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Perspective on Biomimetic Approaches for Design of Antimicrobial Paper Coatings with Hierarchical Surface Structure

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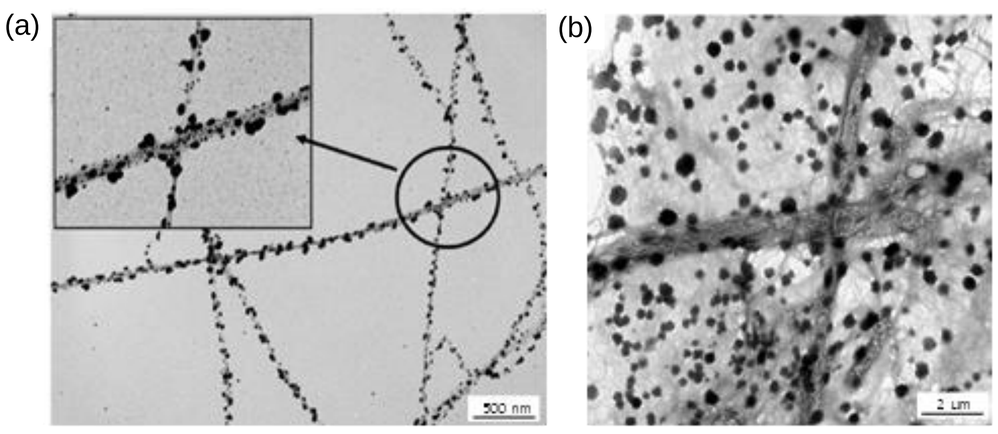
INTRODUCTION & AIM

We present some approaches for the design of paper coatings with improved functionalities, while using bio-based ingredients and bio-mimetic structures that primarily focus on hydrophobic and anti-microbial properties. Both properties are selected in relation with the practical application of papers in packaging industry, while both are simultaneously connected to give better protective properties. The novelty in the approach is, that presented methods are not based on lab-scale application procedures, but they are applicable for upscaling towards industrial processes by spray coating or femtosecond laser texturing.

METHOD AND MATERIALS

The chemical functionalization of cellulose nanofibrils (CNF) with anti-microbial chemical moeities was done. The deposition of Ag nanoparticles onto CNF was performed by the in-situ reduction from $AgNO_3$ precursors, where the CNF acts as a catalyst and direct template structure for the deposition of the anti-microbial compounds The other natural compounds with anti-microbial properties include certain extracts of plant oil, such as eucalyptus oil, neem oil, coconut oil, thyme essential oil, or oregano essential oil, which are known to combat bacteria and preserve food. In our work, the plant oils were used for anti-microbial paper coatings after encapsulation of the plant oils in polymer nanocapsules and their controlled release.

