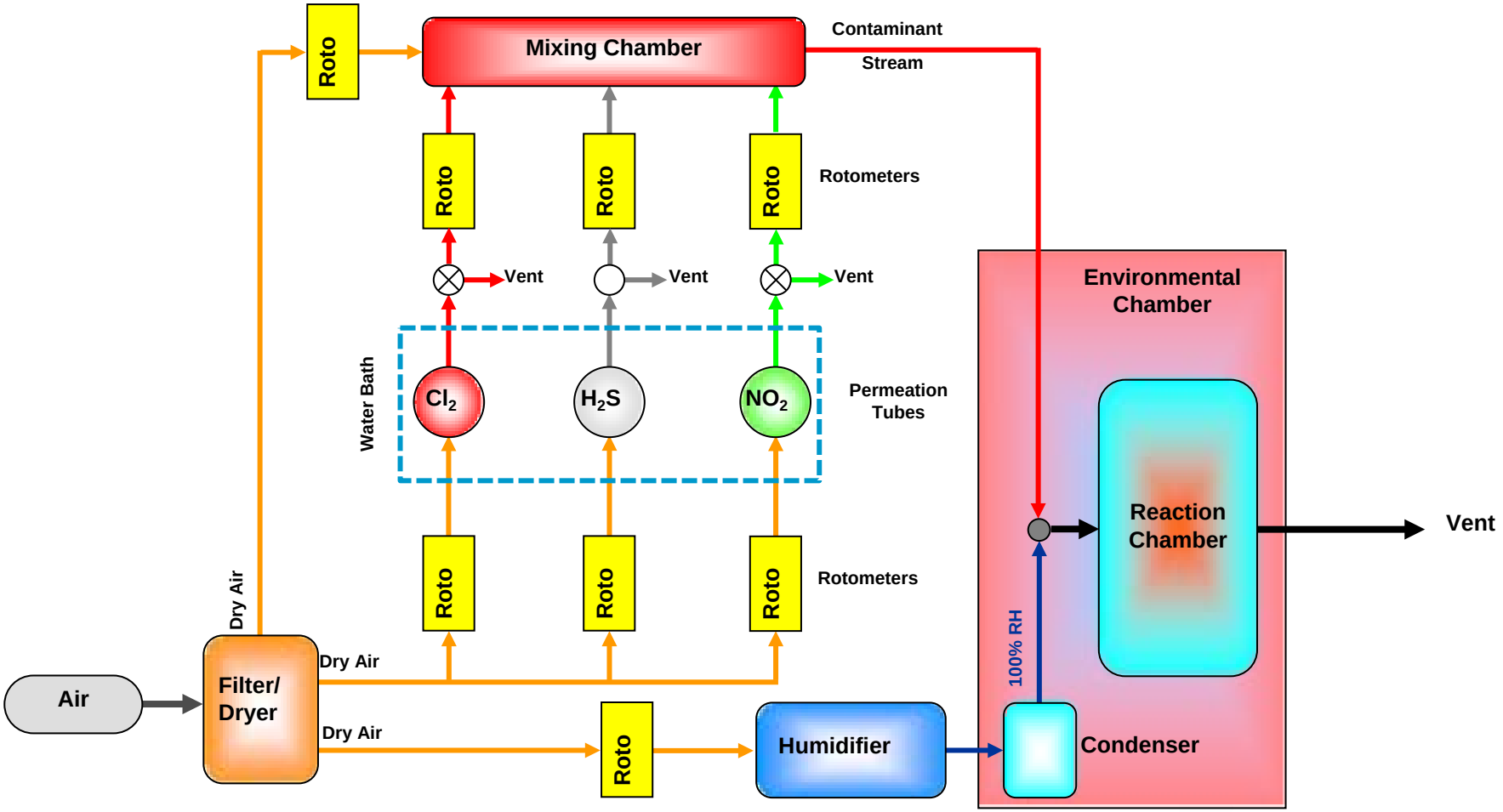
Environmental Control – Mixed Flowing Gas System



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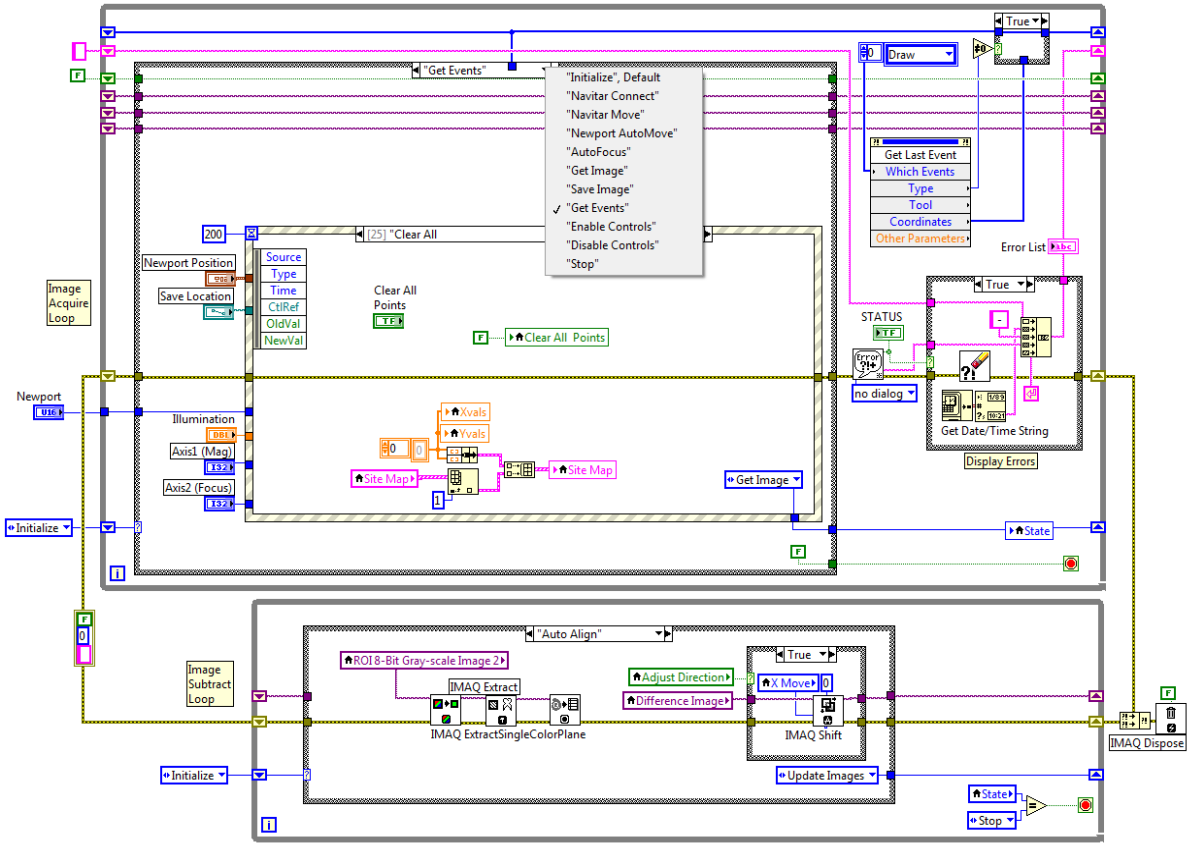
Data Acquisition and Image Analysis Software



