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MARANGONI EFFECT AND ITS POTENTIAL UTILIZATION IN SUPPORTING LUNAR HABITATS AND OTHER EXTRATERRESTRIAL ENDEAVOR

Abstract

Tears of wine is a phenomenon frequently observed as a ring of wine formed near the top of the glass generates droplets that fall back into the wine. This phenomenon is generated by the Marangoni effect driven by the surface tension created via gradient on concentration and temperature within the interface between phases. Besides being observed while drinking wine, the Marangoni effect is crucial for welding metals, manufacturing integrated circuits, and growing crystals; the Marangoni effect might be also crucial in supporting lunar habitats and other extraterrestrial endeavors as vacuum and reduced gravity are expected to augment the Marangoni effect on extraterrestrial molten soil leading to sustainable extraterrestrial in-situ resources utilization (ISRU).

Preliminary Marangoni effect assessment on molten lunar regolith was conducted via JSC-1A lunar regolith simulant under vacuum yielding a spontaneous upwards migration of a uniform molten thin-film front that climbed the crucible wall covering the entire wall's surface and reaching the crucible's top end. A temperature gradient within the melt's bulk and along the crucible's wall generates a surface tension large enough not only to form a meniscus within the three-phase junction (crucible's wall, bulk melt, and vacuum) but also to supersede the gravitational force to create the upwards migration of a thin film front originated on the meniscus. The observed extensive wettability of the melt with the crucible surface, an additional key factor besides surface tension necessary to sustain upwards migration, is atypical to what it has been witnessed on molten JSC-1A lunar regolith simulant under non-vacuum conditions and smaller sample sizes. The unique formation and self-migration of a thin-film front could enable key ISRU processes such as thin-film coating, crystal growth, and feedstock generation for additive 3D printing. Further assessment on the higher-temperature vacuum-driven decomposition of the uniform thin-film front as it climbed the crucible's wall revealed a significant decomposition of various simulant's metal-oxide components into their respective oxygen and metal elements strengthening the feasibility of extraterrestrial generation and fractional separation of oxygen and metals/alloys with minimal need for terrestrial precursors.

The Marangoni effect assessment on molten JSC-1A lunar regolith simulant clearly opens novel pathways in future extraterrestrial ISRU endeavors including manufacturing and mining. Extraterrestrial mining will require an operational approach completely different from the terrestrial one that heavily relies on not only mechanical excavation and transportation but also refinery; an in-situ non-mechanical all-in-one process might be feasible via these two coupled phenomena, self-migration and decomposition.