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Elastic and thermodynamic properties of asteroid Ryugu return samples

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JAXA's Hayabusa2 spacecraft explored near-Earth C-type asteroid (162173) Ryugu. It collected surface and subsurface samples from two locations on the asteroid. These samples were returned to Earth on December 6, 2020. We conducted experiments at APS (Advanced Photon Source) 3-ID beamline on some of these samples. With the presence of iron-bearing minerals, nuclear resonant scattering techniques were applied to study their mineralogy, redox states, as well as atomic bonding and lattice dynamics. Nuclear forward scattering (NFS) and conventional Mössbauer spectroscopy studies are reported elsewhere. Here we focus on microscopic dynamics and inferred elastic and thermodynamic results of the study.

Four coarse Ryugu samples, 1 from the surface location (A0026-F0001) and 3 from the location close to the SCI impact crater (C002-FC004, C0046-FC001, C0061b), were measured using NRIXS (Nuclear Resonant Inelastic X-ray Scattering), a synchrotron radiation based atomic dynamics spectroscopy method. One of the impact locations samples (C0046-FC001) was exposed to air intentionally to study oxidation and modifications seen by the asteroidal material caused by interactions with the Earth' atmosphere immediately after opening the package (2 days) and about 7 months later.

From measured phonon excitation spectra, we obtained aggregate phonon DOS (density of states), various atomic dynamics and thermodynamics properties (e.g., vibrational entropy and specific heat) [1], as well as Debye sound velocities [2]. The phonon DOS are dominated by features attributed to magnetite, along with those from other mineral components as well. Comparatively, excessive low energy modes are observed. Subtle but clear differences can be seen among the samples. Difference between the two measurements of the exposed sample is obvious. Comparison to other direct measurement of elastic properties and simulated thermodynamics will help to understand Ryugu's material properties and to better model its accretion history.

References

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