



An Alternative Method for Surface Cleanliness Characterization

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November 8, 2021

Approved for public release. OTR 2021-00993.



Introduction

Background on Surface Particulate Cleanliness Characterization

- Standard Characterization Technique: **Tapelifts**
 - Industry standard (ASTM E1216)
 - Particle counting on tape is complicated by background artifacts (e.g. air bubbles in adhesive, peeling marks, etc.)

- An Alternative Approach: **Gel-Pak[®]**
 - Repurposed from other applications (e.g., device handling)
 - Comparable performance to heritage 3M 480 tape
 - Based on lab and flight hardware testing
 - Heritage on previous missions (New Horizons¹)



1) Hogue, P. New Horizons Pluto lessons learned during ground processing. in *Optical Systems Degradation, Contamination, and Stray Light: Effects, Measurements, and Control II* **6291**, 629109 (SPIE, 2006).



Overview

Evaluating Gel-Pak[®] as a Surface Sampling Alternative

- Sampling Performance
 - *Compare Gel-Pak[®] against industry standard methodology*
- Cross-Contamination Risks
 - *Assess Gel-Pak[®] contamination potential with outgassing testing*
- Sampling Processing and Analysis:
 - *Assess imaging and particle counting on Gel-Pak[®] samples*

Aerospace in-house testing performed to compare Gel-Pak[®] and 3M 480 tape



Sampling Performance

Testing Liftoff Efficiency

3M 480 vs Gel-Pak[®]



Particle Dispersion



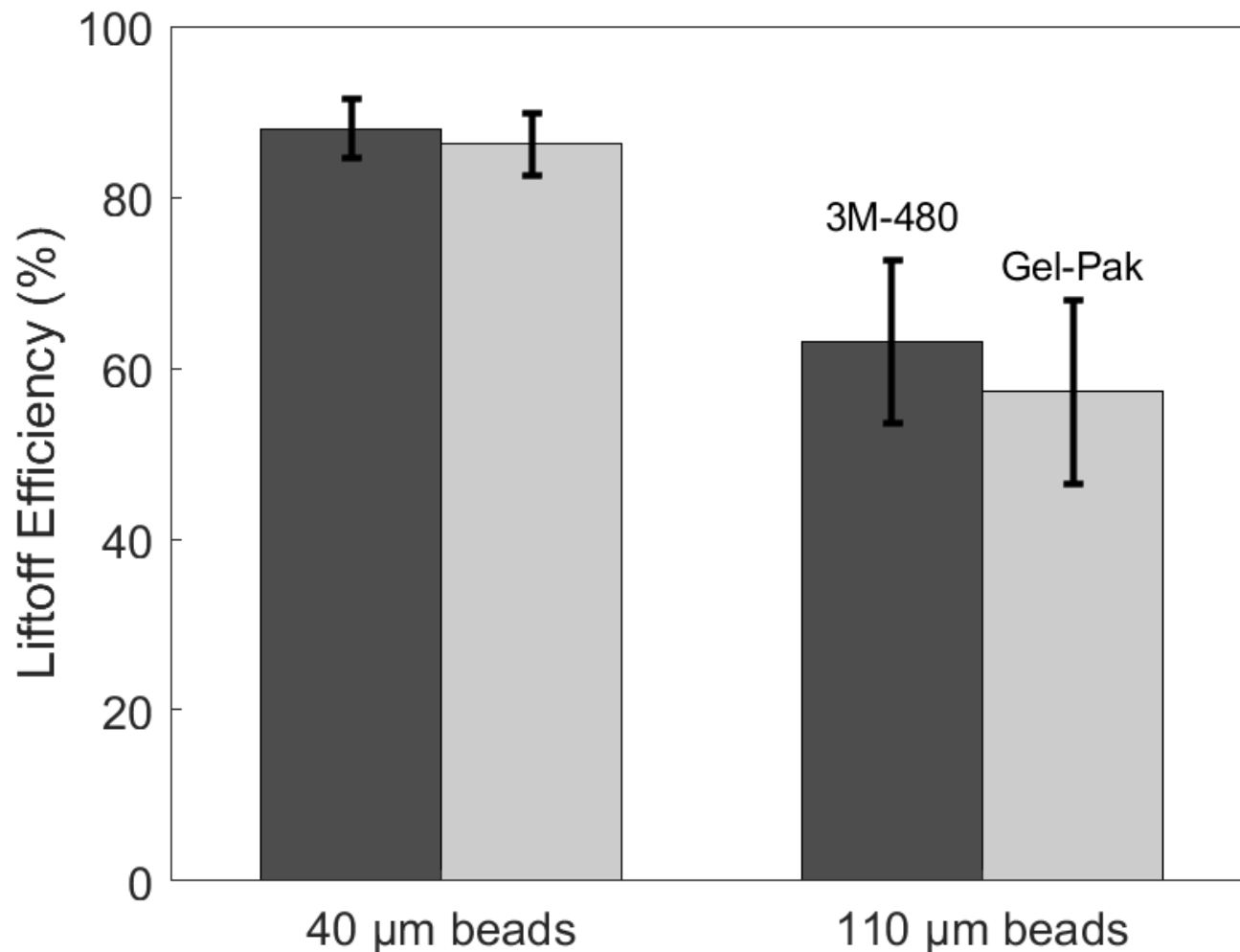
- 1) Disperse particles over test and witness surfaces
 - Use spherical glass beads (40 and 110 μm)
 - Allows differentiation from other particles (dust, fibers, etc.)

