Nanoscale spectroscopic and microscopic investigation of Ryugu samples

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Carbonaceous asteroids are leftover materials from the early solar system. Having escaped harsh planetary processes, they provide clues to understanding the planet formation processes as well as the origin and evolution of the early solar system. The Hayabusa2 spacecraft returned the first samples from the carbonaceous asteroid Ryugu [1,2]. In addition to abundant phyllosilicates (~64–88 vol%;), carbonates, sulfides, and magnetite [3], the returned samples provide uncontaminated pristine organic compositions Macromolecular insoluble [4] and soluble organic matter as well as presolar silicate grains [6,7] have been reported in the Ryugu particles. Extraterrestrial organic matter is typically submicron in size (50-500 nm), and most organic compounds are even smaller [8,9]. Conventional IR methods fail to detect spectral signatures of nanoscale organic matter in extraterrestrial samples because of their insufficient spatial resolutions and other technical limitations.

In this study, we investigated the mineralogy and organic matter content of two Ryugu particles, A0030 (from TD1, chamber A) and C0034 (from TD2, Chamber C), using scattering-type near-field optical microscopy (s-SNOM)-based nanoscale Fourier transform infrared (nano-FTIR) spectroscopy, pseudoheterodyne (PsHet) nanoscale imaging, micro-Raman spectroscopic imaging, and synchrotron-based X-ray microprobe analyses.

Our results show that the two Ryugu particles contain different silicate minerals and organic-rich compositions. The spatial distributions of chemical functional groups and their relations with other components also differ in the studied Ryugu particles. Our results indicate various stages of aqueous alteration and thermal metamorphism processes for Ryugu. The identification of abundant nanoscale organic molecules within the Ryugu grains that could not be identified via micrometer-scale investigations emphasizes the importance of using nanoscale nondestructive methods for studying primitive solar system materials, such as Ryugu particles and those that will be returned soon (such as OSIRIS-REx and MMX samples).

References

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