Space weathering in the interstellar medium by hydrogen ion irradiation

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Cosmic dust mainly forms around AGB stars and in ejecta of supernova explosions. Crystalline silicates are observed from some oxygen-rich AGB stars but almost absent in the interstellar medium (ISM). The low crystallinity of interstellar dust may be caused by amorphization of the crystalline silicate [1]. In this work, we focus on the irradiation of interstellar dust by accelerated ions by shock waves from supernovae. There are several irradiation experiments of dust analogue minerals such as olivine, enstatite, and diopside [1-4], but irradiation experiments with hydrogen ions, which is the most abundant gas species, are limited. Because structural and morphological changes may depend on irradiated gas species [5], we performed hydrogen ion irradiation experiments to constrain on the irradiation conditions to cause structural changes of ISM dust grains.
We used olivine (Fo_{80}), enstatite, synthetic single crystal forsterite, serpentine ($(Mg_{2.8}Fe_{0.2})_3Si_2O_5(OH)_4$), quenched glass with $MgSiO_3$ composition as substrates. Pyrrhotite ($Fe_{0.9}S$) and iron meteorite were also used to observe the structural changes of FeS and metallic iron in IDP and primitive meteorites. Polished samples were cut into 3 ×5 ×0.5 mm sized pieces, and chemically etched to remove the surface deformation layers. Experiments were carried out in the Wakasa Wan Energy Research Center (WERC). We used H_2^+ ions accelerated to 40 keV and 10 keV. The dose for each energy was 10^{16}–10^{18} ions/cm^2 and 10^{17} ions/cm^2, respectively. Samples after irradiation were observed with a field-emission scanning electron microscope (FE-SEM).
All samples irradiated with 10 keV H_2^+ ions showed no the surface modification. The threshold dose for blister formation on Fe-rich olivine (Fo_{70}) by 10 keV H_2^+ ion irradiation was 10^{17} ions/cm^2 [4], in which condition we did not confirm any blister on relatively iron-poor olivine (Fo_{90}). These results indicate that olivine with higher iron content easily occurs amorphization by the ion irradiation.
Elliptical shaped blisters were observed on the surfaces of olivine, enstatite, forsterite, serpentine, and pyrrhotite irradiated with 40 keV H_2^+ ions. The dose amount for blistering on olivine, enstatite, serpentine, and pyrrhotite was 10^{18} ions/cm^2 and on forsterite was 10^{17} ions/cm^2. The blister sizes on forsterite were about 100 nm, on olivine and pyrrhotite were about 3 μm, and on serpentine were about 4–5 μm, respectively. Wavy shaped blisters were observed on enstatite, which were arranged at intervals of a few μm. No structural changes of the surfaces was observed on the iron meteorite and $MgSiO_3$ glass substrates. The dose amount for blistering on enstatite is an order of magnitude higher than that for amorphization [2]. We observed blisters on pyrrhotite, which is inconsistent with irradiation experiments of 1 MeV Kr^+ [6]. Ion mass and size may cause these differences, or the dose amount for blistering and amorphization may not be identical. We plan to observe the interior structures of the irradiated samples with a transmission electron microscope. In this presentation, we will report the results of SEM and TEM observations and discuss the structural changes due to ion irradiation.
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