SOME OBSERVATIONS DURING CARBOTHERMAL REDUCTION OF LUNAR MARE REGOLITH SIMULANT

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Sustainable long-term presence on the moon requires the utilization of in-situ resources available on the lunar surface. The widely abundant resource on the moon is regolith, which is composed of oxides in the form of minerals and rocks. Extracting oxygen, water, metals snd ceramics from regolith via methods such as carbothermal reduction, molten regolith electrolysis, molten salt electrolysis and vacuum thermal dissociation are being widely explored [1-4]. Lunar regolith being rich in silica, present as a complex solid solution in the minerals and rocks, extraction of silicon and its compounds is gaining significance.

We had earlier reported observing silicon carbide whiskers during the carbothermal reduction of lunar highland regolith simulant (LHS-1) using methane, a by product of the Sabatier process, commonly used for converting exhaled CO_2 to water [5, 6]; Argon gas was used to provide an inert environment and does not participate in the reaction. Here we investigate carbothermal reduction of lunar mare regolith simulant (LMS-1), which is chemically distinct from highland regolith simulant (LHS-1). Regolith is heated in a crucible under argon/methane atmospheres at high temperatures, conditions similar to what we had used for the reduction of highland regolith simulant [5].

Scanning electron microscopy (SEM) revealed presence of SiC in multiple forms. Similar to reduction of highland simulants, SiC whiskers were observed. However, in addition, we observed growth of SiC as large faceted crystals 10s of micrometers in size and as nanowires in the form of an interwoven 3D network (Fig 1). The SiC crystals exhibited a clear faceted morphology, reflecting crystallographically oriented growth. The carbothermal reduction of LHS-1 did not yield such nanowires or large crystal forms of SiC.

The differences in the microstructure of the reduction products, between LHS-1 and LMS-1, is attributed to the differences in the chemical and mineralogical composition of the regolith simulants. Lunar highland regolith simulant contains higher fractions of anorthositic rock (75%) and lower amounts of basaltic glass (25%). The higher fraction of anorthosite rock present in the highland simulant leads to the formation of a more homogeneous melt. Lunar mare regolith simulant contains a variety of minerals (such as basalt, pyroxene, anorthosite, olivine and ilmenite) having different melting points. Therefore, it exhibits a range of temperatures over which melting happens compared to the highland regolith simulant [7]. In addition to this, the mare regolith simulant has higher FeO content than highland simulant. Fe and SiO vapours generated from the molten regolith react to form isolated FeSi melts. These isolated melts cause a Zener pinning effect, thereby leading to the formation of interwoven 3D network of SiC nanowires [8]. The SiC crystals were found to be located in regions around the FeSi melted phases. SiC appears to have precipitated as crystals due to the supersaturation of Si and C atoms in the Fe-Si melt system formed during the reduction process [9].

Thus, it appears that SiC can be extracted in-situ from the regolith without the need for significant consumables from the earth. SiC formation is also accompanied by the evolution of CO gas which can be combined with hydrogen to produce water. Hence, the carbothermal reduction process could provide an integrated approach to produce oxygen and SiC from lunar regolith.

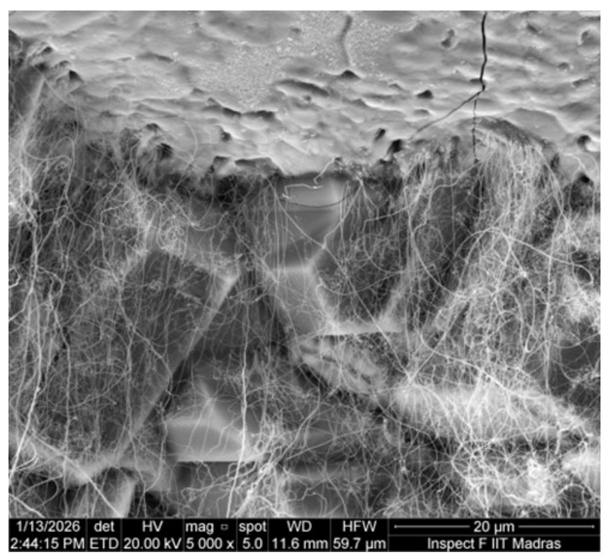

Figure 1. SEM image of SiC crystals and nanofibers grown in the crucible after carbothermal reduction

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