- 2) Apply tape and Gel-Pak[®] to test surface
 - Sampling of adjacent areas

- 3) Particle Counting
 - Compare tape and Gel-Pak[®] to witness surfaces (WS)
 - Two WS used to assess particle distribution uniformity

Comparing 3M 480 Tape and Gel-Pak[®]

In-house Lab Testing: Results



Good agreement between Gel-Pak[®] and 3M 480 sampling on a hard surface



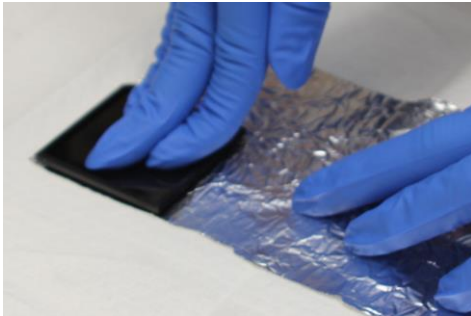
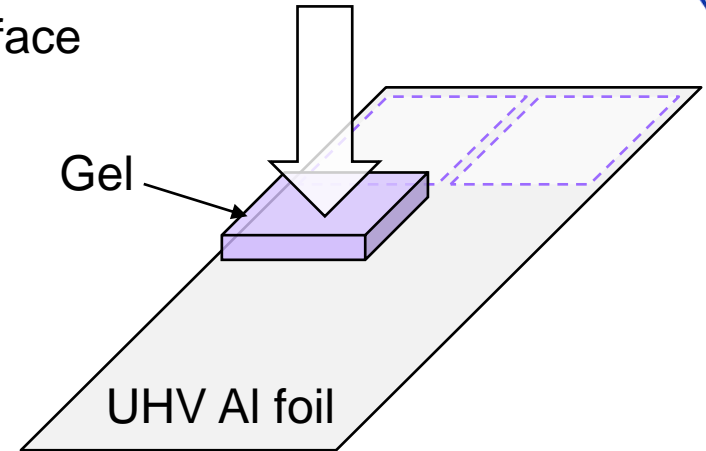
Cross-Contamination Assessment



Cross-Contamination Risk Assessment

Evaluating Outgassing from Gel-Pak[®] Sampling

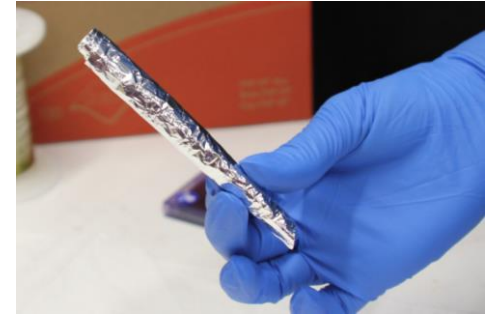
- **Step 1:** Simulate Gel-Pak[®] sampling on clean surface
 - Use pristine, UHV aluminum foil
 - One for Gel-Pak[®] sampling
 - One for control



Stamping



Gel stamped 8 times



Foil rolled up for outgassing experiment

Simulating Gel-Pak[®] Sampling

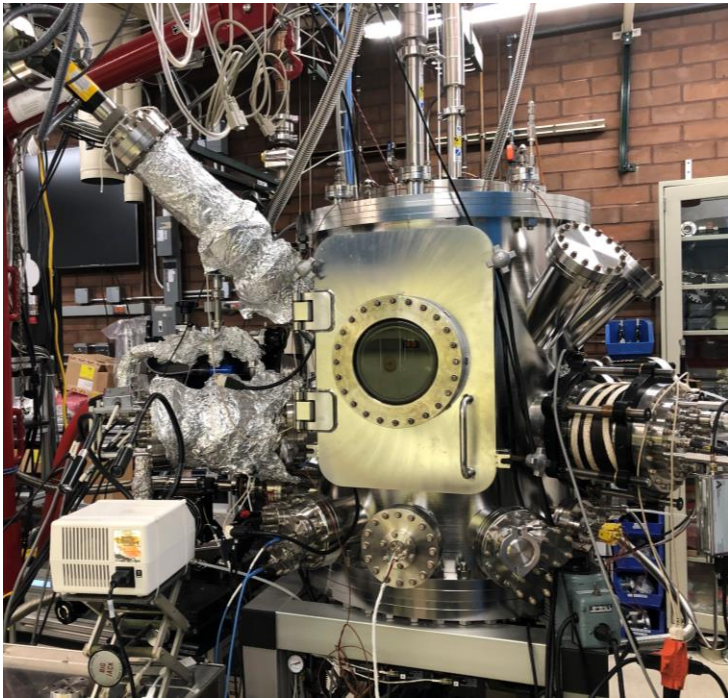


Cross-Contamination Risk Assessment

Evaluating Outgassing from Gel-Pak[®] Sampling

- **Step 2:** Measure outgassing from sampled surfaces
 - *ASTM E1559 outgassing test*

Aerospace In-House Testing Chamber



Sample allowed to outgas for 24 hours:

- 32°C for 2 hours
- 125°C for 22 hours

Outgassed products collected on CQCMs at:

