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DESIGN OF AN ICE CUBE INFRASTRUCTURE CAPABLE OF PERFORMING METAL EXTRACTION FROM A SUBSTRATE THROUGH BIOMINING IN MICROGRAVITY CONDITIONS, USING BACTERIA OF THE GENUS BACILLUS

Abstract

Creating sustainable mining processes to use in space exploration will help obtain affordable, clean energy and innovative means of obtaining materials in situ, eliminating their transportation from Earth. This research focuses on the design of a biomining experiment for the International Space Station through a 1U ICE Cube that sustains a metal extraction mission using microfluidic chips.

The chosen microorganisms species of Bacillus subtilis and Bacillus pumilus have a fermentative metabolism capable of adapting under anaerobic conditions to perform biomining using metal ions such as Fe (III) or Mn (IV). As metal is reduced, CO2 is released in the process and quantified by CO2 sensors in the microfluidic chip, which can be correlated with the biomining rate produced by the bacteria and indicate its viability.

The main objective of the mission is the quantification and comparison of the biomining rate using basalt between two Bacillus species in microgravity conditions. Preliminary tests were performed on Earth to ensure the process behavior, allowing the study of its operation in the ISS while varying external conditions.

Finite element simulations of the behavior of the structure show how the designed ICE Cube can survive the random vibrations during launch and the stay in the ISS, the whole experiment weights less than 700 grams and the calculations indicate that the critical stresses of the structure are never higher than material critical stress, therefore validating the design. In addition, preliminary results of the biomining capacity of the bacteria Bacillus subtilis ATCC 6633 used in the experimentation demonstrate the release of soluble iron ions into the culture medium from the basalt substrate that was verified by Atomic Absorption Spectroscopy. The release of manganese was not evident by this method. Different control conditions were tested and indicate there is no presence of iron ions in the culture medium, the agar used to immobilize the basalt substrate and the bacteria itself.

The electrical interface contains a single board computer and an extension board with microcontrollers. Each experiment contains its own heater, CO2 sensor and temperature control system. Other sensors are integrated on the framework to monitor environmental conditions. Communication with the cube is handled using a TCP protocol to retrieve the telemetry packets in real time.

The upgrade in efficiency of this technique has the potential of facilitating space exploration missions while also improving life on Earth through applications in recycling and material utilization, ensuring sustainability in our cities.