Method for Forming Assembled Nanomaterial Coating by Solute-Assisted Assembly

Lead Investigator

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Background and Unmet Need

Nano-/micromaterial coatings require assemblage on target substrates such as polymers, ceramics, and metals to achieve versatile functionalities for the applications of smart textiles, functional coatings/finishings, energy storage and conversion, catalysts, and other electronics and photonics. However, many desired combinations of nano-/micromaterials and substrates are extremely challenging to achieve due to the incompatible nature of their surfaces such as hydrophilic nano-/micromaterials assembling on hydrophobic or chemically inert polymers. The existing technologies aiming to solve this problem either introduce binders such as adhesive polymers or activate substrates such as acid or oxygen plasma treatment. Those methods are destructive and may decrease the performance of coatings or damage the substrates. Moreover, the added binder, organic solvent, and acid/base may stress our environment. Thus, a nondestructive and eco-friendly assembly method to achieve nano-/micromaterial coatings on various substrates is in demand.

Opportunity

Dr. Li's technology presents a platform technology for assembly methods for various nano-/micromaterials on arbitrary substrates toward smart textiles, high-performance electronics and optics, energy storage, and thermal management. Notably, there are no requirements on the chemical modifications for both nano-/micromaterials and substrates during the assembly process, and the assembly process will always use water as the solvent instead of organic solvents.

This invention introduces solute (such as salt, sugar, and any soluble solute in the solvent) in the aqueous suspension to force the assembly of nano-/microparticles on arbitrary substrates such as polymers, ceramics, and metals. The salts can be any salt soluble in water, such as LiCl, NaCl, KCl, CsCl, $MgCl_2$, $CaCl_2$, $CuCl_2$, $FeCl_3$. At the same time, the cations or anions can be absorbed on nano-/micromaterials, which can further functionalize the coatings.

Adding solute in the solvent alters nano-/microparticle-water-substrate interaction and forces nanomaterial assembly on the substrate. The assembly of the nano-/micromaterials may be assisted in an acoustic field, a shear field induced by dip coating, a mechanical stirring, or a scalable roll-to-roll process.

Examples of suitable nanomaterials or particles include, but are not limited to, a metal, an oxide, a metal hydroxide not soluble in water, a metal salt not soluble in water, transition metal chalcogenide, a carbide, a nitride, a carbonitride, a single element material (e.g., Se, carbon-based nanoparticle, nanotube, or nanofiber), a perovskite, a polymer, a protein, and any combination thereof.

The nano-/micromaterials or particles and the substrate can be both similar or opposite from one another in their surface properties. For systems that the two parts are not alike and extremely challenging to assemble (e.g., hydrophilic MXene on hydrophobic PDMS), this method can enable uniform assembly. For systems where the two parts are alike (e.g., hydrophobic graphene on hydrophobic PDMS) and can achieve assembly without adding solution, this method can promote assembly efficiency.

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The nanocoating market was valued at $10.7 Bn in 2020 and is forecasted to reach $20.1 Bn by 2030 with a CAGR of 6.7%.[1] The rise in demand for nanocoating in the automotive, electronics, medical, energy, and healthcare industries is a key factor contributing to the increasing demand for nanocoating solutions.[2]

Unique Attributes

- Water-based and ecofriendly process.
- Nondestructive process to both nano-/micromaterial and substrate.
- Enables any combinations of nano-/micromaterials and substrates species.
- Increases manufacturing efficiency and reduced manufacturing costs.
- Simplify the coating manufacturing process.
- Coating can be formed on flexible/ rigid, organic/ inorganic substrates.

Applications

A platform technology for assembly methods for nanomaterials on dissimilar or 'unlike' substrates toward smart textiles, high-performance electronics and optics, energy storage, and thermal management.

Stage of Development

Technology Readiness Level 4: Technology Validated in the Lab. Prototype and Proof of Concept.

Intellectual Property

US Patent Application Published September 14, 2023, as US 2023/0286015 A1.

Licensing and Collaboration Opportunity

Villanova University is actively seeking a licensee or partner to support the development or commercialization of the technology presented.

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[1] *Nanocoatings Market by Type*, Allied Market Research, April 2022.
[2] Ibid.