- 25°C, 12°C, and -73°C

Collected species analyzed with mass spectrometer

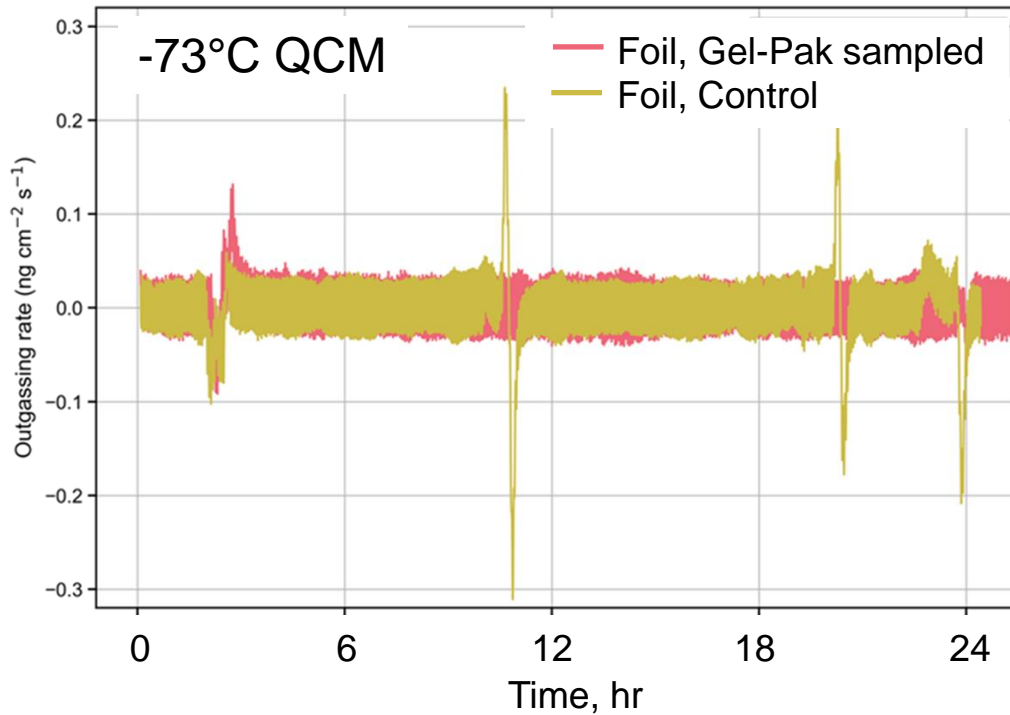
- Can determine type of contaminant (e.g. silicones)

Outgassing test assessing Gel-Pak[®] contamination potential

Cross-Contamination Risk Assessment

Results

- Outgassing rates measured by QCM (Quartz Crystal Microbalance)
 - Negligible outgassing from control and Gel-Pak[®] sampled foil



Temp.	Outgassed Mass (mg / ft ²)
	Gel-Pak [®] Sampled - Control
25°C	0.0
12°C	0.0
-73°C	0.3

