FAST TRACE ELEMENT TOMOGRAPHY AND WDX REE PATTERN MEASUREMENT OF PRISTINE ASTEROIDAL SAMPLE MATERIAL

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Introduction: The sample return mission to the pristine asteroids Ryugu (Hayabusa 2) [1,2] is almost completed and will return micron to mm-sized objects for study of modern instrumentation in laboratories on Earth soon.

Due to it´s immense importance these valuable samples should be treated with extreme care. Thus, any (more or less) non-destructive analytical approach should be the first choise. However, non-destructive measurement techniques, like low dose SEM, ESEM, synchrotron XRD and XRF, are scarce.

Synchrotron Techniques: Synchrotrons around the globe were used to study tiny particles of cometary [3,4] and interstellar sources [5,6,7] collected during NASAs Stardust mission. It was demonstrated that synchrotron sources are valuable tools to measure the main and trace element content of even the tiniest extraterrestrial particles. The development of new analytical approaches to measure REE-patterns in complex sub-micron inclusions applying confocal XRF set-ups and energy-dispersive X-ray imaging detectors [8] represent ongoing work in the framework of a long-term project of our group at the PETRA-III synchrotron facility (Hamburg, Germany) and is already applied to various sample types including asteroidal (e.g. UR-CAIs) as well as Martian sample material.

Rare Earth Elements: The non-destructive, quantitative measurements of REE patterns from mineral species in the collected rock fragments will allow to identify important processes associated with the formation of the first solids of our solar system as well as processing asteroidal material. The detailed study of samples returned from the surface of Ryugu will help to better understand the conditions and chemical variability on the surface of asteroids.

REE-patterns are especially useful as they may record changes in oxygen-fugacity, temperature, fluid content and chemical reservoirs, especially if combined with isotopic studies on the same samples. Important information on the rare earth element fractionation, especially at high temperature condensation and crystallization, as well aslow temperature surface alteration could be obtained from these samples. Also information about Eu-anomaly, the relative enrichment of light REE versus heavy REE and ultimately the overall pattern distribution could be retrieved with the high-energy XRF spectroscopy measurements.

New Analytical Approach: Detection of X-ray fluorescence is commonly performed by energy dispersive detectors, although this detection method is inferior when a high energy resolution is required. L-lines of rare earth elements (REEs) are often only separated by a few tens of eV and an energy dispersive setup results in overlapping signals especially in the presence of transition metal K lines. A novel wavelength-dispersive detection method for X-ray fluorescence spectroscopy is optimized specifically for the detection of REE L-lines. The characteristic X-rays emitted by the sample are dispersed by a fixed Ge(111) analyzer crystal over the active area of an energy dispersive pnCCD detector, enabling high energy resolution detection of X-rays differentiated by their corresponding diffraction angles in the energy range of 4-8 keV. An energy resolution of 12 eV for the Ti-Kα fluorescence line was achieved [9].

References: [1] Tachibana, S. et al. (2014) Geochemical Journal, Vol. 48, pp. 571 to 587. [2] Watanabe, S. et al. (2017) Space Sci. Rev. 208, 3-16. [3] Brownlee, D. et al. [2006] Science. [4] Flynn et al., (2006) Science. [5] Brenker et al. (2014) Meteoritics & Planet. Sci. 49, 1594–1611 [6] Westpfahl et al. (2014) Science, 345, 786-791. [7] Gainsforth, Z. et al. (2014) Meteoritics & Planet. Sci. 49, 1645-1665. [8] Garrevoet et al. (2014) Analytical Chemistry, 86, 11826–11832. [9] De Pauw, E. et al. (2019) Analytical Chemistry (in review).