SOLAR ION PROCESSING OF ITOKAWA GRAINS: RECONCILING MODEL PREDICTIONS WITH SAMPLE OBSERVATIONS.

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Introduction: Analytical TEM observations of Itokawa grains reported to date show complex solar wind ion processing effects in the outer 30-100 nm of pyroxene and olivine grains [1,2,3]. The effects include loss of long-range structural order, formation of isolated interval cavities or "bubbles", and other nanoscale compositional/microstructural variations [1,2,3]. None of the effects so far described have, however, included complete ion-induced amorphization. To link the array of observed relationships to grain surface exposure times, we have adapted our previous numerical model for progressive solar ion processing effects in lunar regolith grains [4] to the Itokawa samples. The model uses SRIM [5] ion collision damage and implantation calculations within a framework of a constant-deposited-energy model for amorphization [6]. Inputs include experimentally-measured amorphization fluences [7], a 2π steradian variable ion-incidence geometry required for a rotating asteroid, and a numerical flux-versus-velocity solar wind spectrum based on [8].

Results: The model depth versus ion damage relations exhibit a cross-over point where He^+ largely replaces H^+ in producing damage effects extending below 25 nm. For the typical ion-processed rim widths of 50-70 nm in Itokawa pyroxenes and olivines, the last stages of rim widening are therefore controlled by the lower He^+ fluxes in the solar wind [8]. Incorporating the experimental critical amorphization fluence for solar wind energy He^+ in olivine [7], the model predicts complete amorphization to a depth of 60-70 nm in Itokawa olivines in as little as ~2000 years of direct solar wind exposure. This is in line with limits for the amount of implanted He^+ that SRIM predicts the olivine structure could reasonably hold before extensive He^+ implantation cavities or "bubbles" should form. (Only limited such cavities/bubbles are observed in the Itokawa olivines [1,2,3].) Ion amorphization data for pyroxene comparable to [7] are lacking, but a large difference in exposure time relative to olivine is not expected based on behavior in higher-energy ion irradiations [9].

Discussion: Our model predicts that olivine grains exposed to the solar wind on the surface of Itokawa should acquire fully amorphous rims, 60-70 nm wide, on a timescale of a few 10^3 years, yet the olivine rims observed to date are nanocrystalline, not amorphous [1,2,3]. Provided the model results are correct, they suggest that the nanocrystalline rims on Itokawa olivine grains developed very rapidly (<2000 years). The fact that this value is orders of magnitude shorter than solar flare track exposure ages [3,10] is not fully understood, but may be because solar flare tracks can continue to accumulate under burial to mm depths, whereas solar wind ion damage cannot.

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