Negligible outgassing after Gel-Pak[®] sampling

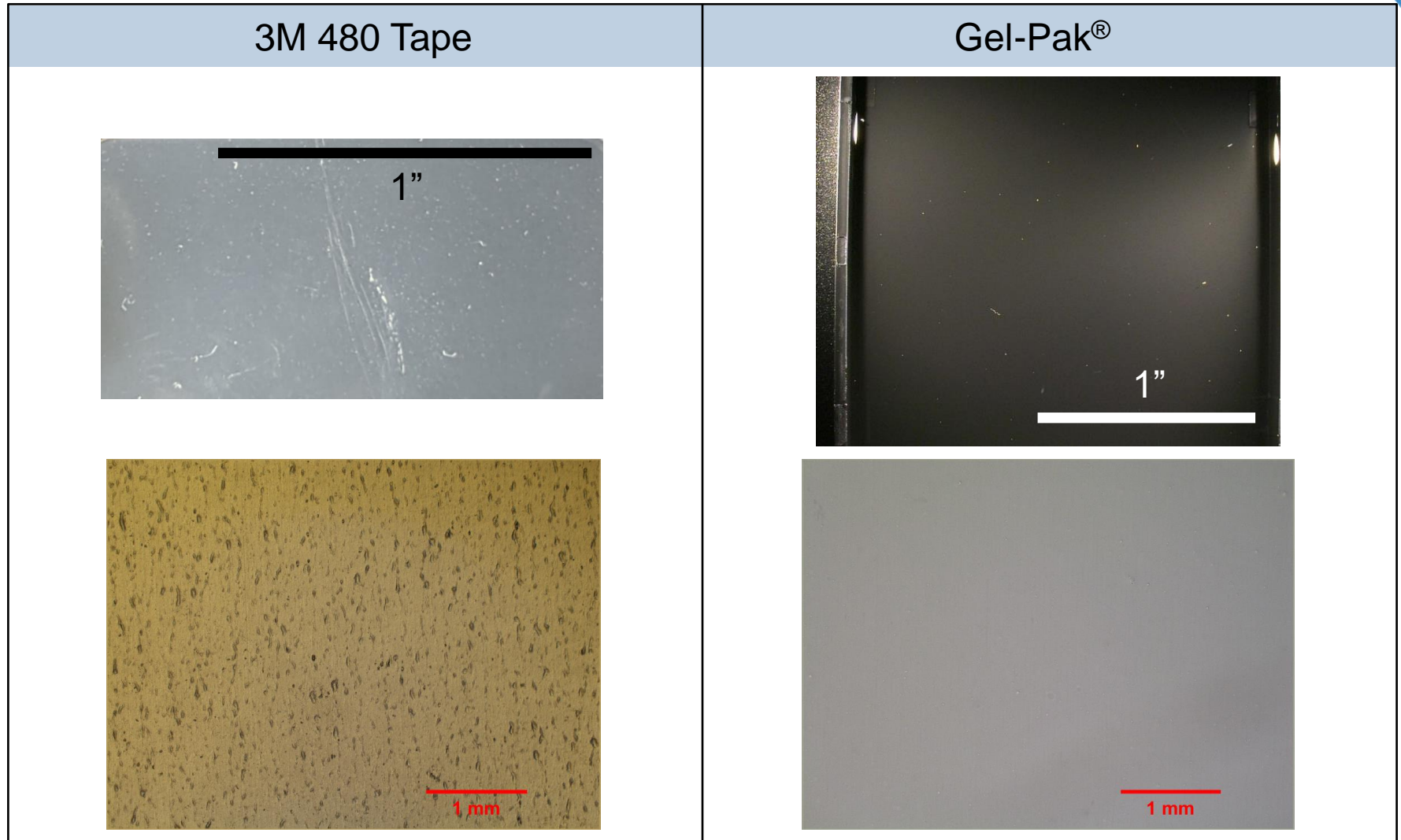


Particle Counting and Analysis



Image Analysis

Comparing backgrounds



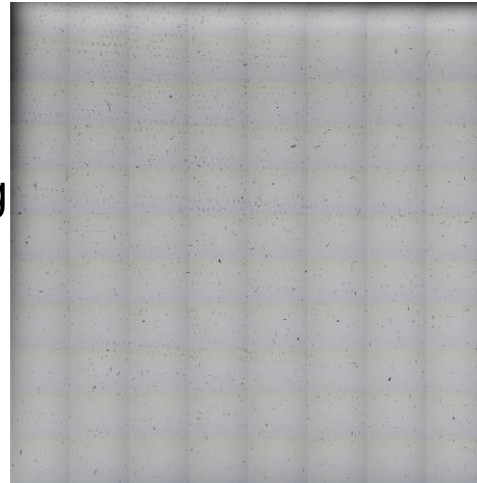
Smooth background of Gel-Pak[®] enables simple image analysis

Sample Analysis

Imaging and Processing



imaging

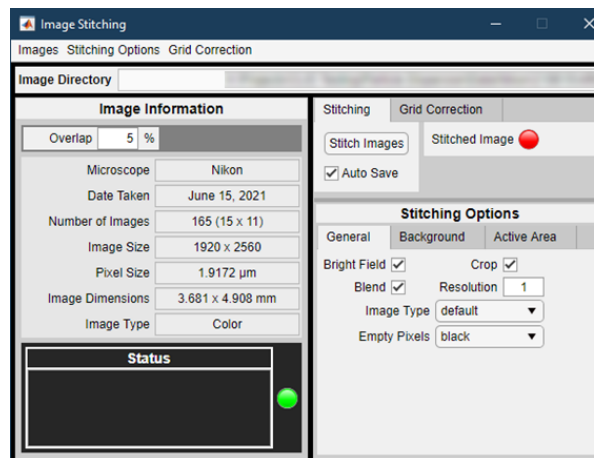


stitching



- Automated sample imaging
 - Using microscope with motorized stage
 - Covers full sample

Image Processing GUI



- Stitches tiles together
 - Outputs single image
- Image Corrections:
 - Relative position
 - Background
 - Blending
- Fully Automated

Sample Analysis

Imaging and Processing



AEROSPACE



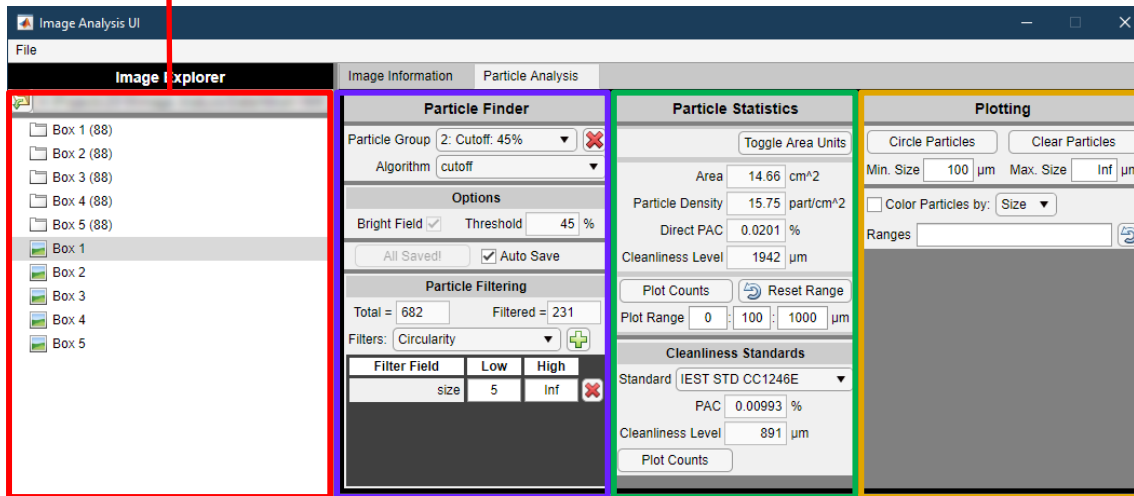
Place GelPak on microscope stage

Image Analysis

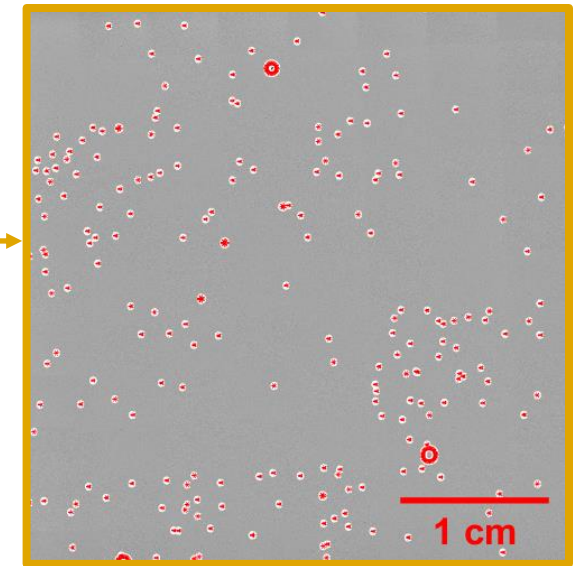
In-House Graphical User Interface Tool for Automated Analysis



