Unraveling the Cr Isotopes of Ryugu

Large-Geometry SIMS reveals unique $\varepsilon^{53}Cr$ values in sample C0027

The examination of samples from the C-type asteroid Ryugu has significantly enriched our knowledge of early solar system materials, yet a consensus on chronological data, pivotal for deciphering Ryugu's evolution, remains elusive. In a recent study, the analysis of Ryugu particles returned by JAXA's Haybusa2 spacecraft unveiled a positive correlation between their $^{55}Mn/^{52}Cr$ and $\varepsilon^{53}Cr$ values (Fig. 1). Employing the Mn–Cr method, an isochron analysis suggested an aqueous alteration age of 4.13 +0.62/–0.55 million years post the formation of CAI, approximately 4563.17 +0.60/–0.67 million years ago. However, sample C0027 exhibited an unusually high $\varepsilon^{53}Cr$ value of +1.27, diverging from the isochron despite its relatively low $^{55}Mn/^{52}Cr$ value of 0.77, indicating distinct components or processes compared to other particles. Intriguingly, C0027's $\varepsilon^{54}Cr$ value did not deviate anomalously from the other samples.

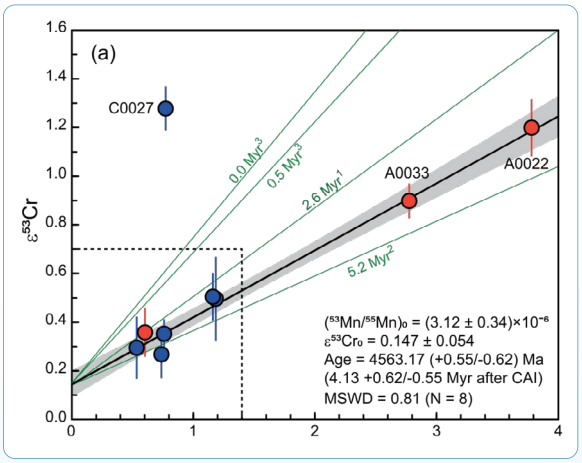


Figure 1: Plots of $^{55}Mn/^{52}Cr$ vs. $\varepsilon^{53}Cr$ and isochrons for Ryugu particles.

To probe the presence of an anomalous $\varepsilon^{53}Cr$ component in C0027, measurements of $\varepsilon^{53}Cr$ values were conducted using a CAMECA Large-Geometry Secondary Ion Mass Spectrometer (LG-SIMS), an instrument uniquely capable of in situ analyses, and designed to achieve excellent precision and reproducibility on stable isotope ratio measurements (Fig. 2). Results revealed a uniformity in $\varepsilon^{53}Cr$ values with no significant differences in values among the matrix, Cr-rich oxides, and phyllosilicate nodules.