- Code written in NI LabView 2010 and Vision Development Module
- State machine design

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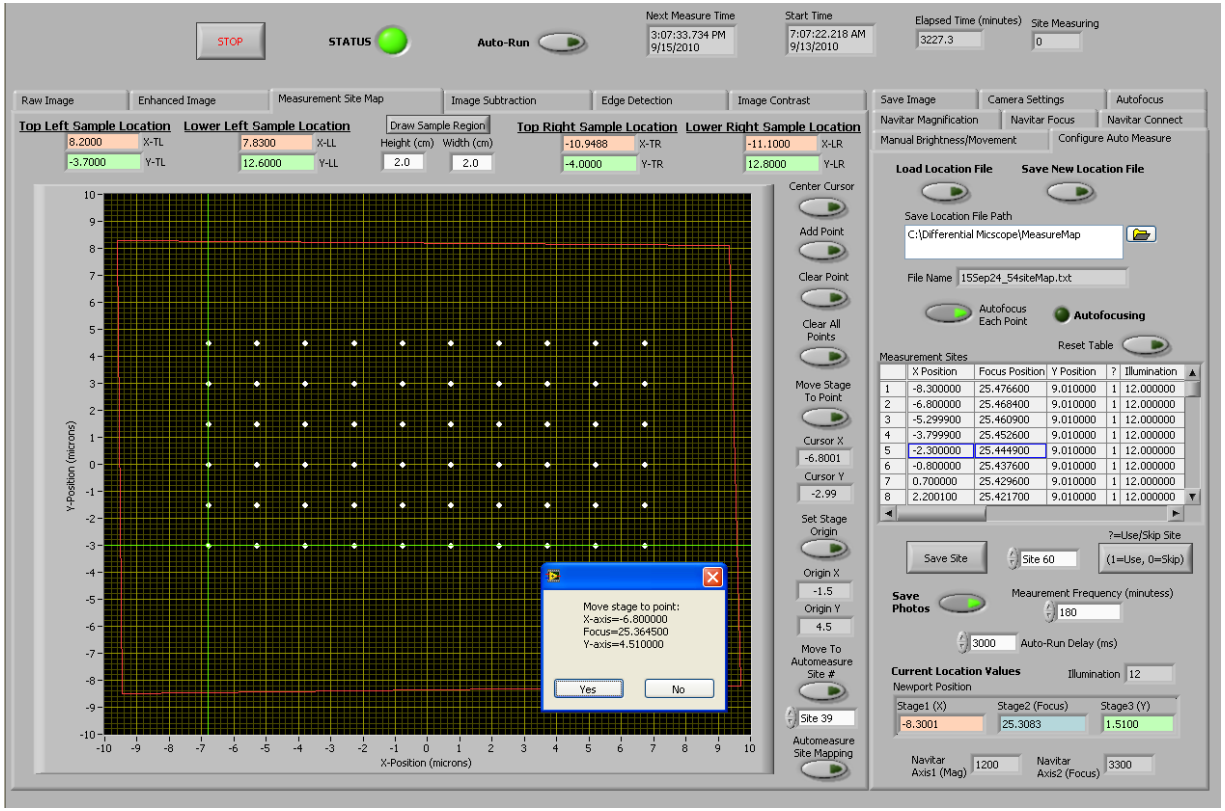
Data Acquisition and Image Analysis Software



- Multiple sites
- Mapping capability with minimal stage backlash/rotation
- Autofocus using Fast Fourier Transform technique

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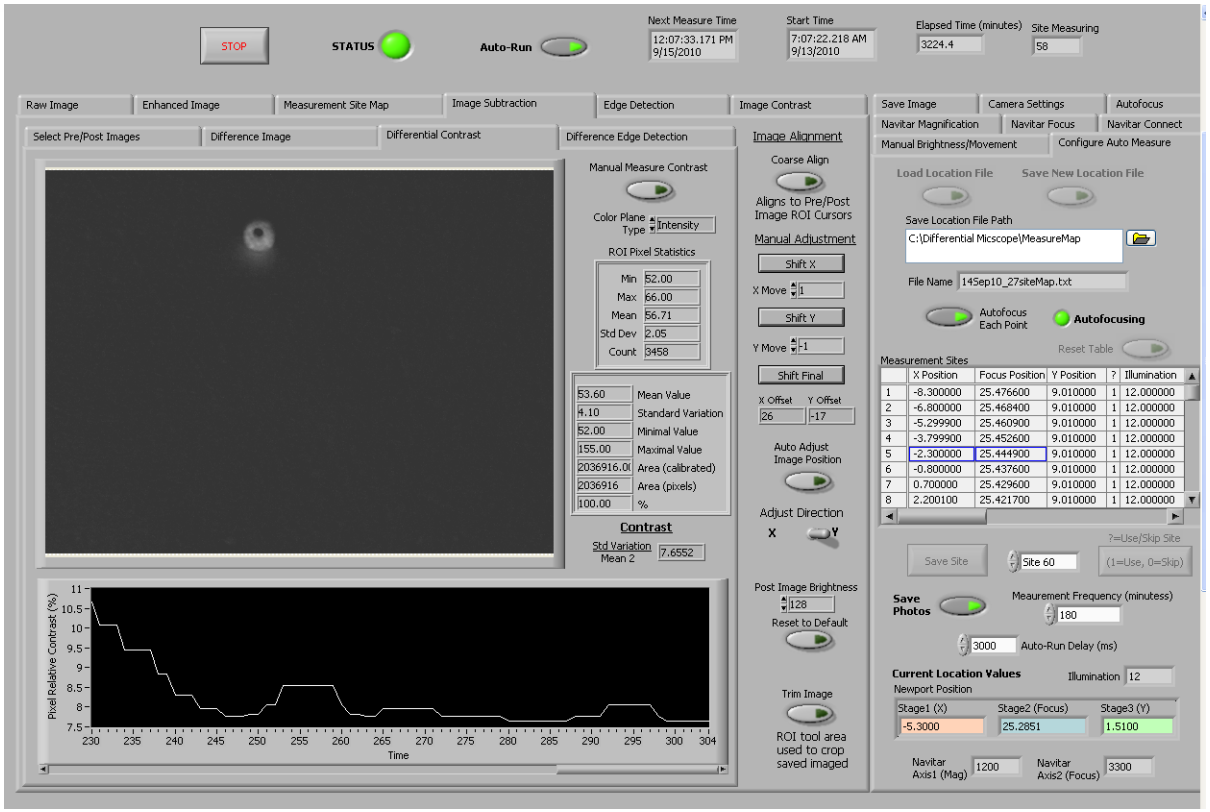
Data Acquisition and Image Analysis Software