File Viewer



Full Image
with particles circled

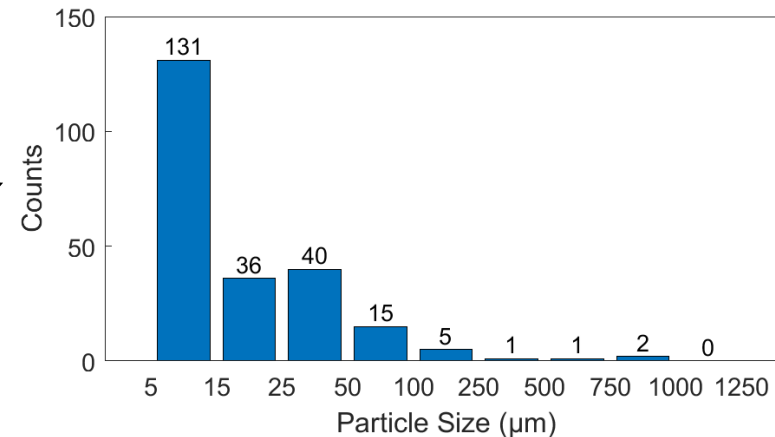


Particle Counting

- Find all particles by pixel thresholding
- Filter by size, shape, etc.

Particle Statistics

- Compute PAC
- Plot particle counts



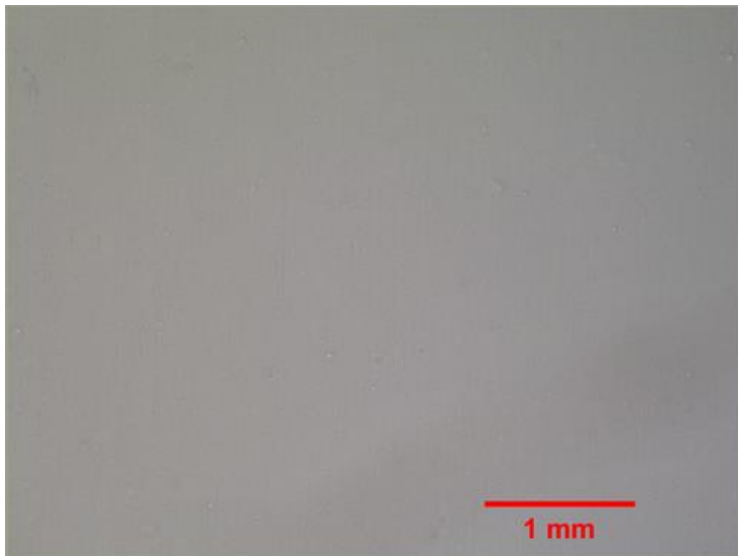


A Closer Look at the Gel-Pak[®] Surface

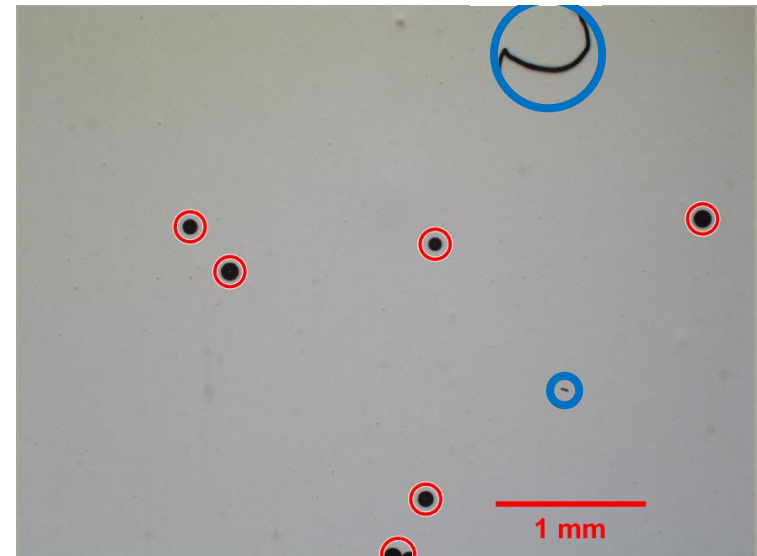
Automated Particle Counting

- Smooth background makes particles stand out
- Automated algorithm can identify particles
 - *Filters based on size, shape, color, etc. can isolate particles of interest*

Clean Gel-Pak[®]



Glass Beads on Gel-Pak[®]



