SELECTING CLEANROOM CONSTRUCTION MATERIALS FOR THE OSIRIS-REX AND HAYABUSA2 CURATION FACILITY AT NASA JOHNSON SPACE CENTER. M.J. Calaway[1], A.S. Burton[2], J.P. Dworkin[3], K. Righter[2], K. Nakamura-Messenger[2], F.M. McCubbin[2], R.A. Zeigler[2], L.F. Pace[2], D.S. Lauretta[4] and the OSIRIS-REx Team. [1] Jacobs, NASA Johnson Space Center, Houston, TX; [2] NASA Johnson Space Center, Astromaterials Acquisition and Curation Office, Houston, TX; [3] Astrochemistry Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD; [4] Lunar and Planetary Laboratory, University of Arizona, AZ; michael.calaway@nasa.gov.

Introduction: In early 2019, NASA Johnson Space Center (JSC) Astromaterials Acquisition and Curation Office [1] in JSC bldg. 31 will commence construction of two ISO Class 5 cleanroom laboratory suites for the Hayabusa2 and OSIRIS-REx sample return missions. These missions will deliver pristine samples of carbonaceous asteroidal material to Earth in 2020 and 2023 respectively. These new curation facilities are designed for initial receiving, preliminary examination, and basic curation characterization and processing of small particles. The facilities were also designed to enable long-term pristine sample storage and preservation of their scientific integrity to promote decades of future research by the international scientific community.

The scientific study of organics in general including biologically abundant compounds, like amino acids, is critical for both missions. In an effort to mitigate terrestrial contamination and preserve any organic signature, the OSIRIS-REx mission implemented a stringent contamination control plan [2] where all sample hardware at time of sample acquisition would be at Level 100 A/2 per IEST-STD-CC1246D (non-volatile residue (NVR) < 500 ng/cm^2). In addition, the mission imposed a requirement of <180 ng/cm^2 for amino acids (and hydrazine) [2]. Given these mission requirements, long-term storage preservation requirements, and information from the Organic Contamination Baseline Study at JSC [3], JSC Curation team decided to carefully select cleanroom construction materials that would not hinder the scientific search for amino acids and the study of organics in the samples.

A year prior to final cleanroom design with RS&H Inc. (architectural firm NASA contracted to design the cleanrooms), we began researching cleanroom candidate construction materials for the floors, walls, ceiling, and plenum areas. An extensive cleanroom literature and industry search was first conducted for finding construction materials that have low particulate shedding and outgassing properties along with good mechanical properties for cleanability, chemical resistance, and minimizing electrostatic charges (e.g., conductive flooring). After the literature and industry search, our team narrowed several candidate materials that would be further tested for their specific outgassing characteristics using ASTM E-595 as well as better understanding the organic compounds using DART-MS analyses. The information gained from these two analyses provided the foundation for the selection of the cleanroom materials.

ASTM E-595 Testing: ASTM E-2312 "Standard Practice for Tests of Cleanroom Materials" states outgassing tests for cleanroom surface materials shall use ASTM E-595 "Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment". ASTM E-595 uses a vacuum chamber at 125 ˚C for 24 hours. Product outgassing is reported in Total Mass Loss (TML%), Collected Volatile Condensable Materials (CVCM%), and Water Vapor Regain (WVR%).

Since the Apollo program, NASA has considered any material <1.0 TML% and <0.10 CVCM% to be a low outgassing material for spaceflight hardware. While this test was originally intended for spaceflight hardware, the curation office adopted the test for a qualitative comparison of ground hardware used in the Lunar Receiving Laboratory to reduce the organic load in the laboratory and gloveboxes. Since 1968, JSC Curation has used NASA WSTF for E-595 material testing.

DART-MS Analyses: At NASA JSC, a Waters Xevo G2-XS QToF, with IonSense DART-MS set up for TLC plate mode was used for organic analyses of the selected construction materials. The instrumentational parameters are as follows:

- Positive ionization performed at 3.0 kV
- Negative ionization performed at 2.5 kV
- Bazooka tube (129 mm) set at 1-2 mm above material surface
- DART source at 9.6 cm

Samples were analyzed by performing a horizontal scan across candidate materials, collecting background scans before and after the sample material: TLC plate to the material to the TLC plate. The DART spectra were collected in positive mode at 300, 400, and 500°C, then a new area was selected for negative mode, which also collected data at 300, 400, 500°C. After data processing, both the POS and NEG spectra were compared among the sample candidates.

Flooring Systems: Vinyl and epoxy flooring systems are the traditional two choices for cleanroom floors [4, 5]. Both flooring systems offer low particulate shedding, chemical resistance, cleanability, durability, and electrostatic conductive floors. Epoxy floor systems have been used extensively in the semiconductor industry due to low outgassing characteristics. Conversely, the biotech/pharmaceutical industry widely use vinyl flooring for good microbial control and resistance to many biocide cleaning chemicals.