- **Integrated and standalone differential image analysis modules**
  - Semi-automated image alignment
  - Differential contrast used to verify/establish optimum alignment

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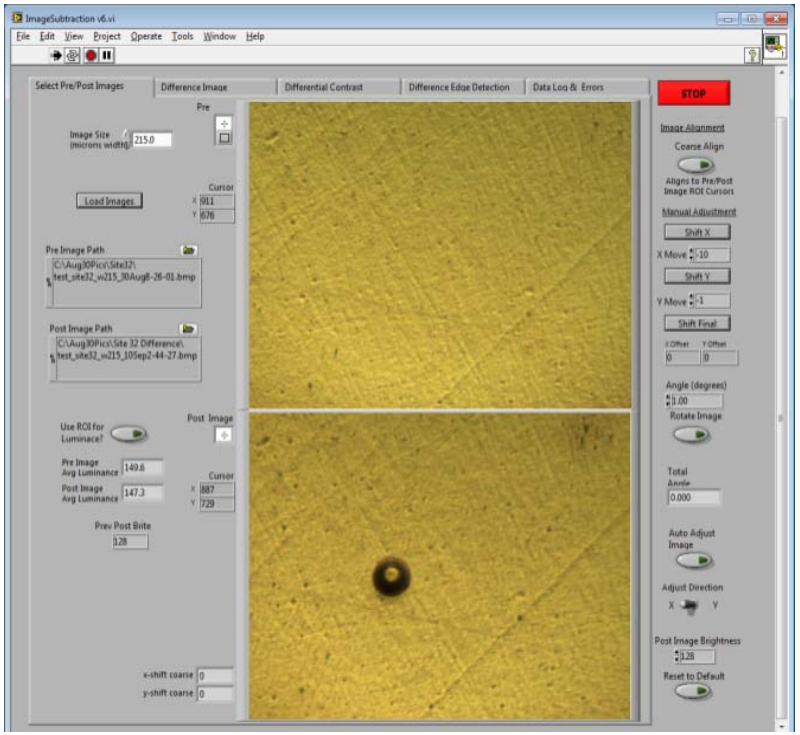
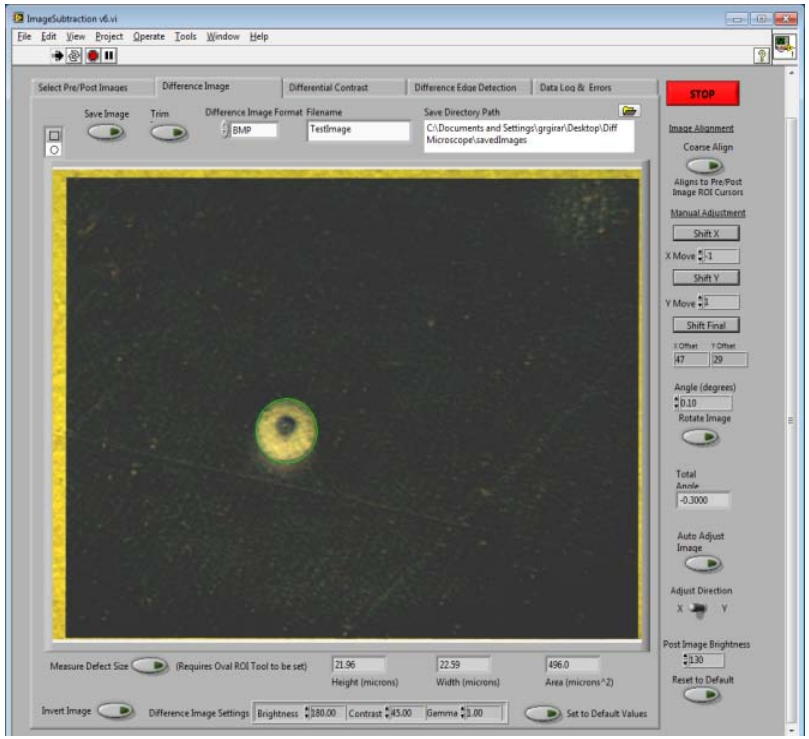
Data Acquisition and Image Analysis Software





- **Pre and post (or live) images combined to form difference image**
- **Measurement utility to quantify defect size**

