Introduction: Sample preparation, handling, and mounting are important aspects of many analytical techniques, especially when investigating material collected from sample return missions, which must be preserved after any investigative study. Moreover, mounting must be performed in aseptic conditions to mitigate terrestrial contamination, thus making any manipulation more difficult. Based on the various analytical techniques, several types of sample holders (SH) have been proposed in the literature for sample return missions [e.g., 1,2,3]. However, no SH has yet been reported for X-ray photoelectron spectroscopy (XPS) analysis – which provides clues to the surface (< 10nm) chemical state of the investigated sample – fundamental to understanding the space weathering effect on pristine material [e.g., 4].

Here, we propose a new SH suitable for maintaining small-size (1.5-10mm) and high-friable grains – e.g., CI-type carbonaceous chondrites (CC) – in stability conditions during coordinated surface analysis. The sample holder was developed to preserve asteroidal grains for non-destructive and non-invasive surface analytical techniques, i.e., XPS, micro-IR, and micro-Raman. Moreover, a sample holder container (SCH) was employed to support the transport of the SH in a secure, safe manner and without exposure to the terrestrial atmosphere. This work was designed for the analysis of two mm-size grains from the Ryugu asteroid allocated to our group during the second AO for Hayabusa2 samples [5].

Sample holders (SH): For XPS, micro-IR, and micro-Raman coordinated analysis strict constraints are required for the SH. In particular, the following requirements needed to be satisfied due to the specific nature of the samples employed in the analysis here described: (i) hold the small and friable grain still during the analysis; (ii) provide secure and safe transportation of the sample; (iii) compatible and adaptable for the different techniques (iv) withstand in Ultra-High Vacuum (UHV) condition; (v) hold exposed the same surface for different analysis; (vi) allow simple mounting and removal of the sample; (vii) induce the lowest contamination as possible; (viii) preserve the original texture and morphology of the grain.

We propose a new SH composed of: high-pure (>99.9%) Molybdenum (Mo) flag-style Omicron plate (Mo-FSOP), Mo washers, Mo wire (50 μm in diameter), Mo laminas, Tantalum (Ta) screws, and sintered alumina oxide (Al₂O₃) plate with two small cavities (1-2mm) to host the grains (Fig. 1). Molybdenum and Al₂O₃ offer several advantages such as high hardness, mechanical stability, resistance to chemical products, and low-absent degassing in UHV conditions.

The base of the Al₂O₃ plate was assembled with the top-surface of Mo-FSOP by double-sided adhesive carbon.

![Fig. 1. Sample holder configuration for XPS and other surface techniques. The small-size (1.5-2.5mm) Tagish Lake (TL) grains were fixed between the Al₂O₃ plate and molybdenum (Mo) wire (50 μm in diameter). Tantalum (Ta)-s1 represents the pin screw, while Ta-s2 represents the mobile screws. When the grain-wire configuration is stable, the Ta-s2 screws are definitively fixed.](image-url)
the portable glove box (under inert atmosphere - pure nitrogen). Then, the grains were mechanically fixed between Al₂O₃ and Mo wire (Fig. 1,2) without further treatment. We used a single wire for grains <5mm in length. Conversely, for grains >5mm in length, the possibility of using two wires can be evaluated. In this study, we mounted two small-size grains (1.5-2.5mm in length) in the same sample holder (Fig. 1).

No particular constraints or tools are required for the mounting, just precise tweezer fine tips with cut and apposite screwdriver to fix the Ta screws and block the wire in the desired position (Fig. 1). The screw n.1 (s1) has a pin function (Fig. 1), i.e. it block the wire, while screws n.2 (s2) are mobile (Fig. 1), i.e. they are positioned between two laminas, and fixed by screws when the wire-grain configuration is stable. The wire has one degree of freedom, i.e., it can move freely only between the two screws (s2) direction, as long as they are loosen. The grain is first positioned on the appropriate Al₂O₃ cavity-host (1-2mm), then Mo wire is oriented and positioned over the grain by tweezer. The wire end is then stretched by a tweezer until it touches the surface of the grain; at the same time, the Ta screw is tightened, and therefore, the wire grain is blocked (Fig. 1,2).

![Fig. 2. Backscattered electron (BSE) image example for wire-grain configuration. Here, the grain was fixed between Mo wire and Mo flag-style Omicron plate, where a small host-cavity was made. The high friability of the Tagish Lake (TL) meteorite is clearly shown by the small dust particles lost from the grain during the mounting and transport.](image)

**Sample holder container**: We designed a sample holder container (SHC) capable of holding the previously described SH. This container was developed to keep the samples under low pressure or inert gas environments (e.g., pure N₂) to allow transport in security safe from facility to facility, minimizing terrestrial contamination. The geometry and materials of the SHC are briefly described in Fig. 3. The sample holder was fixed by a stainless steel screw at the base of the SHC chamber (Fig. 3) on a portable glove box. A lateral valve can consent to the entry/exit of inert gas.

**Considerations**: Rigorous constraints are required when working with extraterrestrial materials, so every sample holder has its strengths and weaknesses [1,2,3]. Both are briefly summarized below for the new sample holder here discussed:

**Strengths**: (i) the sample holder developed and tested in our study shows a stable condition of the grains during surface analysis (e.g., XPS) and the transport between facilities as long as the grains have been properly mounted and fixed; (ii) compatibility for XPS, micro-IR and micro-Raman techniques; (iii) small-size, friable and irregularly shaped grains can be mounted; (iv) inert and high-pure materials (Al₂O₃ and Mo) mitigate the sample contamination; (v) grains can easily be removed from the sample holder; (vi) grains preserve the original texture and morphology.

**Weaknesses**: (i) The mounting operation is a delicate step for these grains and could be more or less complicated from grain to grain; (ii) good manual skills are required from the operator; (iii) the highly friable nature of these materials can compromise the mounting.

**Acknowledgments**: This project is fully financed by large program INAF: PRESTIGE (Pristine Returned Sample Testing InvestiGation and Examination) (F.O. 1.05.12.01.05).