Chemical and physical treatments to improve surface hydrophobicity for passive anti-icing applications

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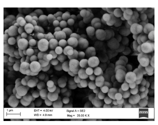
Introduction

In recent years, the interest in hydrophobic surfaces has considerably grown, finding applications in many industrial fields, including aerospace, automotive, and biomedical. In particular, the risk of accidents caused by ice adhesion on critical aircraft surfaces is a significant concern and the development of superhydrophobic coatings provides a method to prevent water adherence to surfaces and has the potential to avoid ice growth and deposition. There are two main methods for preparing superhydrophobic surfaces: one is to construct structured surfaces inspiring to natural organisms, and the other is to modify low surface energy materials by physico/chemical treatments. Different technologies such as plasma surface modifications, physical and chemical deposition, layer by layer deposition, electrospinning, hydrothermal process and sol-gel processing have been studied. In this work the combination of plasma treatments and micro/nanostructured coating has been applied to Polylactic acid with Carbon Nanotubes (PLA/CNT) composite substrate obtained by hot press technology. The perfluorooctanoic fluoropolymer-coated silica nanoparticles have been used as coating and applied to the surface by dip coating.

Micro/Nanostructured Coating synthesis



SEM image of Si nanoparticles (NPs) from TEOS

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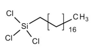
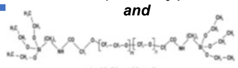


Trichloro(octadecyl)silane and



Fluoropolymer-FluorolinkR-S10

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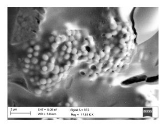
Fluoropolymer coated SiO_2 NPs in solution



SEM image of fluoropolymer coated SiO_2 NPs dropped on aluminum substrate

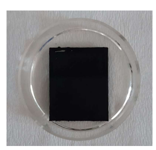
A material with excellent water repellence properties was prepared. 400 nm silica nanoparticles (Si NPs) were synthetized from tetraethyl orthosilicate (TEOS) and then trichloro(octadecyl)silane and fluoropolymer (Fluorolink S10) were cross-linked between Si-O-Si groups via a simple sol-gel chemistry to obtain fluoropolymer-coated SiO_2 NPs.

Composite samples preparation

Hot pressing

Hot pressed samples of PLA/CNT composite were prepared by Filoalfa alfaohm filament.

Temperature : 220 °C
Pressure: 5 tons
Quenching Temperature: 22 °C
Thickness: ~200µm



Hot pressed sample

Plasma CF4 treatment

Low pression Plasma CF_4 treatments were applied to enhance hydrophobicity of substrates and/or to activate the surface to the deposition of hydrophobic coatings.

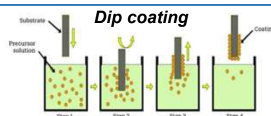
Tucano plasma system

Sample	Treatment
S1	**Power**= 5 Watt **Time**= 5 min **Flow**= 20 sccm
S2	**Power**= 5 Watt **Time**= 10 min **Flow**= 20 sccm
S3	**Power**=10 Watt **Time**= 5 min **Flow**= 20 sccm

Deposition of hydrophobic coating

Fluorolink S10 fluoropolymer (S4) and fluoropolymer coated SiO2 NPs (S5) solution were deposited on substrate by dip coating and than the samples were dried on hot plate.

Dip coating



Time of immersion= 5 minutes

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Temperature=80°C
time =1h

Sample	Treatment
S4	Fluorolink S10 in isopropyl solution
S5	Fluoropolymer coated SiO_2 NPs isopropyl solution

Combination of plasma treatment and deposition of hydrophobic coating

A combination of plasma treatment and deposition of fluorolink S10 fluoropolymer (S6) and fluoropolymer coated SiO2 NPs solution (S7) were applied.

Plasma CF_4

Power=10 Watt
Time= 5 min
Flow= 20 sccm

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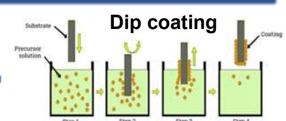
Dip coating



Time of immersion= 5 min

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Temperature = 80°C
time = 1h

Sample	Treatment
S6	Plasma CF_4 + Fluorolink S10 in isopropyl solution
S7	Plasma CF_4 + fluoropolymer coated SiO_2 nanoparticles isopropyl solution

Wettability

The surface wetting analysis materials was performed by contact angle (CA) measurements of deionized water by sessile drop method using an OCA 20 (Dataphysics, Filderstadt, Germany) goniometer.

Sample S5 shows the highest water contact angle (WCA) value probably due to micro/nanostructured hydrophobic surface created by fluoropolymer coated SiO_2 NPs on the composites surface.

Sample	WCA (°)
Not treated	73,3
S1	89,6
S2	111,2
S3	68,1
S4	107,8
S5	**124,4**
S6	113,5
S7	105,2

Conclusion remarks

- ✓ Micro/nanostructurated hydrophobic fluoropolymer coated SiO_2 NPs were synthetized
- ✓ Composite PLA/CNT hot pressed samples were prepared
- ✓ Composite hydrophobicity was improved by using three different treatment:
  1. plasma CF4
  2. coating with fluoropolymer or fluoropolymer coated SiO_2 NPs
  3. a combination of Plasma CF4 and hydrophobic coating
- ✓ An increase of hydrophobicity was always obtained
- ✓ The best result was achieved in presence of hydrophobic fluoropolymer SiO_2 NPs coating (WCA= 124,4) with an increase of about 70% respect to not treated sample.

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