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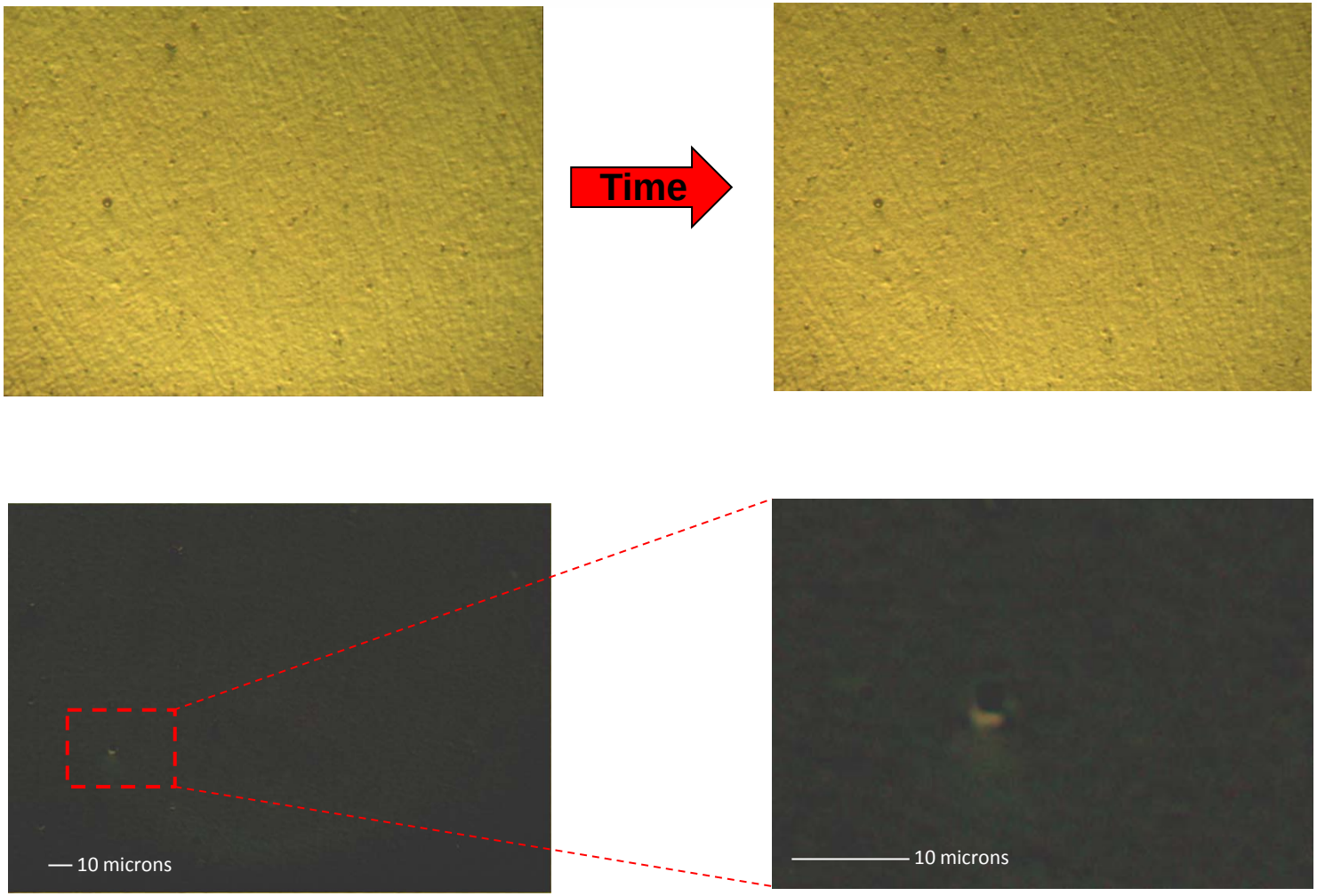
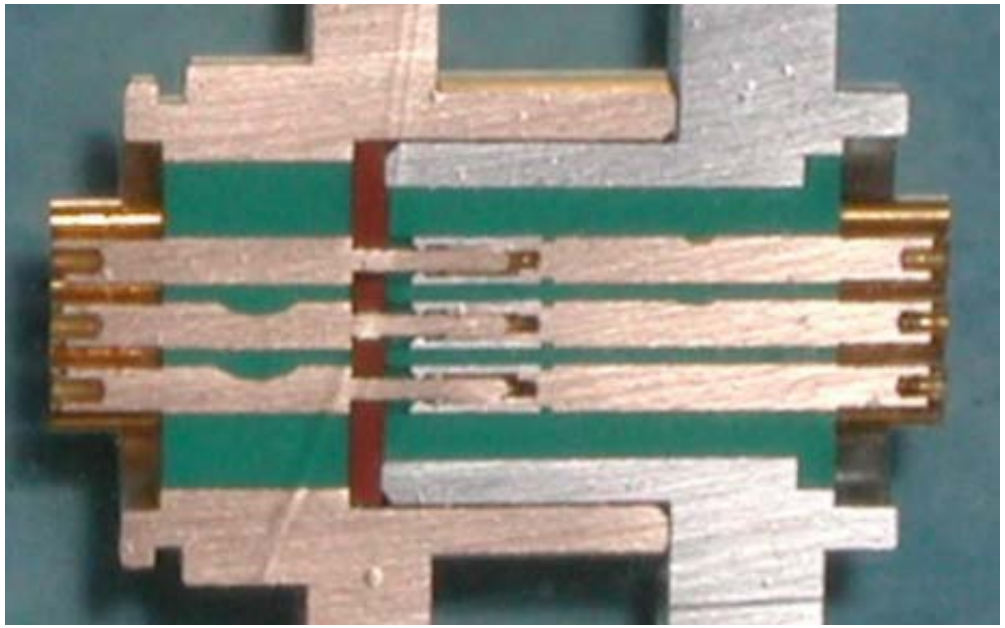
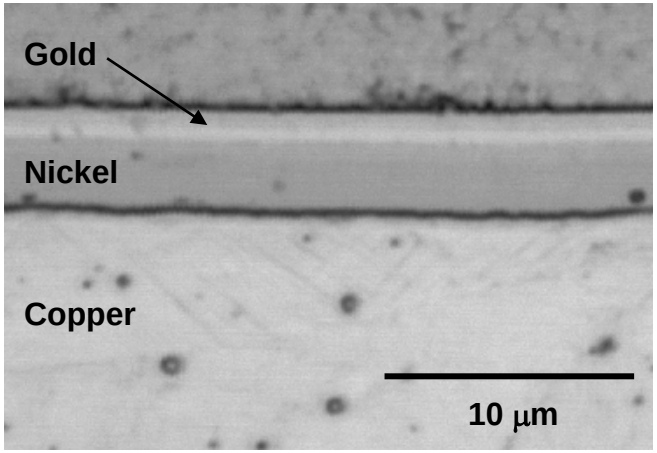
Data Acquisition and Image Analysis Software Resolving Individual Defects



System Demonstration:
Atmospheric Corrosion of Connector Materials





- Atmospheric corrosion of gold plated copper features used in electrical and electronic devices can impact their reliability and effective service life.
- Effective modeling requires that the relevant corrosion degradation phenomena be understood and the key kinetic parameters determined

System Demonstration: Atmospheric Corrosion of Connector Materials

- Oxygen free copper panels, mechanically lapped to a 15-20nm RMS finish
- Electroplated with one of two metallurgies
  - 2.5 μm Au (ASTM Type I, Code C, class 2.5)
  - 2.5 μm Au over 5 μm Ni