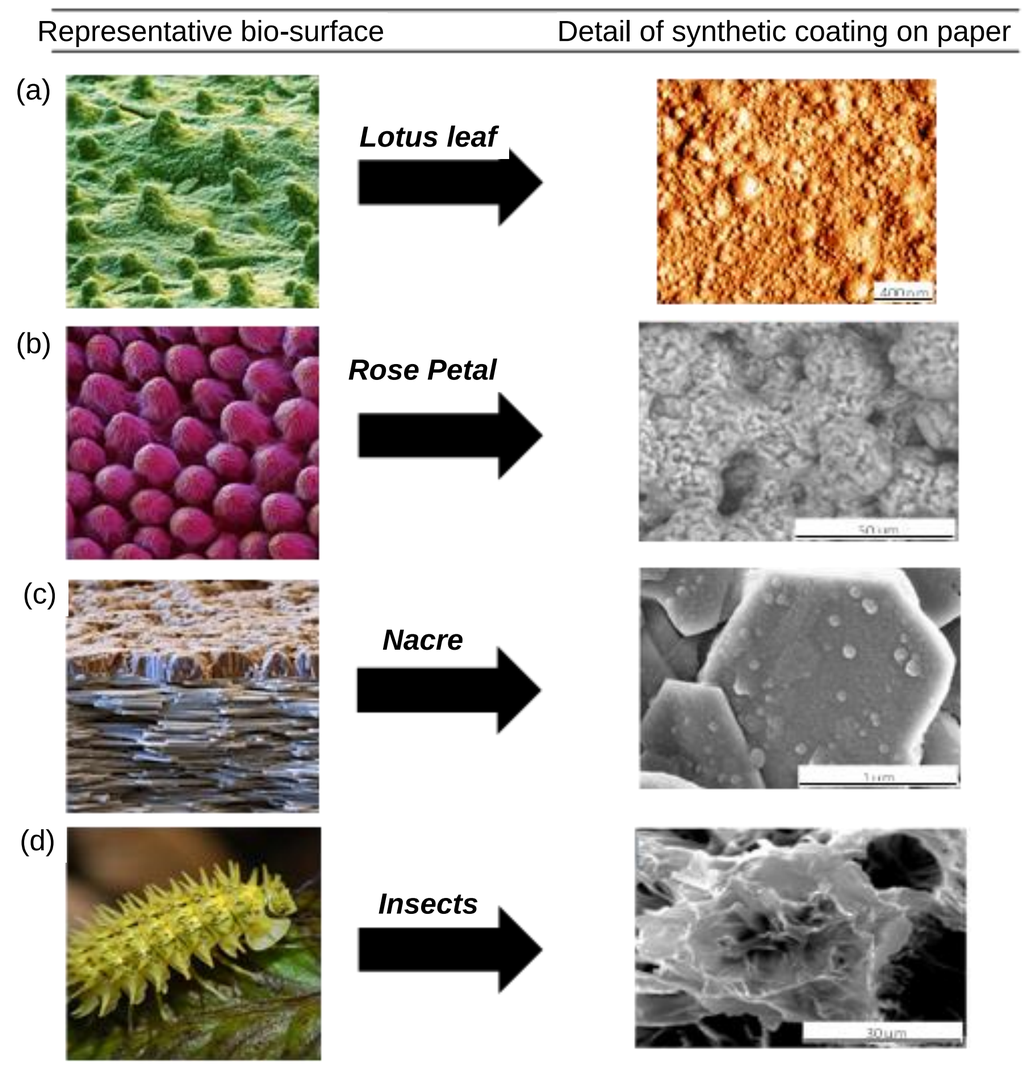


Illustrative examples of biomimicry in creating anti-microbial paper coatings with selection of specific anti-microbial chemical compounds, such as e.g. (a) functionalized nanocellulose with Ag nanoparticles [1], Reprinted with permission from (c) 2010 American Chemical Society, (b) functionalized nanocellulose with encapsulated plant oil [2].

The industrial processing of functional paper coatings including anti-microbial agents is favored in presence of functionalized CNF, owing to its inherent rheological properties and shear thinning effects that allow for continuous application under spray coating. The latter coating technique is known to provide conformal coatings that preserve the intrinsic roughness of the substrate, in case the macroscale roughness of the paper, and decorates it with a 1 to 5 µm thin coating with eventual nanoscale roughness.

RESULTS & DISCUSSION

As inspired by a Lotus flower leaf, the superhydrophobic properties are evoked by a combination of macro- and nanoscale surface roughness together with coverage of a hydrophobic wax layer. We explored the role of bio-based ingredients in hydrophobic paper coatings, including vegetable oils, biopolymers, or biowax. The increase in hydrophobicity postulated in previous section is a first step in controlling affinity for microbial/bacterial attachment, proliferation and growth, as creation of a water-depleted environment disfavors comfort of adhering organisms. In addition, anti-microbial chemical moieties found in nature should be incorporated in combination with control of the surface topography.



Illustrative examples of biomimicry in creating water-repellent paper coatings with hierarchical surface structure, based on (a) vegetable-oil nanocapsules [3], (b) polyhydroxybutyrate particles [4], (c) intercalated kaolinite clay [5], (d) biowax precipitation [6].

CONCLUSION

According to present technological state-of-the-art, the spray coating of paper surfaces with aqueous suspension coatings provides ample opportunity for mimicking hierarchical surface structures with combined hydrophobic and anti-microbial resistance on paper, through control of surface topography and selection of bio-based compounds that occur in organized particle structures or have inherent antimicrobial properties

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