The James Webb Space Telescope: contamination control and materials

Elaine Stewart
NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 2077

Introduction

https://www.nasa.gov/sites/default/files/thumbnails/image/jwst_primary_mirror_in_nasa_goddard_clean_room.jpg

- Expected launch in 2021 from French Guiana
- Optimized for infrared wavelengths and observation 1.5 million kilometers from Earth
- Integrated Science Instrument Module (ISIM) contains:
    - Near-Infrared Camera (NIRCam)
    - Near-Infrared Spectrograph (NIRSpec)
    - Mid-Infrared Instrument (MIRI)
    - Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS)

JWST will look back 13.5 billion years to “First Light” which occurred 100 – 250 million years after the Big Bang when the first stars and galaxies formed. Its ability to observe very high redshifts will enable astronomers to study the faintest galaxies, observe stars forming within clouds of dust, determine how galaxies evolved, and search for exoplanets[1,2].

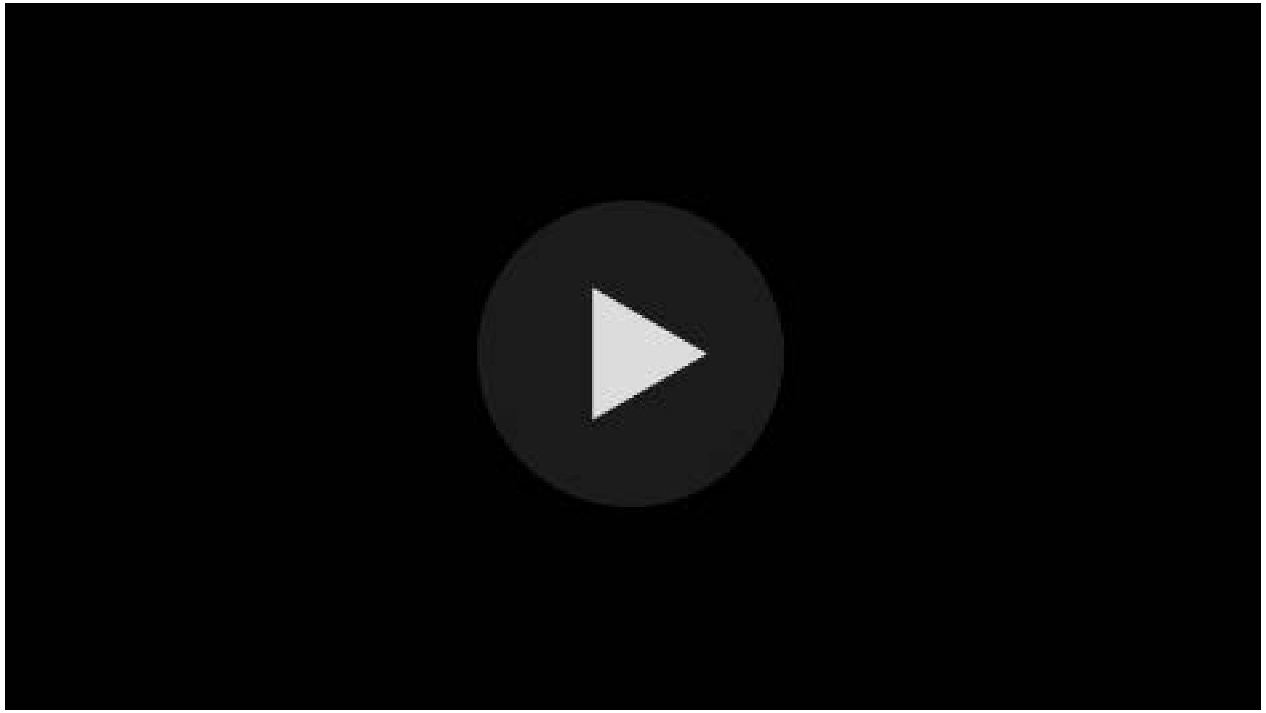
Contamination Sensitivity

Image credit: NASA

Molecular Contaminants	Sources of Contaminants
Hydrocarbons	Plastics
Pthalates	Adhesives
Palmitates	Lubricants
Esters	Expoxies
Silicones	Potting Compounds

JWST is extremely sensitive to even small amounts of contamination, which can directly cause degradation to performance of the telescope, and impact the mission lifetime. Contamination control has been an essential focus of this mission since conception of the JWST observatory[3].

Path of Light



Video Credit: NASA, ESA, and G. Bacon (STScI)

The mirror cleanliness is imperative due to the path of light for JWST when looking at targets.

