Advanced Curation Development of Tools and Methods for Microparticle Processing

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Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center is currently developing new tools and methods for the collection, storage, handling and characterization of particles <100μm in diameter, or microparticles [1]. Astromaterials Curation currently maintains four microparticle collections [2]: Cosmic Dust that has been collected in Earth's stratosphere by ER2 and WB-57 aircraft, Comet 81P/Wild 2 dust returned by NASA's Stardust spacecraft, interstellar dust that was returned by Stardust, and a portion of asteroid Itokawa particles that were returned by JAXA's Hayabusa spacecraft. NASA Curation is currently preparing for the anticipated return of two new astromaterials collections – asteroid Ryugu regolith to be collected by Hayabusa II spacecraft in 2021 (a subset of samples will be provided by JAXA as part of an international agreement) [3], and asteroid Bennu regolith to be collected by the OSIRIS-REx spacecraft in 2023 [4]. In order to maximize the scientific yield from these valuable acquisitions, it will be necessary to develop methods that extend our current microsample handling capabilities. Here we describe recent progress in the development of sample handling techniques that will enhance our microparticle curation capabilities.

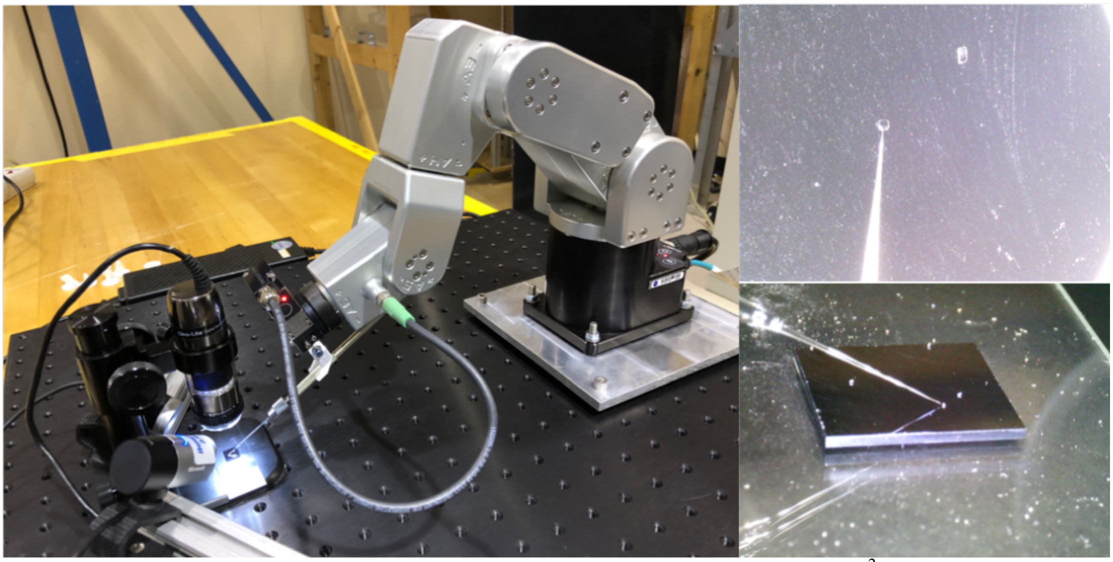

Figure 1: Meca500 robot arm manipulating 0.2mm magnetite particles on 1cm^2 silicon chip.

Six-Axis Robot Arms for Particle Manipulation: We have been investigating the use of compact six-axis robot arms to facilitate microsample handling within gloveboxes. 3-axis micromanipulators are currently in use in the Stardust and Cosmic Dust curation facilities; although they have been extremely successful for activities involving the transfer of isolated particles in the 5-20 μm range (e.g. from microscope slide to epoxy bullet tip, beryllium SEM disk), their limited ranges of motion and lack of yaw, pitch and roll degrees of freedom restrict their utility in other applications. For instance, curators removing particles from cosmic dust collectors by hand often employ scooping and rotating motions to successfully free trapped particles from the silicone oil coatings. While cosmic dust curators have been remarkably successful with these kinds of particle manipulations using handheld tools, operator fatigue limits the number of particles that can be removed during a given extraction session. The challenges of microparticle curation will be exacerbated by dry N_2 environments of sample cabinets (i.e. gloveboxes) in which Hayabusa2 and OSIRIS-REx samples will be processed. We have recently developed a robotic micromanipulation test platform using the Mecademic Meca500 six-axis robot arm with 5μm reproducibility and an observed step resolution of 1μm. The Meca500 system we designed is controlled via a custom graphic user interface (GUI) either by clicking control buttons within the GUI, or by PC mouse control within a range-of-motion field. Our GUI also includes embedded video feed from a Dino-Lite 5 megapixel USB microscope and a second USB camera mounted at 45 degrees relative to the sample surface for positioning/altitude information. In addition to the GUI control system, we are investigating other means of controlling the Meca500, including videogame controllers and haptic feedback devices.

