Plasma deposited organic coatings on MWCNT for dispersion in polyurethane

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Abstract: In this work, we study how the plasma treatment of multi-walled carbon nanotubes through a low-pressure capacitively coupled RF glow discharge can improve the dispersion of the particles in solvents suited for polyurethane chemistry. Results show that nitrogen-rich and oxygen-rich plasma polymer films increase dispersion in water, while HMDSO films increase dispersion in organic solvents.

1. Introduction

Multi-walled carbon nanotubes (MWCNT) have shown the potential to offer anti-microbial properties through either cell-wall penetration or oxidative stress [1][2]. The introduction of MWCNT in a solid polyurethane coating could grant antimicrobial properties to the coating. The effect could last over a long time, reducing the need for manual disinfection. However, raw MWCNT tend to agglomerate, especially when introduced in liquids. Functionalization of the MWCNT surface using plasma deposited organic coatings can help reduce the agglomeration and offer better dispersion of the nanoparticles in different solvents used in polyurethane synthesis.

With the use of a low-vacuum RF plasma chamber, the MWCNT are functionalized with three plasma compositions and then dispersed in five solvents to evaluate the dispersion quality and stability over time. These nano-fluids will then be used in the polyurethane synthesis to create nanocomposites whose antimicrobial and mechanical properties will be investigated.

2. Methods

MWCNT are produced in-house on a stainless-steel mesh substrate acting as a catalyst for the synthesis using a CVD setup. This produces a MWCNT forest, offering more surface area for plasma functionalization than commercially available carbon nanotube powder.

While on the substrate, the MWCNT are placed inside a low-pressure plasma chamber. A capacitively coupled RF glow discharge in different gas mixtures (nitrogen-rich, oxygen-rich and HMDSO) is used to coat the particles with three different types of plasma-polymer film. The films are characterized through XPS analysis.

The coated stainless-steel meshes are submersed in glass cuvettes containing one of the five different solvents used in polyurethane chemistry (water, ethanol, butyl acetate (BA), ethyl acetate and ethyl 3-ethoxypropionate). MWCNT are cleaved from the substrate through sonication for 10 minutes and released in the solvents. The dispersion of the particles in the fluids are measured through agglomeration size with dynamic light scattering and opacity of the fluid through transmittance measurement.

3. Results and Discussion

A higher transmittance value of the light in the nano-fluid indicates an heterogenous dispersion of the MWCNT, while a low transmittance indicates that the particles are well dispersed and not agglomerated with themselves. Initial results, shown in table 1, show that in water, O-rich and N-rich functionalization offer good dispersion with, respectively, 63.57% and 56.43% transmittance against 91.11% for unmodified particles, after 36 days. These functionalizations also offer stable solutions, with transmittance change of 13.6% and 9.6% against 45.0% over the same period. Si-rich films don't achieve a significant dispersion in water. Transmittance for this solution is 86.64% after the same time period.

Table 1: Time evolution of the transmittance of MWCNT dispersion

Coating used	Dispersion media	Transmittance after 1 day (%)	Transmittance after 36 days (%)
None	Water	46.15	91.11
N-Rich	Water	63.97	56.43
O-Rich	Water	50.02	63.57
Si-Rich	Water	68.75	86.64
None	BA	17.44	19.33
N-Rich	BA	22.33	30.66
O-Rich	BA	11.78	19.18
Si-Rich	BA	9.38	14.11

In the organic solvents used, raw MWCNT already disperse better than in water. In butyl acetate, it's the HMDSO-plasma functionalization that offers the best dispersion, with a 14.11% transmittance after 36 days. In comparison, the unmodified solution has a 19.33% transmittance, and the N-rich plasma functionalization is at 30.66%.

4. Conclusion

The investigation of the dispersion of functionalized MWCNT in different solvents shows that plasma-polymer films can be used to increase the dispersibility of otherwise incompatible particles in solvents. Functionalization of the particles with N-rich and O-rich plasma polymer films demonstrate better dispersion in water and ethyl acetate than unmodified particles. HMDSO-plasma offers better dispersion in organic solvents, but minimal improvements in water.

Acknowledgement
This abstract is based on work financially supported by the Natural Sciences and Engineering Research Council of Canada, Mitacs and Nanophyll Inc.

References

[1] Yu. G. Maksimova, Appl Biochem Microbiol, vol. 55, no. 1, pp. 1–12, (2019).
[2] L. Ding et al., Journal of nanoscience and nanotechnology, vol. 20, no. 4, pp. 2055–2062, (2020)