Optical Telescope Element (OTE) Cleanliness

	PAC	Molecular (Angstroms)
Primary Mirror (PM)	1.5	350
Secondary Mirror Assembly (SMA)	.5	350
Tertiary Mirror Assembly (TMA)	.5	350
Fine Steering Mirror (FSM)	.5	325

To ensure these requirements are met, silicon wafers are used to represent the surface of the mirrors. These wafers have followed the mirrors since as early as 2013 to demonstrate the condition of these optics as closely as possible.

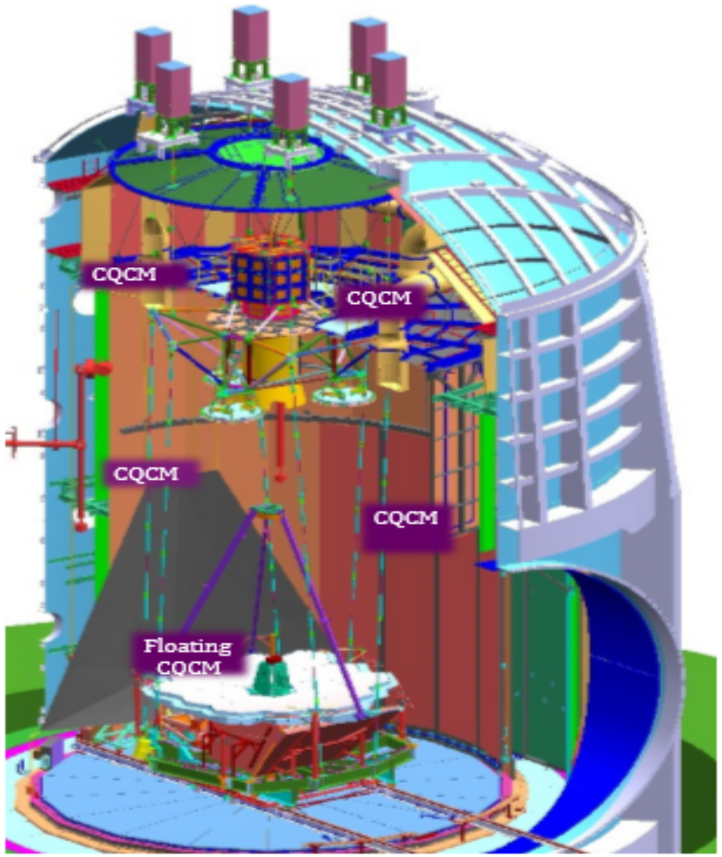
Wafers are monitored using:

-Image analysis (IA)

-Ellipsometry

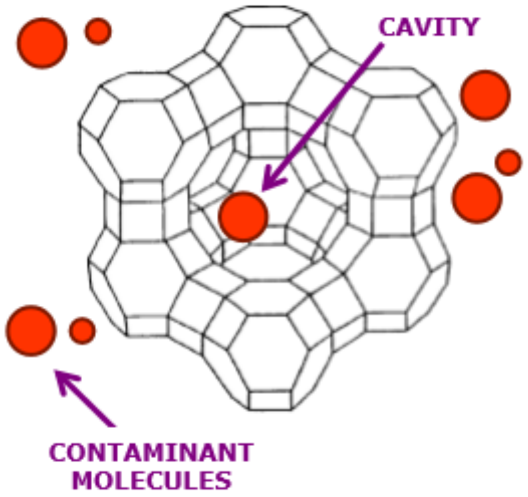
Chamber A Thermal Vacuum Test

- In 2017, a 90+ day long test was performed on JWST to validate the sensors and mirror alignments in the temperatures of deep space. A schematic of Johnson Space Center's enormous Chamber A is shown with the placement of the cryogenic quartz crystal microbalances (CQCMs). With the use of both a nitrogen and helium shroud, the telescope was subjected to colder than 50 K conditions[7]. Thermal monitoring of outgassing during cryo-chamber tests is accomplished by the highly sensitive CQCMs[4].



