POLYMER/CERAMIC COMPOSITE NANO-FIBER MAT FOR LUNAR SURFACE HABITAT THERMAL CONTROL

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INTRODUCTION

With temperature variations between -170°C and +115°C, designing for habitation on the lunar surface presents many challenging problems. NASA is considering the design of a habitat thermal control system to provide a shirt sleeve environment for crew and equipment inside of the long duration lunar outpost. To minimize the thermal load, the focus of this paper is to develop a novel sun shield of micrometer thickness using electro-spinning technology. Polymer-ceramic composite nanofiber mats are studied for their optical properties. The proposed polymer-ceramic composite shield is designed to be made in space using electro-spinning for easy transportation. Initial research by the authors indicated that various polymer mixtures had been spun, however, very few studies had been found to be conducted under reduced pressure conditions [1]. This paper presents the electro-spinning of polymer/ceramic-nano-particle composite mats under vacuum condition and their physical radiation properties.

EXPERIMENTAL SETUP

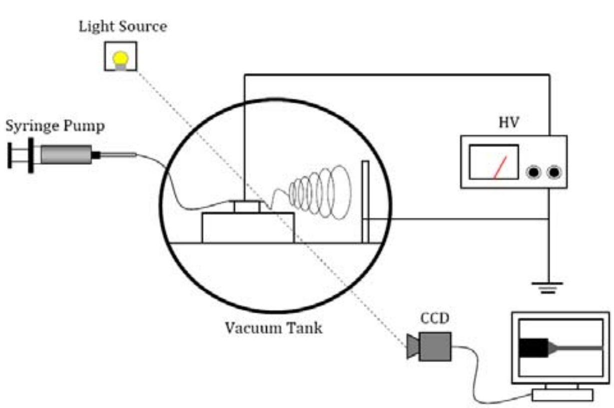

Fig. 1 – Electro-spinning rig setup

The electro-spinning rig, designed by the authors, is shown in Fig.1. In order to conduct electro-spinning under vacuum, an internal platform was constructed to stabilize the equipment inside of the vacuum tank (Fig.2). The capillary tube was fixed to a small vehicle which could be manually adjusted along its axis on a track to vary the distance between the capillary tube and the counter electrode. The counter electrode was attached to an acrylic plate and could be swapped out fairly easily. The high voltage source was connected to the capillary tube, and the counter electrode was grounded. Tubing was run from the syringe pump outside the tank to the capillary tube inside the tank to provide the supply of nano-particle loaded polymer suspension.

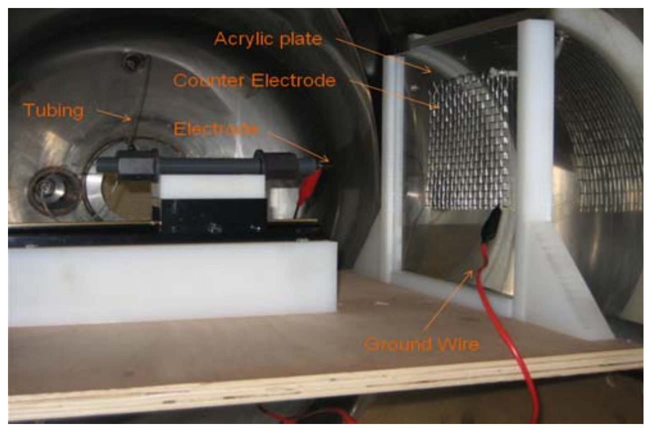

Fig. 2 - Internal platform of the rig

There are many factors that contribute to each liquid's ability to be spun, including conductivity, surface tension, and vaporization characteristics of the polymer solvent. The flow rates, voltages, and distance between electrodes had to be varied in order to achieve a successful process.

ELECTROSPINNING RESULTS

PVP (polyvinyl pyrrolidone) is used in this study. It was found that a 10% polymer solution produced the best results, both by itself or mixed with nano-additives. A 5% solution did not have enough polymer in it to form a good mat, while a 15% solution was too thick to allow electro-spinning. The as-sprayed polymer mat on metallic collector is shown in Fig.3.