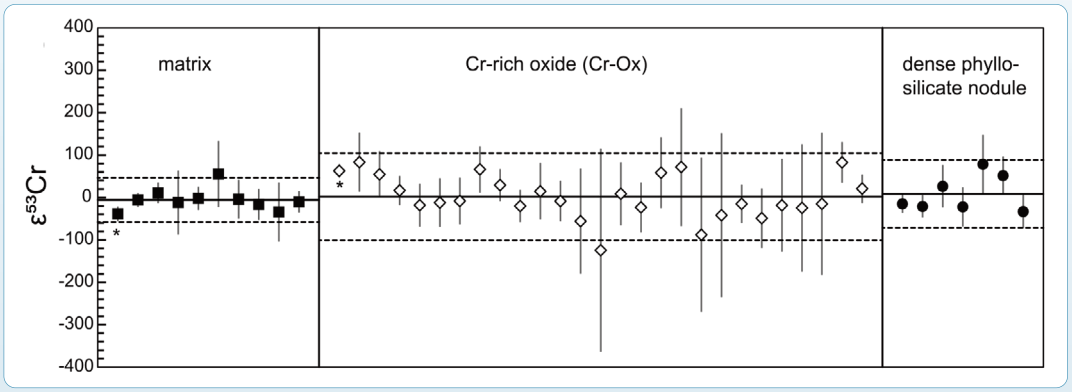


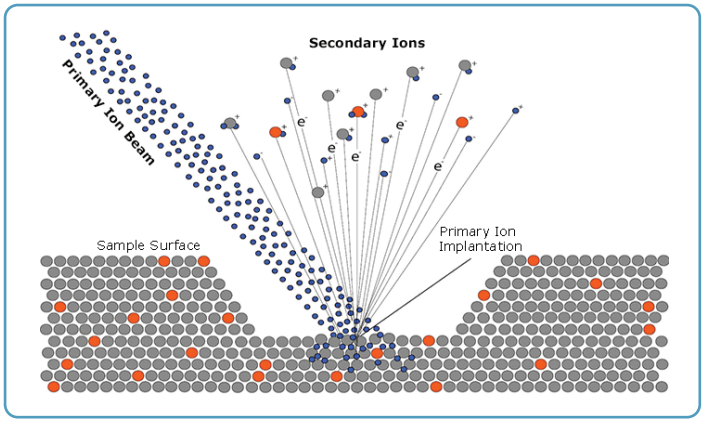
Figure 2: LG-SIMS isotope ratios of the matrix, Cr-rich oxide,and dense phyllosilicate nodules from all target areas in C0027 (total = 6875 µm2). Error bars are 2SE estimated from countingstatistics. Solid and broken lines are average and 2SD of each domain.

The elevated $\varepsilon^{53}Cr$ value in C0027 or its low $^{55}Mn/^{52}Cr$ compared to the isochron could originate from two scenarios: an exceptionally high ^{53}Cr component in the dust that formed Ryugu or multiple stages of Mn/Cr fractionation during aqueous alteration. While mass balance calculations suggested a high $\varepsilon^{53}Cr$ value for a Cr-rich oxide, local analysis indicated no significant variability in $\varepsilon^{53}Cr$ values. Thus, the first scenario appears less likely and the second seems more plausible. Despite sharing similar mineralogy and composition with other Ryugu particles, C0027 exhibits a notably higher abundance of phyllosilicate nodules, suggesting distinct alteration processes. These nodules, lacking carbonate and sulfide minerals, likely underwent alteration selectively leaching Mn relative to Cr, resulting in excess ^{53}Cr. Further research on the origin and evolution of these nodules is required to validate this scenario.

Due to its high lateral resolution enabling precise in situ measurements and its high mass resolving power effectively eliminating mass interferences, LG-SIMS proves an indispensable analytical technique for understanding and addressing local sample heterogeneities, offering invaluable insights into rare and precious materials.

Adapted from: R. Tanaka et al. Unraveling the Cr Isotopes of Ryugu: An Accurate Aqueous Alteration Age and the Least Thermally Processed Solar System Material. DOI: 10.3847/1538-4357/ad276a

