Space weathered rims on iron sulfide of Itokawa regolith particles.

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Iron sulfides are ubiquitous in chondritic meteorites and cometary samples. Although iron and sulfur are major solid-forming elements in the early solar system materials, their presence in presolar environment is poorly understood. One of proposed alteration processes of iron sulfides in intersteller environment is the destruction of solid iron sulfide by irradiation of ions accelerated by supernova shocks [1]. On the other hand, iron sulfides are also expected to be altered on the surface of S-type asteroid by solar wind irradiation and micrometeorite bombardments, causing depletion of sulfur abundance on the asteroid [2]. The modification processes of materials exposing to the space environment are known as space weathering in a wide. In order to understand the evolution of iron sulfide and its relation to the life cycle of iron and sulfur in the galaxy, the behavior of iron sulfide under space weathering should be addressed. Regolith particles recovered from S-type asteroid Itokawa preserve various space weathering features [3]. However, little is known about space weathering structures on iron sulfide relative to silicate minerals. In this study, we investigated surface microstructures on iron sulfide of Itokawa particles in order to evaluate space weathering effects to iron sulfide.

We observed surface features of eleven Itokawa particles focusing on troilite (FeS) using a field-emission scanning electron microscope (SEM). Two particles were investigated for further study. Regions of interest were selected based on the SEM observation, and electron-transparent sections including particle surface were prepared using a focused ion beam (FIB). We observed the sections using a field-emission transmission electron microscope (TEM).

From SEM observation of Itokawa particles, submicron sized craters and blisters, which are evidences of micrometeorite bombardment and solar wind implantation [3], were often recognized on troilite as well as silicate surfaces. Some troilite surfaces have whiskers ranging from several tens nm to 2 μm in length. We lifted out FIB sections from troilite surfaces where the whiskers develop on its surface. TEM analysis shows that the whiskers have a structure of body-centered cubic iron. Fe whiskers were found to be elongated nearly along the low-index crystallographic axis. Numerous vesicles were observed beneath the troilite surface to a depth of 90 nm.

The vesicular rim of troilite might have formed by hydrogen and helium gases after the accumulation of solar wind hydrogen ions and helium ions. In this study, we also conducted hydrogen ion irradiation experiments in order to evaluate the alteration of iron sulfide by solar wind ion irradiation. The hydrogen ion irradiation experiment results in the formation of similar vesicular rim. The iron whiskers on Itokawa particles might have been produced through selective sputtering of sulfur atoms by solar wind irradiation [4] and/or reduction of iron sulfide with the production of Fe metal and H_2S as the gas phase [5]. Characteristic diffusion distance of iron atoms in iron sulfide reaches 1 μm for ten years [6] under radiative equilibrium temperature at Itokawa's perihelion (400K). Therefore, iron atoms can sufficiently diffuse from troilite into iron whiskers during short stay of regolith particles on Itokawa's surface. The whisker growth along low-index axis may minimize its surface energy. Fe whisker growth mechanism could be similar to the stress relief mechanism as previously reported for various metal whiskers, such as Ag whiskers on Ag_2S [7].

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