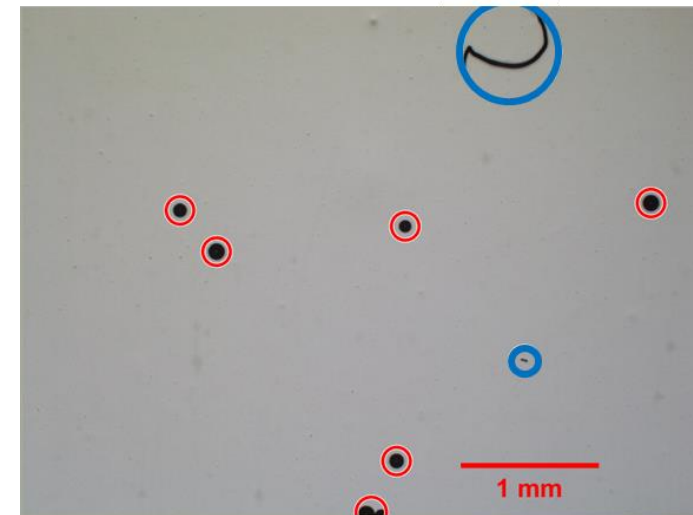
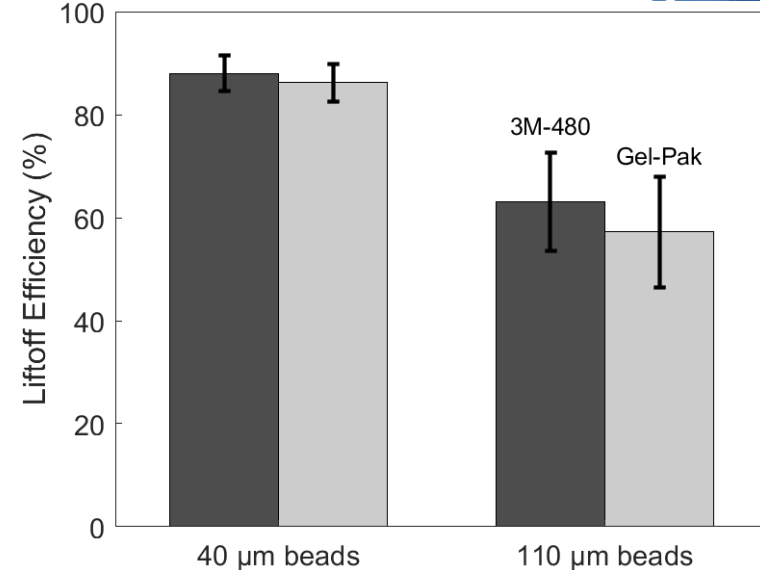
*Identified glass beads circled in red

*Other particles circled in blue

Good contrast of particles from background for automated counting

Conclusions

- Reasonable agreement in surface cleanliness measurements using Gel-Pak[®] and 3M 480 tape
- Negligible cross contamination from Gel-Pak[®] sampling
- Gel-Pak[®] simplifies sample processing and analysis
 - *Enables analysis automation, enhancing counting accuracy*
- Future Work:
 - *Aerospace is looking for partnership in further assessing Gel-Pak[®] and its application in flight programs*
 - *Investigation of cleanliness sampling on non-flat surfaces in work*



Gel-Pak[®] is a promising for surface cleanliness characterization



Acknowledgements

- Aerospace Technical Investment Program
- Dr. Ming (Mike) Lee
 - *Aerospace Program Office (Systems Dynamics and Environments)*



Backup

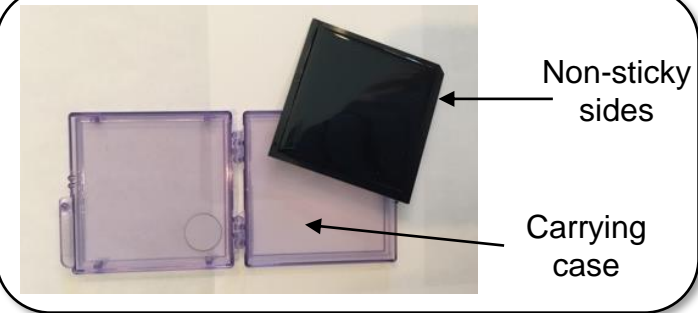
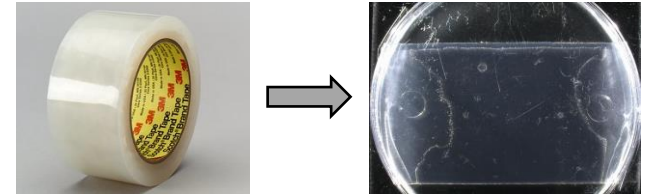


Other Advantages

Improvements with Gel-Pak[®]

- No sample preparation required
 - *Tape segments must be carefully peeled from roll*
 - *Can optionally perform pre-counting*
- Simplified sample handling and transport
 - *Rigid tray makes handling easy*
 - *Gel-Pak[®] was designed for device handling, and can be easily transported*
- Easier and more consistent surface sampling
 - *Tape must be slowly and steadily peeled from surface to avoid adhesive artifacts*
 - *Rigid Gel-Pak[®] design simplifies uniform application of pressure when sampling*
 - *Reduces user error and variability*
- Particles may be easily transferred for chemical analysis (e.g. SEM/EDX)

Tape Preparation



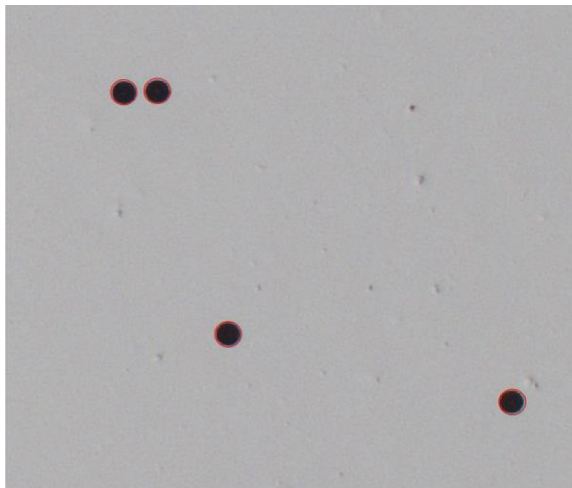
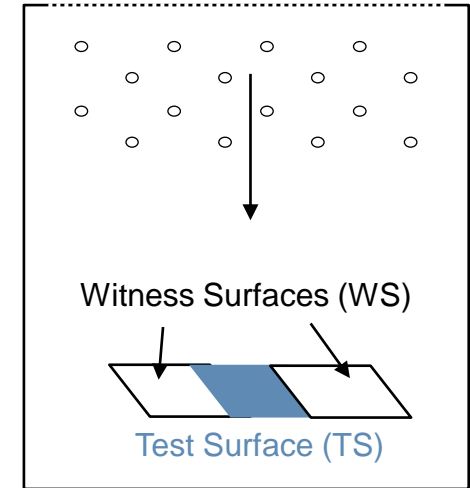
Gel-Pak[®] simplifies sample preparation, collection, handling, and transport



