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M1Po3B-08: Electrospun Polyvinylidene fluoride co-hexafluoropropylene (PVDF-HFP) for Passive Thermal Management in Space

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Managing heat in space is essential for spacecraft to operate within acceptable thermal limits, and ensure the success of extended missions. Future applications, such as the storage of cryogenic propellants in space depots, impose strict requirements on thermal control, making it necessary to adopt efficient means to meet these requirements. Consequently, while both active and passive thermal control techniques are applied, passive thermal management is preferable to address the radiation-dominated heat transfer in space. This approach would require materials that exhibit exceptional optical properties like low solar absorptivity (or high solar reflectivity) and high infrared emissivity. Hence, the need to advance materials with superior optical properties for space applications is critical. We address this need by developing new materials consisting of nanofibers as the radiation-exposed exterior surfaces of space objects for passive temperature control.

This study uses electrospinning to fabricate the nanofibrous materials from polyvinylidene fluoride-co-hexafluoropropylene (PVDF-HFP) co-polymer. Scanning electron microscopy reveals its porous structure, which consists of randomly ordered nanoscale fibers. This porous structure imparts a strong light scattering ability, as evidenced by its very high solar reflectance (>99%), obtained from ultraviolet-visible and near-infrared spectroscopic characterization. The material also emits strongly in the mid-infrared wavelengths, which is desirable for self-cooling. Thermogravimetric analysis was also performed on the material to gain insight into its thermal stability.

The harsh environmental conditions in space affecting spacecraft materials make it necessary to assess the materials'performance in similar conditions before they qualify for use in space. To this end, we exposed the nanofibrous PVDF-HFP material to (a) ultraviolet radiation, (b) a thermal vacuum environment to assess its outgassing characteristics, and (c) thermal cycling tests between cryogenic and high temperatures to understand the material's resistance to extreme temperature swings. Subsequently, we characterized the optical properties to quantify the effects of exposure to these extreme conditions. We observed only marginal changes indicative of good extraterrestrial durability. The material's thermal control performance was assessed in a vacuum chamber operated at 300K to emulate space-like conditions of a dark background, low pressure, and extraterrestrial solar illumination from a solar simulator providing 1367 W/m2 intensity. In addition, experimentally validated COMSOL thermal models were used to predict the material's thermal control performance under different conditions. From these observations and with further optimization, the nanofibrous PVDF-HFP holds good promise as a passive thermal control material for space applications.

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