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METHOD FOR FORMING ASSEMBLED NANOMATERIAL COATING BY SOLUTE-ASSISTED ASSEMBLY

Primary Investigators

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Background and Unmet Need

Coating electronics and performance materials requires assembling nanoparticles on targeted substrates such as polymers, ceramics, and metals. Many high-performance materials have hydrophobic or chemically inert surfaces. As a result, nanomaterial or particle coatings characteristically do not naturally stick to these surfaces, restricting their applications for aerospace, high altitude, battlefield, and other extreme environments.

Currently, techniques for high-rate, cost-efficient, and environmentally friendly functional coatings and electronics are limited. Commonly used dip coating technologies are based on evaporation with very low coating speeds. State-of-the-art nanomaterial coating speeds can range from hours to even days to produce high-performance nanomaterial coatings.

As a result, the demand for an efficient and cost-effective platform method for specialized coating remains.

Opportunity

Dr. Li and his colleagues have invented a universal salt-assisted assembly method that produces ultra-thin, uniform coatings with exceptional mechanical stability and washability on polymers, including high-performance polymers for extreme temperatures.

Utilizing a novel salt-assisted assembly (SAA) method, this technology offers several advantages over state-of-the-art methods. The dip-coating process of SAA process is substantially faster compared to conventional dip coating because of the differences in assembly mechanisms. In traditional coating of dip methods, the evaporation at the solid-liquid-vapor interface forces the deposition of particles onto the substrate. In comparison, the SAA process is not evaporation driven. The assembly happens immediately when the polymer substrate is submerged into the nanomaterial water suspension. In the SAA process, the dipping speed reaches 1.5 m min^{-1}, 1–3 orders of magnitude higher than conventional dip coating.[1]

The SAA utilizes extremely abundant and non-toxic solutes, such as salt, sugar, or acid bases to trigger the interactions between nanomaterials and polymer substrates. As a platform coating method, examples of suitable nanomaterial include but are not limited to MXene, metal, metal oxide, metal hydroxide not soluble in water, metal salt not soluble in water, a transition metal chalcogenide, carbide, nitride, carbonitride, polymer, protein, and single element materials such as carbon-based nanoparticles, fiber, and tubes. Further, the proprietary coating method enables any combination of material, any number of coating layers, as well as the ability to fine-tune layer spacing on nanosheets.

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[1] Zhao, L., Bi, L., Hu, J. *et al.* Universal salt-assisted assembly of MXene from suspension on polymer substrates. *Nat Commun* **15**, 10027 (2024). https://doi.org/10.1038/s41467-024-53840-y

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The investigators have completed experiments on 16 polymers, including those with the highest mechanical strength and thermal resistance, such as hydrophilic Kevlar, polyimide, and hydrophobic PE and PEEK.

The bond durability has been tested with washing experiments with Mxene coated onto Kevlar fabric. It was determined that, based on a washing frequency of once a week for one hour, such wearables can last for at least three years without degradation.[2]

The textile coating market alone has been valued at $4.4 Billion in 2023 and is expected to grow to $5.4 billion by 2028 at a compound annual growth rate of 4.6%. Increased demand for functional coatings continues to drive the growth of these markets.[3]

Unique Attributes

- Rapid coating speeds with strong bond strength.
- Utilization of abundant non-toxic solutes to ensure occupational and user safety, procurement from non-stressed supply chain product. Assembly process avoids use of toxic organic solvents and possible chemicals for surface treatment.
- Universal solution for the assembly of nanomaterials into high-performance polymers.

Commercial Applications

While this method originally was developed to deposit MXene onto hydrophobic surfaces, this method can be applied broadly to any nanoparticle or nanomaterial coating onto performance material surfaces.

Stage of Development

Technology Readiness Level 5: Validated in Relevant Environment

Intellectual Property

United States Patent application filed January 2025.

Licensing and Collaboration Opportunity

Villanova and Drexel Universities are seeking a licensee to commercialize the invention.

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[2] Zhao, L., Bi, L., Hu, J. et al. Universal salt-assisted assembly of MXene from suspension on polymer substrates. Nat Commun 15, 10027 (2024). https://doi.org/10.1038/s41467-024-53840-y

[3] Textile Coating Markets by type, Markets and Markets, February 2024.