The Technique Behind



Dynamic SIMS

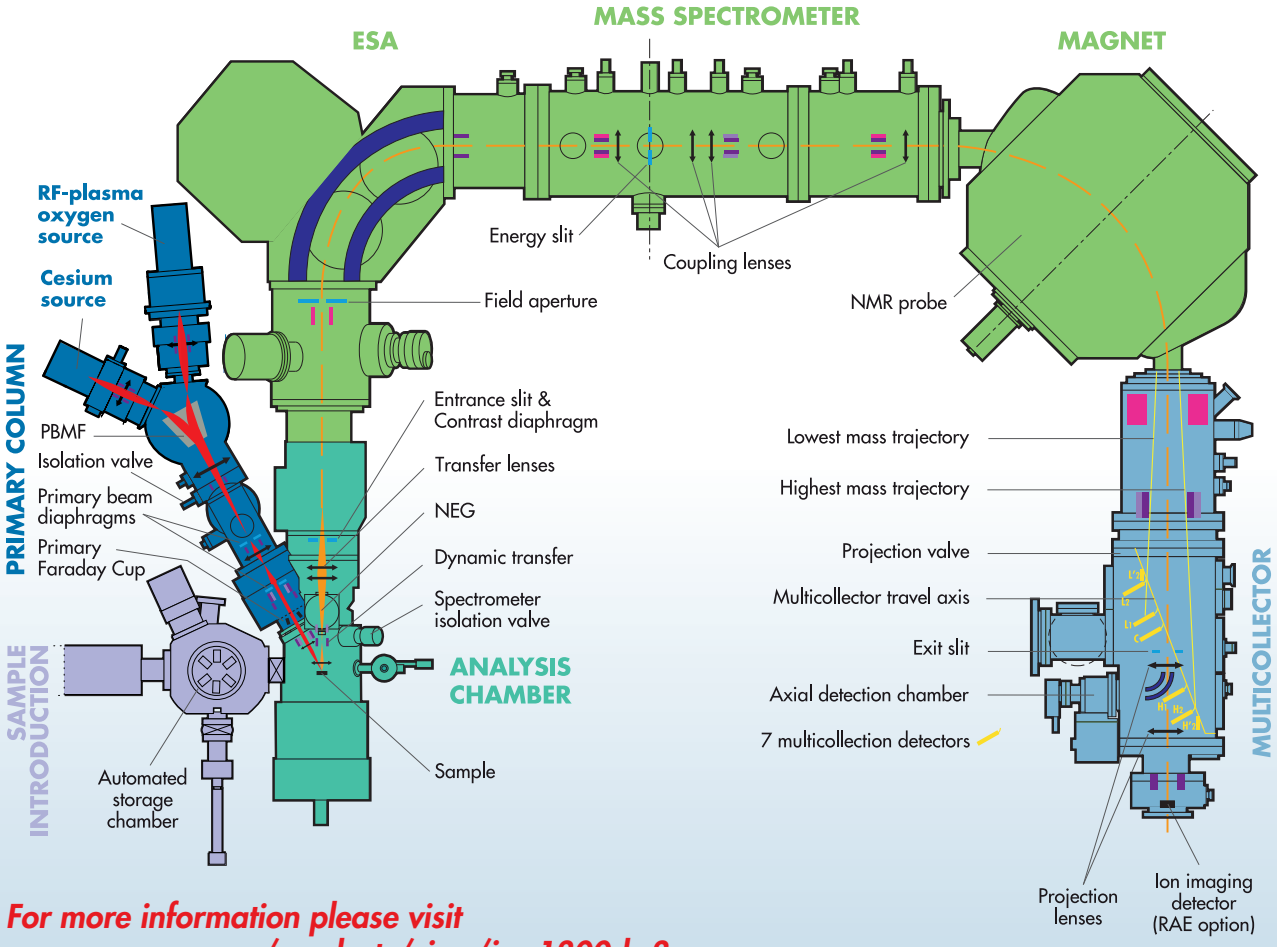
When a solid sample is sputtered by primary ions of few keV energy, a fraction of the particles emitted from the target is ionized. Secondary Ion Mass Spectrometry consists of analyzing these secondary ions with a mass spectrometer.

The SIMS technique is "destructive" by its nature (sputtering of material). It can be applied to any type of flat, solid material that can be kept under vacuum.

In dynamic SIMS, bulk composition and in-depth distribution of trace elements are investigated with a depth resolution ranging from sub-nm to tens of nm. SIMS is recognized as the most sensitive elemental and isotopic surface analysis technique.

CAMECA IMS 1300-HR³

The latest generation multicollection Large-Geometry SIMS is equipped with a high-brightness RF-plasma oxygen ion source in addition to the cesium microbeam source. It also includes an automated storage chamber for analysis of multiple mounts in chained mode.



For more information please visit
www.cameca.com/products/sims/ims1300-hr3

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