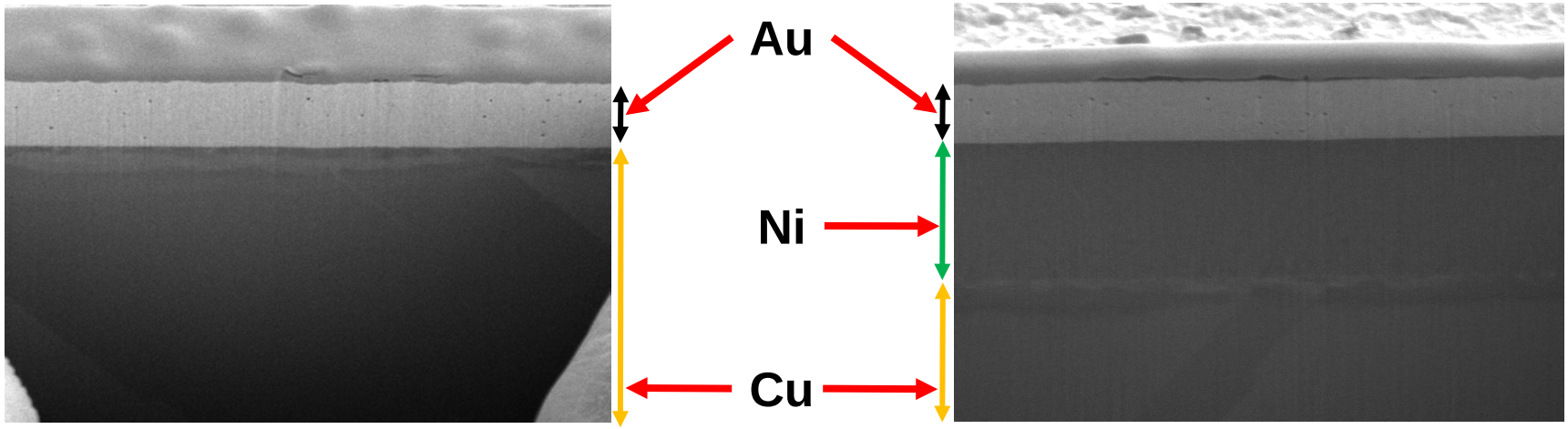


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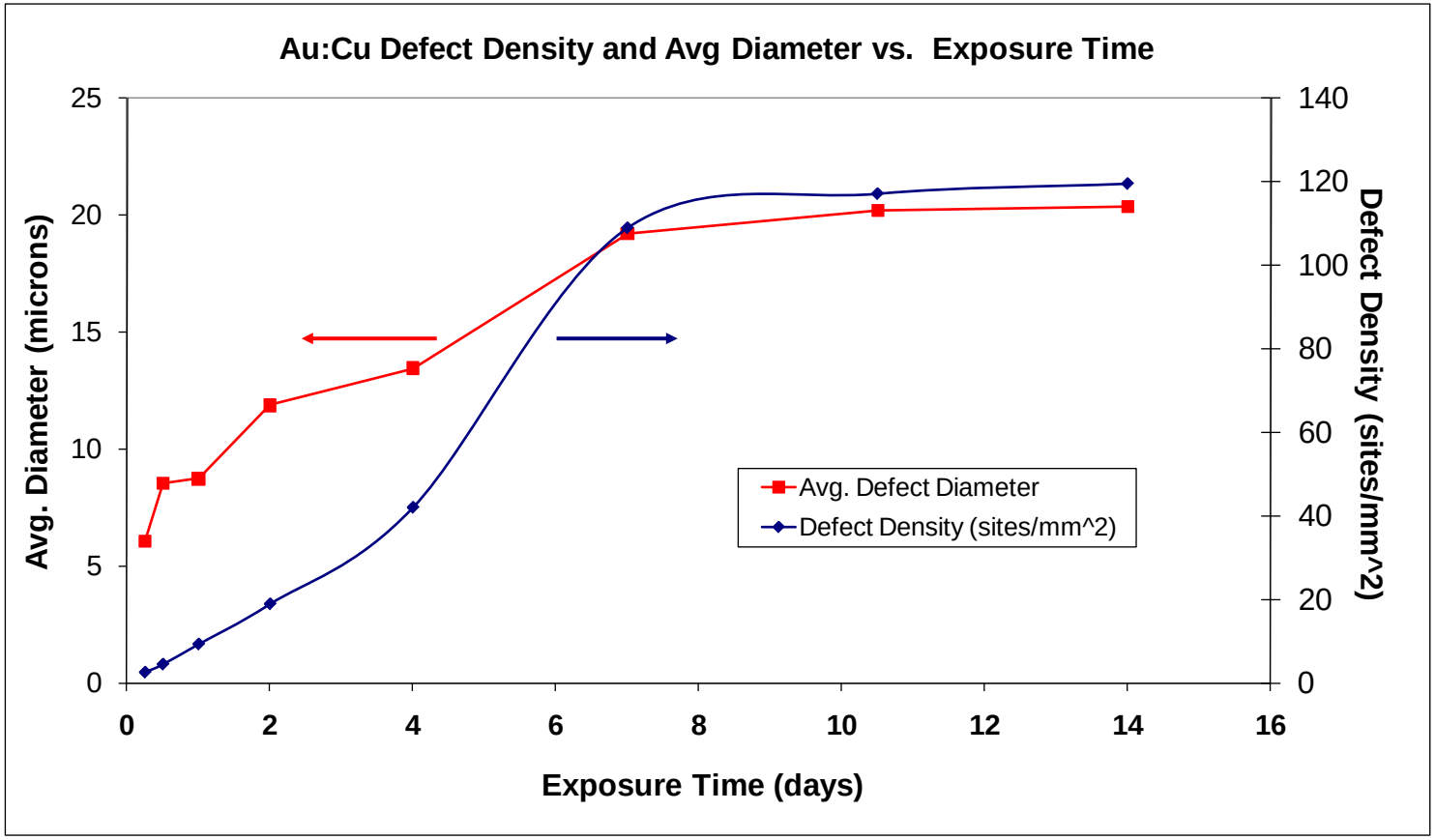
Image Analysis – Defect Density vs. Time
Au:Cu Samples



- 60 discrete regions monitored as a function of time
- Defect size approximated as a circle

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Image Analysis – Defect Density vs. Time
Au:Ni:Cu Samples

