CLEANING GENESIS MISSION PAYLOAD FOR FLIGHT WITH ULTRA-PURE WATER AND ASSEMBLY IN ISO CLASS 4 ENVIRONMENT. J. H. Allton, NASA/Johnson Space Center, Mail Code KT, 2101 NASA Parkway, Houston, TX 77058, USA, judith.h.allton@nasa.gov.

Introduction: Genesis mission to capture and return to Earth solar wind samples had very stringent contamination control requirements in order to distinguish the solar atoms from terrestrial ones. Genesis mission goals were to measure solar composition for most of the periodic table, so great care was taken to avoid particulate contamination. Since the number 1 and 2 science goals were to determine the oxygen and nitrogen isotopic composition, organic contamination was minimized by tightly controlling offgassing. The total amount of solar material captured in two years is about 400 micrograms spread across one m^2. The contamination limit requirement for each of C, N, and O was $<10^{15}$ atoms/cm^2 [1]. For carbon, this is equivalent to 10 ng/cm^2. Extreme vigilance was used in preparing Genesis collectors and cleaning hardware for flight. Surface contamination on polished silicon wafers, measured in Genesis laboratory is approximately 10 ng/cm^2 [2].

"Start Clean – Stay Clean" a whole mission approach: Contamination control was integrated into the Genesis mission from the very beginning: in mission design, in spacecraft design, in spacecraft cleaning and assembly, and in sample curation. This abstract focuses on cleaning and assembly of the payload, a science canister containing 300 solar wind collectors. The contamination sensitive solar collectors were isolated inside of a science canister in which organic materials (including lubricants and seals) were severely restricted and which was equipped with a molecular sorbent filter for pressure equalization upon re-entry. The mechanisms of the few moving parts were isolated and vented outside of the canister. The canister outer structure was fabricated from aluminum 7075 and interior structure from 6061. All interior aluminum surfaces were not anodized, to avoid the higher surface area and contamination introduced by the anodization process.

Cleaning and assembly environment: Canister components were cleaned and assembled inside of an ISO Class 4 laminar flow cleanroom [3]. Assembly was done by individuals totally enclosed in HEPA-filtered Teflon suits (Fig. 1). Gloved hands never touched cleaned hardware, to preclude transfer of any nitrile glove residue. Even smallest screws were installed using stainless steel tweezers.

Cleaning process rationale: The hardware was cleaned using ultrapure water (UPW) to avoid leaving any organic residue. [Note for future cleaning: UPW-may be especially useful if certain cleaning solvents are banned because of ozone depleting or greenhouse gas properties.]

Fig. 1. Engineers, enclosed in HEPA-filtered suits, assemble Genesis collectors into the science canister inside of an ISO Class 4 cleanroom at Johnson Space Center. Small pieces of cleaned aluminum foil are used to grasp the collector array, so that gloves never directly touch the hardware.

Ultrapure Water (UPW): UPW water (ASTM D5127-07), with metal cation and anion concentrations in the low parts per trillion, was chosen as the cleaning fluid for Genesis hardware because it was thought to leave very low residue. This ultrapure water, prepared by continuous filtration (at 0.04 µm particle size), irradiation with UV, and ion exchange, is characterized by a resistivity of 18 megohm-cm and a total oxidizable carbon (TOC) concentration of <10 ppb (typically <2 ppb). The Genesis ultrapure water system supplies 10 gal/min. The UPW is monitored continually for TOC content and particles down to 0.05µm in size (can detect single bacterial cells). Water this pure is a reactive solvent. It reacts with containers; thus, it is produced and used dynamically. Cleaning is done with flowing UPW, either in an ultrasonic cascade tank (Fig. 2) or megasonic wand for large items (Fig. 3). The resulting particle cleanliness level for two large items, the canister cover and base, is shown in Fig.4.

Fig. 2. Genesis array frame is cleaned with flowing UPW in a 30-inch diameter cascade tank enhanced with ultrasonic energy.

Fig. 3. Megasonically energized flowing UPW is used to clean large Genesis canister base.