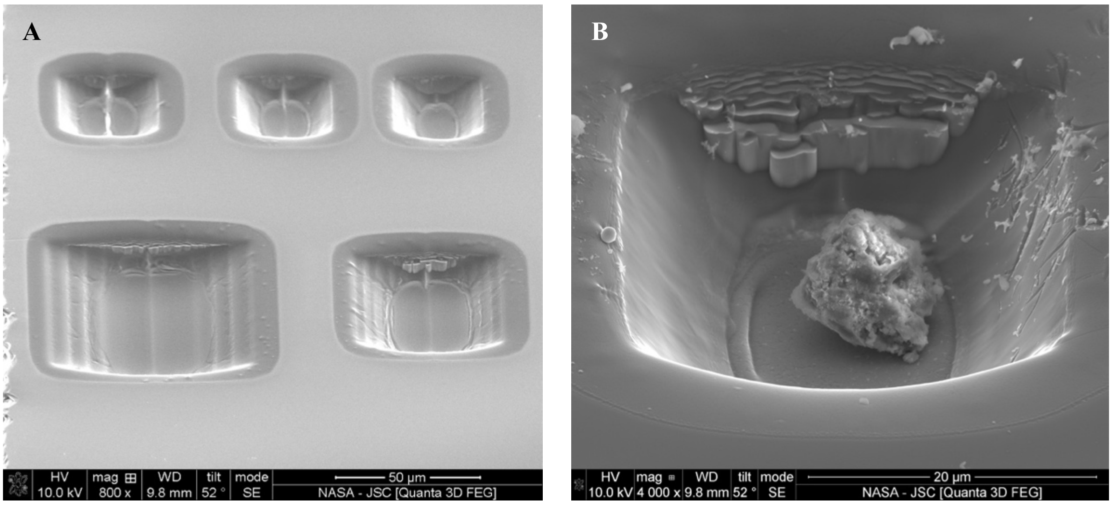

Figure 2: A) Particle receptacles produced via FIB milling. B) Secondary electron image of 10µm particle in well.

Charge-Dissipative Substrates: Microparticles removed from cosmic dust collectors have traditionally been stored and distributed to investigators in glass concavity slides; we have identified friction between these slides and particles as a major source of sample electrification. In cases where substrate transparency is not a curation requirement, the glass slide may be replaced with a charge-dissipative substrate such as silicon. Particles retain a high level of visibility on such substrates, and triboelectric charging [5] is significantly reduced such that microparticles can be reliably manipulated in ambient atmospheric conditions without the use of a Po-210 source. Recently, we have experimented with producing storage receptacles in silicon using focused ion beam (FIB) milling. We used an FEI Quanta 3D-FEG Focused Ion Beam (FIB) to mill several shallow (<20µm) depressions between $30\mu m^2$ and $80\mu m^2$ into the surface of a silicon chip; material was sputtered using a 65nA Ga^+ beam at 30kV. A 10µm particle of CM2 meteorite was placed into one of the FIB-produced wells using a micromanipulator. The charge-dissipative nature of the Si chip enabled us to successfully acquire a secondary electron image of the stored particle using a 190pA beam current at 10kV. Storage substrates that also enable electron beam imaging and characterization are desirable, as they minimize the need for high-risk microparticle transfers between storage and analysis substrates. We are currently investigating this technique to produce storage wells in other charge-dissipative substrates that could enable in-situ elemental analyses.

References:
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