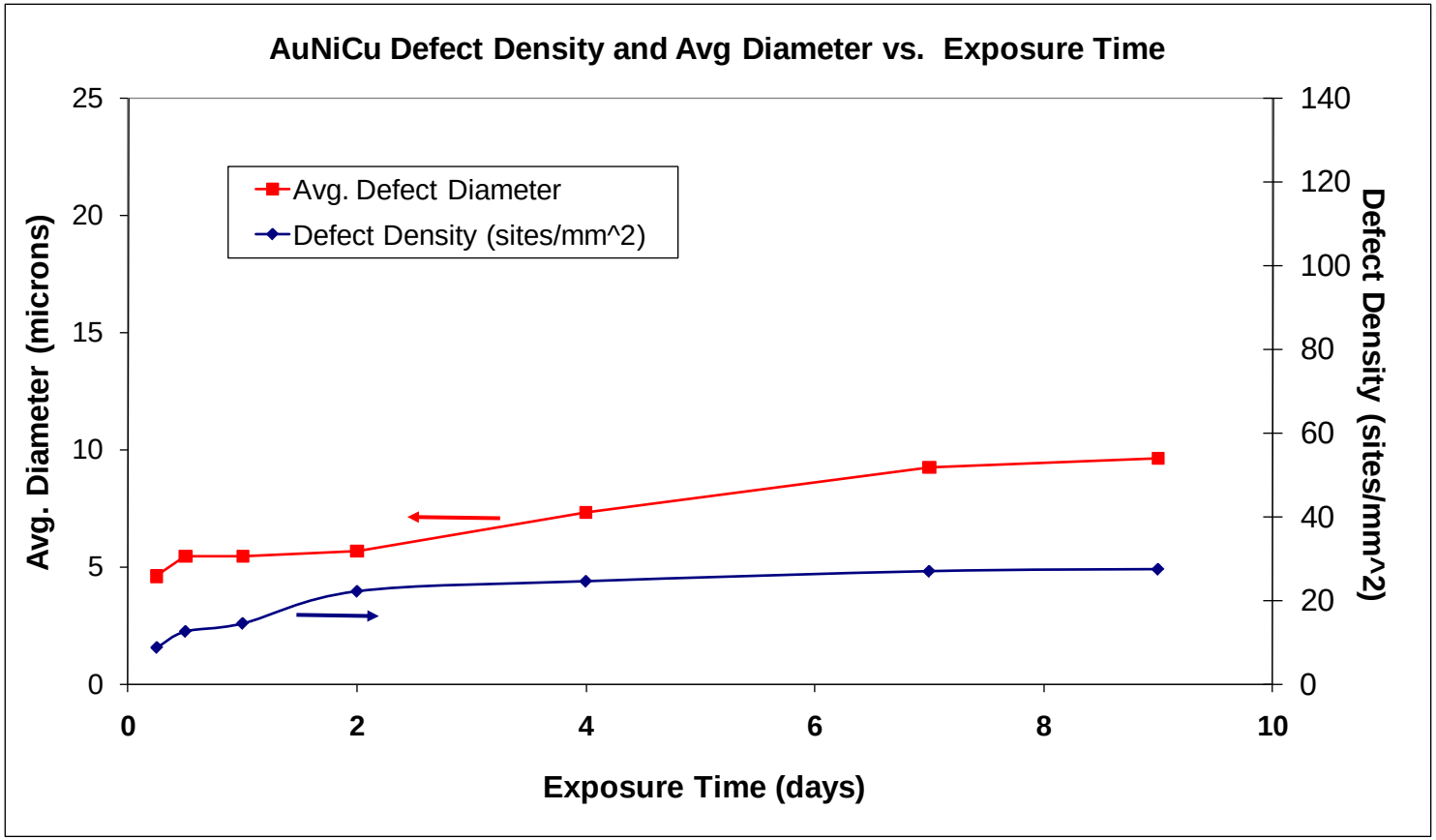

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Image Analysis – Defect Size Distribution vs. Time
Au:Cu Samples

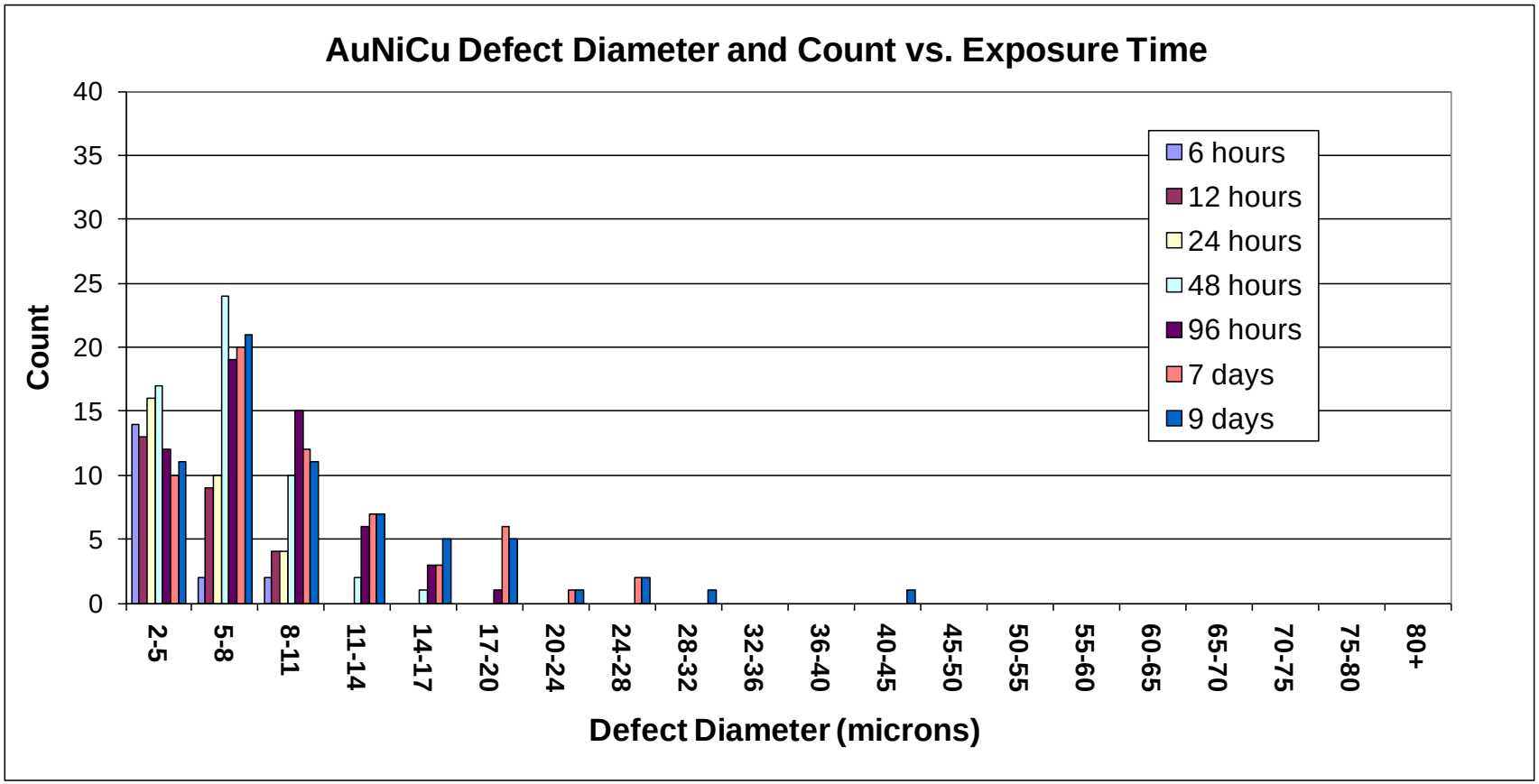

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Image Analysis – Defect Size Distribution vs. Time
Au:Ni:Cu Samples