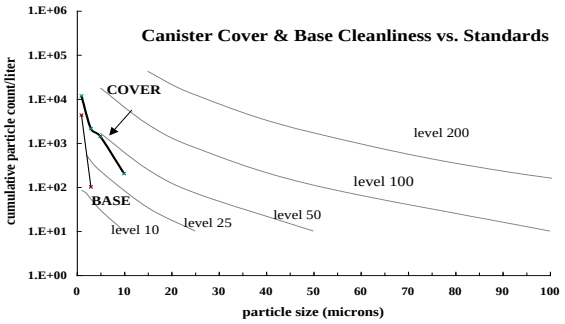

Fig. 4. Cleaning curves for large item canister cover and base are better than level 50 (IEST-STD-1246D). These items were cleaned as pictured in Fig. 3 and assessed by rinse water counts.

Hardware Cleanability: Clean design (coved corners, no blind holes, no inaccessible areas), smooth surfaces, and cleanable materials are required for rigorous cleaning. Stainless steel is very cleanable in UPW. Bare aluminum, as required to keep inorganic contaminants low, is reactive and challenging to clean with UPW. Fig. 5 shows effects of extended cleaning at high temperatures; therefore, aluminum parts were cleaned at 40° C.

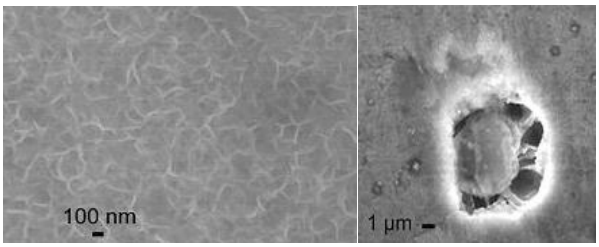

Fig. 5. Left is wrinkled texture of hydroxide formation on 6061 after 30 min. at 75° C (scale bar is 100 nm). Right is etched pit in 6061 after 30 min. at 50° C (scale bar is 1 µm).

Keeping organic contamination low during assembly: The organic lubricants and staking compounds were used inside of the canister only when demonstrated necessary and in extremely small amouts. For example, staking compounds were applied to exterior fasteners with the tip of a dental pick. A very small amount of Braycote lubricant was applied to the 94-inch circumference canister seal with a number 00 artist brush. Everytime a gloved hand came into contact with the Braycote container, the person left the lab and changed gloves.

How well did we do? Since Genesis solar wind samples were returned to Earth for analysis, an assessment of cleaning efforts can be made, at least for the organics. The hard landing in the Utah dry lakebed and breach of the canister containment cancels lab cleaning efforts. Even with the stringent controls on organics in the laboratory molecular contamination was acquired in orbit, most probably from offgassing of RTV and silicones. Ellipsometry measurements indicated a discontinuous film thickness of about 50 Å [4]. XPS measurements indicated silicone and fluorine. This film was thin and did not interfere with solar wind capture. The in-space UV exposure polymerized the film, requiring removal with UV ozone treatment [5].

Success! Genesis investigators, through persistence and ingenuity, have achieved the number 1 and 2 science goals of determining the oxygen and nitrogen isotopic composition of the Sun to high precision [6] [7]. The surprising (to many) oxygen abundances have directly challenged the basic solar system model and spurred new experimentation. Results have also been published for noble gases and some transition elements..

Summary:

- Clean assembly can be achieved inside of an ISO Class 4 laboratory.
- UPW is an effective solvent for cleaning particulates without leaving an organic residue.
- Even trace amounts of necessary lubricants and elastomers can migrate to sensitive surfaces at the monolayer level.

References: [1] Burnett D. S. *et al*. (2002) *Space Sci. Rev*. 105:509-534. [2] Allton J. H. and Burkett P. J. (2012) Abstract #6028 this volume.. [3] ISO 14644-1, Inst. Of Environ. Sci., Arlington Heights, IL. [4] Allton J. H. *et al*. (2006) *LPS XXXVII*, Abstract #1611. [5] Calaway *et al*. (2007) *LPS XXXVIII*, Abstract # 1627. [6] McKeegan K. D. *et al*. (2011) Science June 24, 2011, 1528-1532. [7] Marty *et al*. (2011) Science June 24, 2011, 1533-1536.