To block wavelengths from UV to infrared, nano-additives including Aluminum Oxide, Titanium Dioxide, Zirconium Oxide, and Zinc Oxide were tested. The first nano-additive mixed with the polymers was zinc oxide. It immediately reacted with the polymer solution, and caused the mixture to become a solid. Zirconium oxide caused the same problem with the polymer solutions, which used water as a solvent, but mixed well with PVP and alcohol. Aluminum oxide and titanium dioxide mixed well with both water and alcohol based polymer solutions. The polymer solutions and additives were mixed by volume, and a 50/50 mixture was found to yield the best results. The only exception to this was PVP with alcohol and titanium oxide, which needed to be mixed as a 60/40 (polymer dominated) solution in order to be thin enough to allow electrospinning, and PVP with alcohol and zirconium oxide, which needed to be mixed as a 37.5/72.5 (additive dominated) solution for the same reason.

Fig. 3 - Polymer mat on mesh electrode collector

SPECTRORADIOMETER TESTING

An integrating sphere (IS-1000, Optronic, FL), connected to an irradiance standard (OL 752-10) and a UV/Visible spectroradiometer (OL 754) powered by a programmable current source (OL 65 Optronic, FL), was used to produce spectral distributions of reflectance and transmittance between 250 nm and 800 nm, at 5-nm intervals. The spectral absorptance (α_λ) of the samples was calculated from the transmittance (τ_λ) and reflectance (ρ_λ). The spectral distributions of the electro-spinning polymer-TiO_2 mat samples collected on fine mesh from 250 to 800 nm are shown in Figs 4 and 5.

CONCLUSIONS

Of the successfully sprayed polymers, PVP-TiO_2 mats showed the best balance of shielding properties and spray and handling ability. It proved very successful at shielding the desired wavelengths; spanning the UV, visible, and near IR spectra, and achieving minimal transmission through the specimen. Vacuum conditions increased the effectiveness of shielding, and did not hinder the electro-spinning process. The improved performance is believed due to the fast drying rate in vacuum which brings more nano particles close to the surface of the nanofibers.

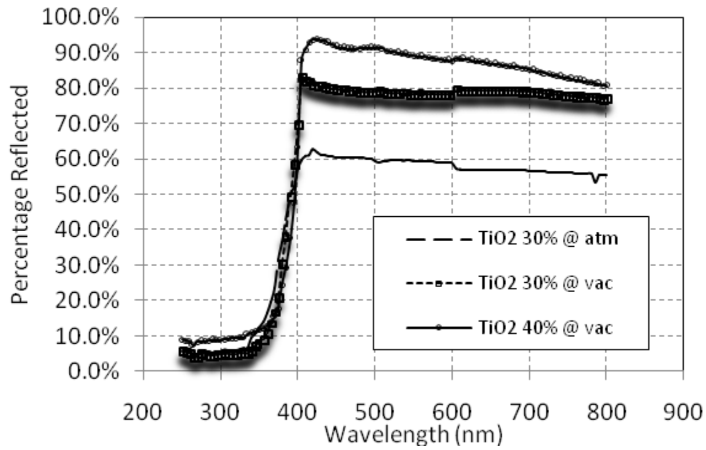

Fig.4 - Reflectivity for electro-spinning samples

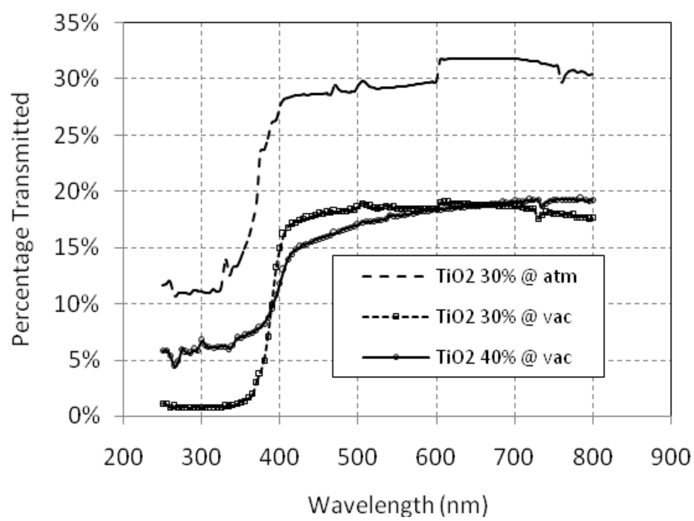

Fig.5 - Transmissivity for electro-spinning samples

ACKNOWLEDGEMENTS

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REFERENCES

[1] Hur, S.; Kim, W.D.,2006, The electrospinning process and mechanical properties of nanofiber mats under vacuum conditions, Key Engineering Materials, v 326-328 I, p 393-396, 2006