Investigation of Reversibly Assembling Materials Using Force Spectroscopy

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Abstract

NASA's plans to return humans to the Moon, and eventually to Mars, have enabled numerous research and development opportunities, as well as widespread public interest in routine spaceflight. In-space manufacturing (ISM) is one of the increasingly significant efforts being investigated and will soon become synonymous with space operations during long duration missions in which significant support will be necessary.

Although advances in in-situ resource utilization (ISRU) and additive manufacturing (e.g., 3D printing) have propelled ISM applications in recent years, there remain limitations to these approaches. In fact, it is likely that a suite of technologies for ISM will better satisfy the needs of the next generation of exploration missions. Reversibly assembling materials is an alternative approach to the current ISM technologies developed for mass reduction for long duration space exploration. These materials are a way to enhance the ISM capabilities through the use of highly tunable, multi-functional microspheres that possess reversibly assembling properties that can be harnessed on their own or utilized in additive manufacturing instruments already demonstrated in space.

In this work, the reversibly assembling materials system was composed of synthesized epoxy microspheres coated with co(polycarbonate urethane)s functionalized with Diels-Alder (DA) click chemistry functionalities. The thermally reversible DA reaction has gained increasing interest over the years due to the mild reaction conditions and on-demand reversibility. However, the DA reaction is highly dependent on the polymer system. Here, we used an atomic force microscope to conduct force spectroscopy to investigate the adhesive interactions between click chemistry functionalized microspheres. The spontaneous click chemistry reaction initiated upon heating was successfully demonstrated and the repeatability of the adhesive interactions was characterized. The force spectroscopy data analysis elucidated reversibly assembling behaviors that provided insight into the viability of this materials system for ISM applications.