Survey for Fe-Si in Apollo 16 Regolith Sample 61501,22

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Metallic iron (micron to submicron spherules) is relatively abundant in lunar regolith and is widely believed to have formed by reduction of Fe during space weathering (micrometeorite/cosmic ray bombardment; [1]). Iron-silicides (Fe-Si) and native silicon require more reducing conditions than Fe\textsuperscript{0}, and though predicted to be present in the lunar regolith have only been reported from one lunar meteorite and one lunar regolith sample [2,3,4]. Fe-Si and native silicon are only stable at extremely reducing conditions and have been proposed to form by a mechanism similar to that of metallic iron [3]. The stability of native silicon requires ten orders of magnitude lower oxygen fugacity than metallic iron at temperatures above 1600 K [5].

After the discovery of Si\textsuperscript{0} and Fe-Si in lunar regolith 61501,22 [2] and given the paucity of these phases in lunar samples reported in the literature, we systematically searched 61501,22 to locate additional Fe-Si specimens to determine their relative abundance and advance the understanding of their formation. Regolith grains for inspection were first selected under UV light (Apollo 16 regolith sample 61501,22) to re-create the conditions that led to the discovery of Fe-Si and Si\textsuperscript{0} by Spicuzza et al. [2]. Further study of lunar Fe-Si from Apollo samples, however has been limited to non-destructive methods because until now there was only one 60-µm plagioclase grain containing Fe-Si and Si\textsuperscript{0} from the original study [2].

During the initial analysis of Fe-Si [6], it was suggested that carbon (~1-2 wt. %, determined by EPMA) might be present in the Fe-Si, but the possibility of analytical artifacts has not been resolved. The presence of carbon was hypothesized to explain the ultra-reduced conditions. In order to determine with certainty the presence of carbon in these phases, a destructive technique (SIMS or atom probe) is necessary. Therefore we sought additional examples of Fe-Si/Si\textsuperscript{0} from 61501,22 to test this hypothesis.

We prepared 3 grain mounts of UV fluorescent grains (from 61501,22), in three size fractions (Mount 1: UV, 0.8-1mm, Mount 2: UV, 0.5-0.8mm, Mount 3: UV, < 0.5mm) as well as one mount with randomly selected UV and non-UV fluorescent grains (Mount 4: Random, < 0.5mm) to see if Fe-Si is limited to UV fluorescent grains. To date, two of the four mounts have been examined by SEM. In mount 3 (< 0.5 mm UV fluorescent, figure 1, a-c), we found examples of Fe-Si (a few nm to 2 µm in size, ~Fe\textsubscript{3}Si) in 10 grains (out of 441 grains). In mount 4 (Random < 0.5mm) we found a further 10 grains (out of 561 grains) containing Fe-Si. While we have not yet confirmed additional samples of Si\textsuperscript{0}, these results increase by an order of magnitude the number of reported grains containing Fe-Si. Moreover, all found instances of Fe-Si were present encapsulated in a glassy matrix of anorthitic composition, referred to as glassy-anorthite (presumed glassy based on textural similarity to that present in [2]). Thus Fe-Si in this lunar regolith sample is relatively common, and may be more common in the lunar regolith in general than previously reported.
Figure 1: BSE images of Fe-Si occurrences in Apollo 16 sample 61501,22. Grain number is in the format of mount-quadrant-row-column. a) Glassy An. spherule containing Fe-Si. b) Two glassy An. grains in an agglutinate, the top grain contains Fe-Si blebs while the bottom only Fe-metal. c) Glassy An. grain in agglutinate containing Fe-Si, the right half of the grain is crystalline anorthite. d) Glassy An. grain containing Fe-Si. e) Glassy An. grain containing a filled crack consisting of glassy-An. and Fe-Si blebs. f) Glassy An. grain containing Fe-S and Fe-mtl, Fe-Si is restricted to the highlighted vein feature.

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