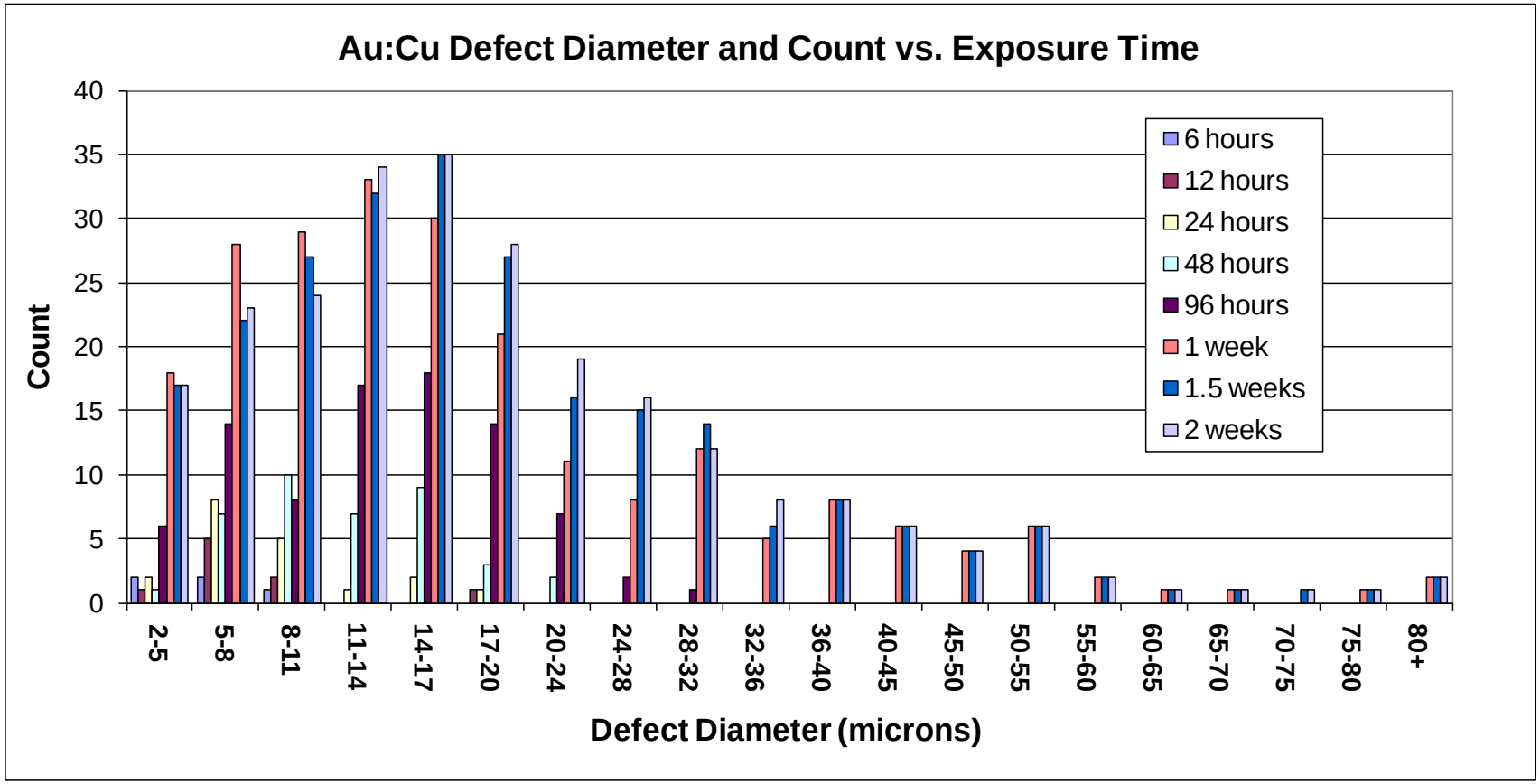

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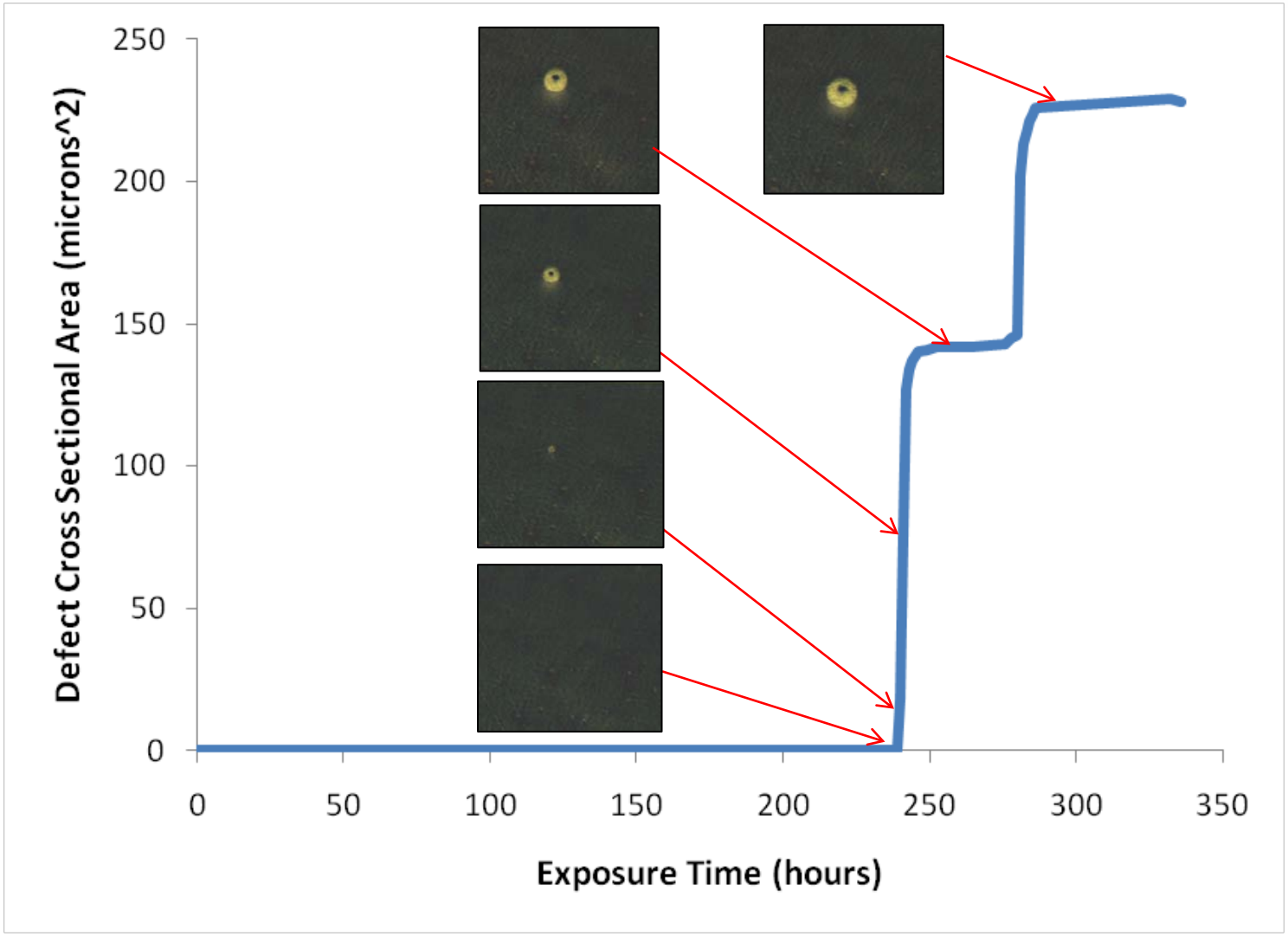
Image Analysis – Individual Defect Size vs. Time
Au:Ni:Cu Sample



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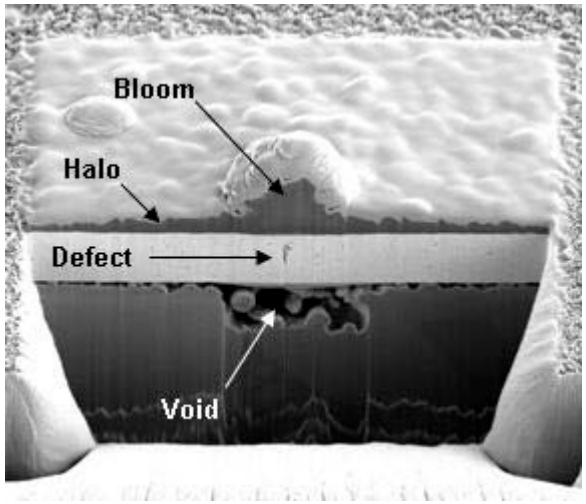
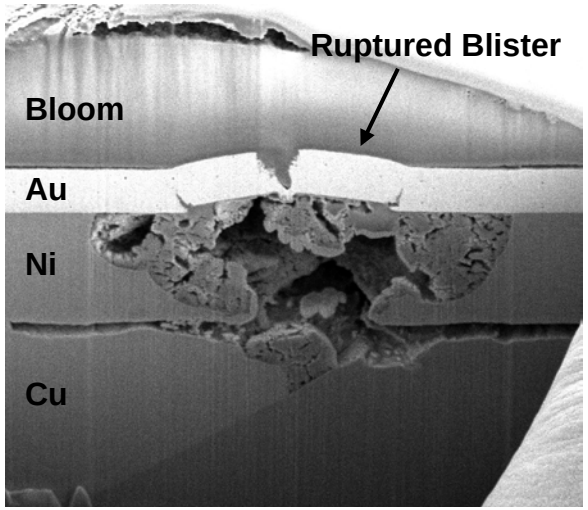
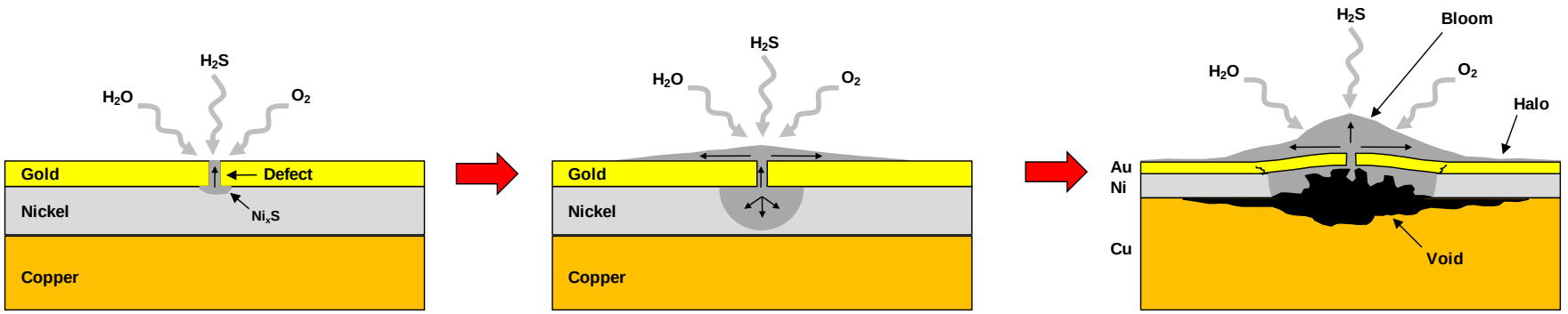
Why Is There A Multi-Stage Growth Process?

Au:Cu



Au:Ni:Cu





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Summary/Conclusions

- **Differential imaging system has been developed which enables samples undergoing atmospheric corrosion to be imaged in real time**
  - System functionality demonstrated on noble metal plated copper as used in microelectronic connectors

- **System has provided considerable insight into the sulfidation process for noble metal plated copper**
  - Unbiased measure of corrosion site density and size distribution
  - Time dependent evaluation of corrosion site size
    - Multi-stage growth process revealed
    - While additional work is necessary to confirm, experiments to date agree with mechanism proposed for site nucleation, growth, and passivation/stifling