Superhydrophobic and oleophobic surfaces for sustainable medical textiles

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Contact Angle and Wetting Behavior

\[ \gamma_{SL} \quad \gamma_{SV} \quad \gamma_{LV} \]

\( \theta_e \): Apparent Contact Angle

\( \theta_i \): Intrinsic Contact Angle

\( \theta_e \): No wetting

\( 180^\circ \)

\( 90^\circ \)

\( 0^\circ \)

Equilibrium

Complete wetting

Cassie-Baxter

Wenzel
Design of Cassie Baxter Surface

\[ \cos \theta_r^{CB} = f_1 \cos \theta_e - f_2 \]

\[ f_1 = \frac{\text{Area in contact with liquid}}{\text{Projected area}} = \frac{R \alpha}{R + d} \]

\[ f_2 = \frac{\text{Area in contact with air}}{\text{Projected area}} = \frac{(R + d) - R \sin \alpha}{(R + d)} \]
Chemical Modification with F-silane through Microwave Reaction

Water on modified nylon

Dodecane on modified nylon
Geographical Modification I - NyCo Multifilament Woven Fabric

\[
\cos \theta_r^{\text{particles}} = \frac{R_p}{R_p + d_p} (\pi - \theta_e) \cos \theta_e + \frac{R_p}{R_p + d_p} \sin \theta_e - 1
\]

\[
\cos \theta_r^{\text{multifilament}} = \frac{\pi - \theta_r^{\text{particles}}}{2} \cos \theta_r^{\text{particles}} + \frac{\sin \theta_r^{\text{particles}}}{2} - 1
\]

\[
\cos \theta_r^{\text{NyCo}} = \frac{4(\pi - \theta_r^{\text{Multifilament}})}{2\sqrt{3} + 1} + 1 + 4 \sin \theta_r^{\text{Multifilament}} - 1
\]
Geographical Modification II - Nylon Hydroentangled Nonwoven Fabric

\[
\cos \theta_r^{CB} = f_1 \cos \theta_e - f_2
\]

\[
\cos \theta_r^{CB} = \frac{R(\pi - \theta_e)}{d + R} \cos \theta_e + \frac{R}{d + R} \sin \theta_e - 1
\]

\[
R \approx 10 \, \mu m \\
78^\circ \leq \theta_{e-dodecane} \leq 81^\circ \\
d \leq 131 \, \mu m
\]

\[
155^\circ \leq \theta_{r-dodecane} \leq 156^\circ
\]
Superhydrophobicity vs Superoleophobicity

\[ mg \sin \alpha = \gamma_{LV}(\cos \theta_R - \cos \theta_A) \]

Self-cleaning effect by superhydrophobicity.
(Source: Barthlott, W., Neihuis, C., *Planta*, 1997, 202, 1.)
Roll-off Angles and Contact Angle Hysteresis

• Wenzel Model

\[ \cos \theta_e^W = r \cos \theta_e \]
\[ G_e^W = \frac{r \sin \theta_e}{\sin \theta_e^W} \]
\[ \Delta \theta_H^W = G_e^W \Delta \theta_H \]

• Numerical Example

\[ \theta_e = 120^\circ, \quad \theta_h = 15^\circ, \quad a = 0.01\text{mm}, \]
\[ d = 0.2\text{mm}, \quad \text{and} \quad h = 1\text{mm} \]

In Wenzel model, \( r = 1.9 \)
\[ \theta_e^W = 162^\circ, \]
\[ G_e^W = 5.32, \]
\[ \text{and} \quad \theta_h^W = 80^\circ \]

• Cassie-Baxter Model

\[ \cos \theta_e^{CB} = \Phi_S (\cos \theta_e + 1) - 1 \]
\[ G_e^{CB} = \frac{\Phi_S \sin \theta_e}{\sin \theta_e^{CB}} \]
\[ \Delta \theta_H^{CB} = G_e^{CB} \Delta \theta_H \]

• Numerical Example

\[ \theta_e = 162^\circ, \quad \theta_h = 15^\circ, \quad a = 0.01\text{mm}, \]
\[ d = 0.2\text{mm}, \quad \text{and} \quad h = 1\text{mm} \]

In Cassie-Baxter model, \( \Phi_S = 0.0023 \)
\[ \theta_e^{CB} = 177^\circ, \]
\[ G_e^{CB} = 0.04, \]
\[ \text{and} \quad \theta_h^{CB} = 0.6^\circ \]
Conclusion
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