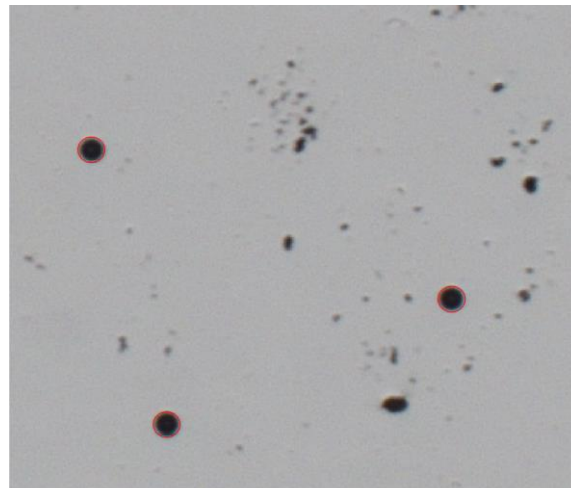
Liftoff Efficiency Image Analysis

Only circular particles are included

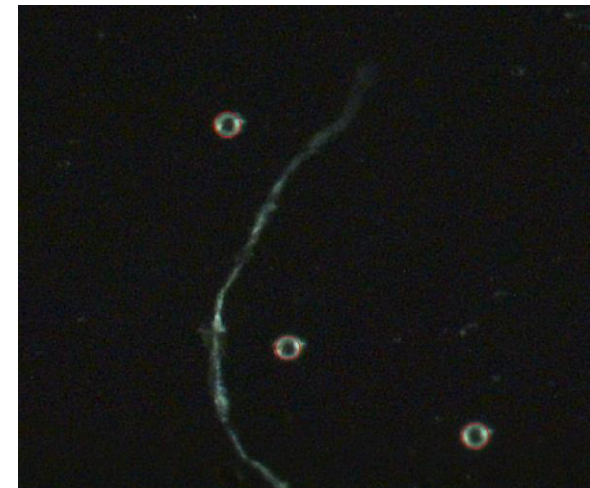
- Particle sampling efficiency:
 - *The ratio of glass bead density on the Test Surface to that on the Witness Surfaces*
- Particle counting implemented via in-house MATLAB code
 - *All circles are automatically detected*
 - *Particle density per unit area is calculated*
 - *Imaging analysis on 3M 480 tape is possible using idealized spherical shape of glass beads in dark field*