Table 1 shows the results for all the tested flooring system candidates. The lowest TML% and CVCM%

was a flooring system called Stonchem 441 by Stonhard. This is a new non-traditional floor system that uses a 100% solids polyurea-polyurethane hybrid lining system. It uses no adhesives and is applied like epoxy in liquid form and then allowed to cure. This immersion grade lining provides a durable, flexible, waterproof membrane that can withstand significant impact and abrasion. The second lowest was a flooring system called Arizona Performance Floor Epoxy 750. This is a 100% solid, two-component, 2:1 mix ratio epoxy system. Epoxy 750 has been used as a cleanroom flooring system in Aerospace, biotechnology, pharmaceutical, and semiconductor industries. While the DART-MS results of both of these systems showed more diversity in the organic compounds when compared to vinyl flooring systems, they were both significantly lower in their outgassing characteristics.

Material	TML %	CVCM %	WVR %
Stonchem 441 Floor System	1.47	0.00	0.55
Arizona PF Epoxy Floor System	3.41	0.08	0.38
Sherwin Williams Pro Industrial Water Based Epoxy System	3.47	0.21	0.80
AkzoNobel Devoe High Performance Coatings Tru-Glaze Water Based Epoxy System	4.80	0.48	0.55
HooverWells Rez-stone Epoxy Floor System: custom 1	5.40	0.04	0.22
Stontrace LC5 Floor System	5.53	0.00	4.79
Gerflor Gerfix Spray Adhesive for Vinyl Flooring	7.84	1.96	0.19
Gerflor Mipolam Biocontrol Vinyl Flooring (NOT performance grade)	8.99	4.16	0.06
AQUAPON WB 2-Part Epoxy System	9.29	1.49	0.56
Gerflor Mipolam Biocontrol Performance Vinyl Flooring	10.24	5.41	0.07
HooverWells Rez-stone Epoxy Floor System: custom 2	11.98	0.03	0.32
Gerflor Vinyl Flooring with adhesive	18.08	7.37	0.26

Table 1: ASTM E-595 Results for Tested Flooring Systems.

Wall Systems: Cleanroom walls are typically designed as a modular panel or epoxy painted gypsum board (drywall). For ISO Class 5 cleanrooms, drywall is difficult to seal penetrations and can add particulates overtime. In addition, traditionally applied cleanroom paints usually outgas more than composite panels, which use advanced coil coating paint system with high temperature curing ovens [4, 5].

Material	TML %	CVCM %	WVR %
Lasco Wall Panel; Larson Aluminum Composite with Polyester Paint	0.20	0.04	0.01
Arcoplast Gel-coat on Fiberglass Composite Wall Panel	0.39	0.01	0.09
Gerflor Decoclean PVC Wall Panels	0.40	0.04	0.11
Arcoplast Arcylic Wall Panel	0.48	0.01	0.12
Ultrabond ECO 901 Adhesive for Gerflor PVC Wall Panels	2.43	0.02	1.32
Gerflor Decoclean PVC Wall Panels with adhesive	2.83	0.06	1.43

Table 2: ASTM E-595 Results for Tested Wall Systems.

Table 2 shows the E-595 results for all wall panels tested. The Lasco wall panel (Larson aluminum composite wall panel with Duracoat XT-20S corporate white paint) offered the best results. A similar panel is currently used for the Genesis and Stardust curation cleanrooms. The Gerflor system uses adhesives to glue the panel to drywall where the adhesive significantly raises the outgassing. The DART-MS spectra showed few peaks for the Lasco and Gerflor PVC panel. However, both acroplast systems had a complex diversity of organics.

Paint Systems: The lowest outgassing cleanroom paint systems are two-part epoxy paints [4, 5]. Table 3 shows the E-595 results from three selected paint systems from three major manufacturers. While epoxy paint will not be used inside these working cleanrooms, parts of the cleanroom air plenum walls will require paint. Sherwin Williams 2-part epoxy paint was chosen based on the lowest outgassing result.

Material	TML %	CVCM %	WVR %
Sherwin Williams Pro Industrial Water Based Epoxy System	3.47	0.21	0.80
AkzoNobel Devoe High Performance Coatings Tru-Glaze Water Based Epoxy System	4.80	0.48	0.55
AQUAPON WB 2-Part Epoxy System	9.29	1.49	0.56

Table 3: ASTM E-595 Results for Tested Paint Systems.

Summary: All selected material systems were rated for ISO Class 5 or below for particulate shedding and long-term durability, including the use of heavy gloveboxes and equipment on the floor. The DART-MS results were useful for identifying material with the least organic compound diversification as well as classes of compounds that could affect amino acid research. However, in some cases, the team chose a lower outgassing material to minimize the total organic carbon (TOC) load of the laboratory. The DART-MS spectra peak heights also correlate well with E-595 outgassing results.

Based on the material specifications, mechanical properties, DART-MS analyses, and outgassing results, the RS&H cleanroom design incorporated:

- *Walls/Ceilings:* Lasco Wall Panel
- *Floor:* Stonchem 441
- *Plenum Wall/Door Paint:* Sherwin Williams Epoxy System

Both curation cleanroom laboratories are intended to be commissioned in the spring of 2020.

Reference: [1] Allen et al. (2011). Chemie der Erde-Geochemistry, 71(1), 1-20. [2] Dworkin et al. (2018) Space Sci Rev, 214: 19. [3] Calaway et al. (2014). NASA/TP-2014-217393. [4] Whyte, W. (Ed.). (2000). Cleanroom design. Wiley. [5] Whyte, W. (2010). Cleanroom technology: fundamentals of design, testing and operation. Wiley.

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