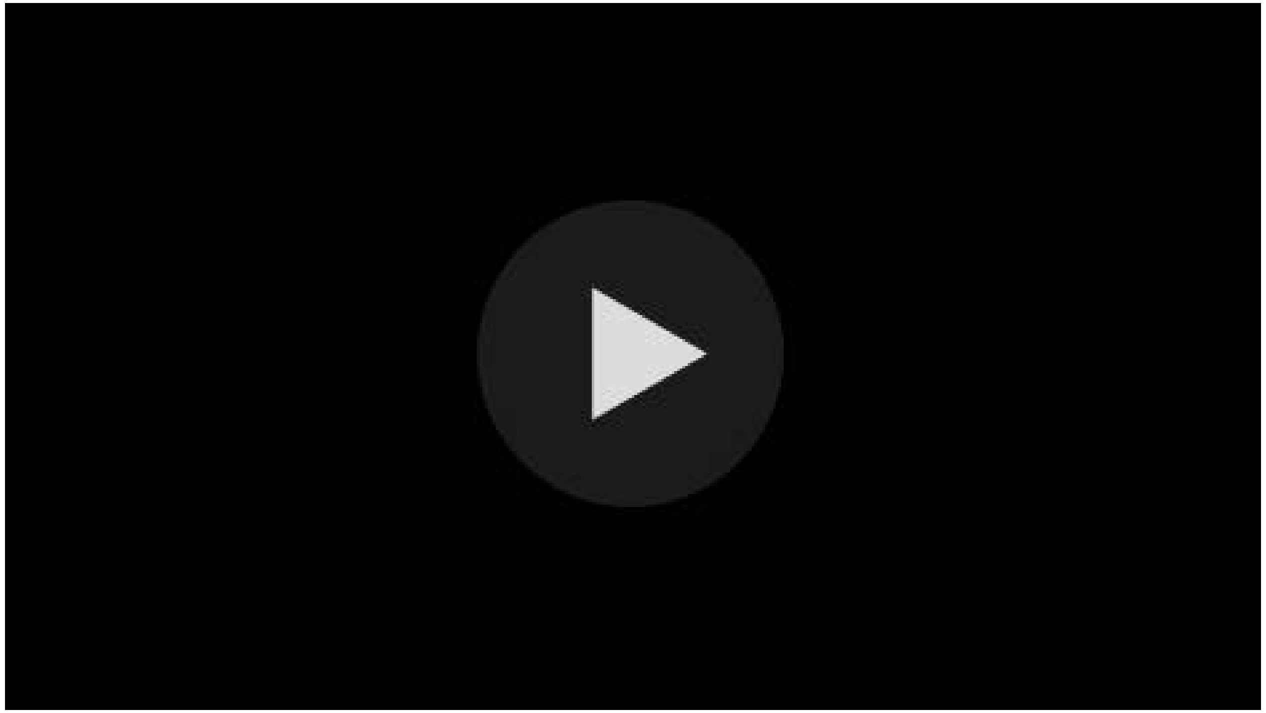
Cryogenic chamber contamination control

- Molecular Adsorber Coating (MAC). MAC can be used in chamber environments to reduce outgassing rates, reduce the pump down process, and achieve high vacuum and lower pressures. MAC was specifically used, in this case, to trap silicone based contaminants and prevent harmful outgassed species from depositing on sensitive JWST surfaces[9].



Ongoing Efforts

- A challenge present in monitoring cleanliness on JWST includes the various orientations possible for surfaces such as optics and instruments.



Video Credit: NASA

Ongoing project examining percent area coverage (PAC) on vertical and horizontal silicon wafers.

Conclusions

http://www.americaspace.com/wp-content/uploads/2014/02/dfd.jpg

In the path forward to launch, contamination will continue to be closely monitored. Molecular and particulate contamination will be mitigated to ensure mission success of JWST.

Acknowledgements

- **Thank you to NASA Goddard Spaceflight Center and specifically:**
  - Eve M Wooldridge, Kelly H. Nelson, Joseph O. Ward, Alan Abeel, Zao Huang, Matt Macias and the entire Goddard contamination engineering and technician team, Johnson engineering and technician contamination team, and the Northrup Grumman contamination engineering and technician team.

https://jwst.nasa.gov/images/people.jpg

Sources

- [1] "NASA's James Webb Space Telescope". Space Telescope Science Institute. https://jwst.stsci.edu/about-jwst
- [2] "Webb Telescope Science Themes." NASA GSFC. https://jwst.nasa.gov/science.html
- [3] Burns, et al. "Contamination Control and Hardware Processing Solutions." NASA, 5-537166.
- [4] Wooldridge, et al. "Contamination control requirements implementation for the JWST." SPIE, 2014.
- [5] Abeel and Huang. "James Webb Space Telescope primary and secondary mirror segment assembly cleaning: a quantitative assessment". SPIE, 2018.
- [6] "JWST Light Path." NASA, ESA, STScl Animation, 2015.
- [7] Clark. "JWST shipped to Texas." Spaceflight Now, 05/09/2017
- [8] Quartz Crystal Microbalance openqcm.com.
- [9] Abraham, et al. "The use of Molecular Absorber Coating to mitigate vacuum chamber contamination." SPIE, 2016.