Gel-Pak® used as WS



Gel-Pak® sampled from TS

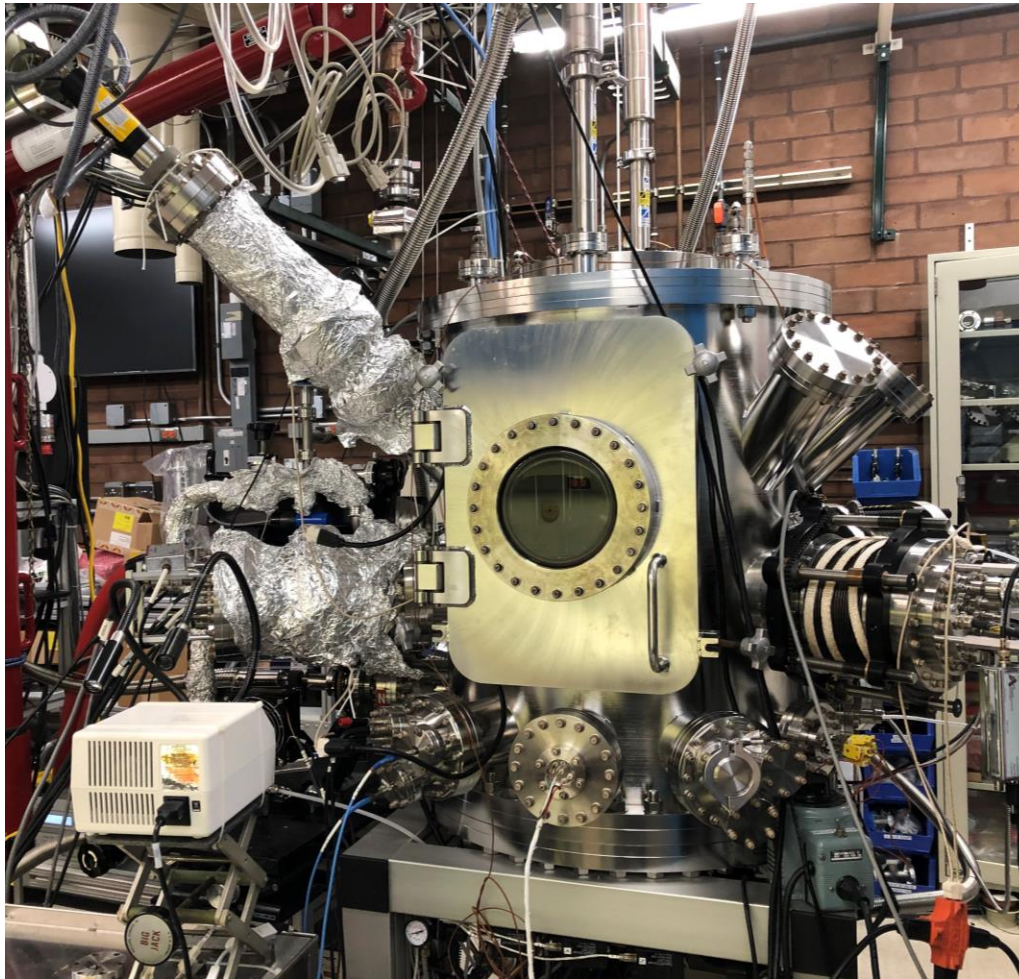


3M 480 tape sampled from TS

Particle sampling efficiency calculation is done by automatic imaging analysis

Contamination Effects, Research & Testing Chamber

CERT Chamber

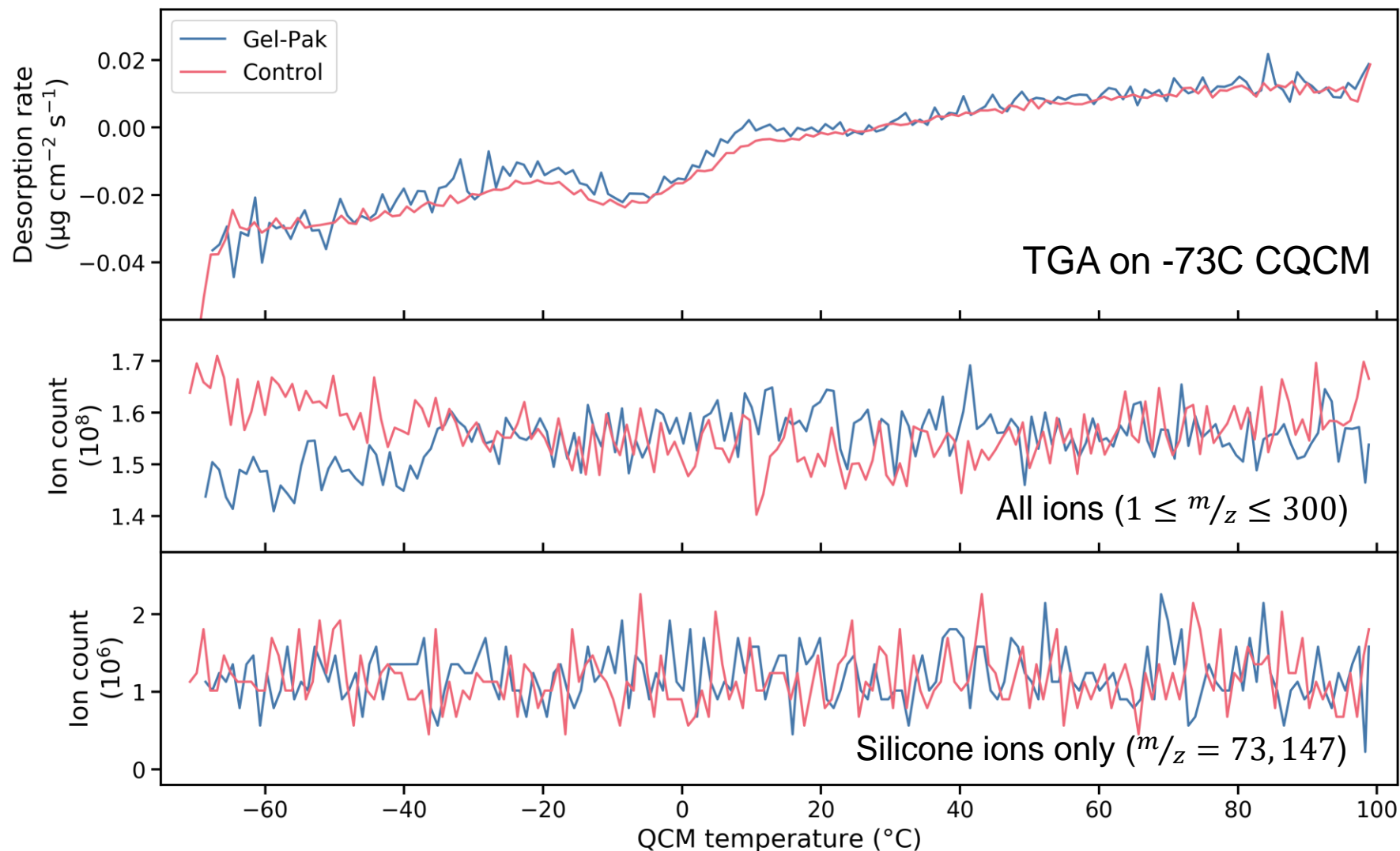


- **ASTM E1559 testing capability**
 - Base pressure in the low 10^{-9} Torr
 - Effusion cell with temperature range from 0°C to 212°C
 - 4 CQCMs
 - Two Extrel mass spectrometers
- **Other custom features**
 - Deuterium lamp for UV exposure testing
 - Microscope and light scatter measurements to test droplet formation on surfaces
 - Vis-NIR spectrometer for spectral transmission measurements

General purpose test facility for space material contamination effects

Gel-Pak[®] Sampled Al Foil Outgassing Results

TGA on -73°C CQCM



Negligible difference between Gel-Pak[®]-sampled and control surfaces