Technology Offer

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Empa
Materials Science and Technology

Graphene inks

Additive-free graphene inks for printed electronics (2D) and structural elements (3D)

- **highly concentrated for efficient printing**
- **rheology adjustable to all major printing and coating techniques, no need for post-treatment**
- **up-scalable and versatile technology, large choice of solvents, substrates, and 2D materials**

Invention

A simple and efficient preparation process for inks with a high solid content of 2D materials has been developed. The method can be used for pristine 2D materials of virtually all types, to prepare additive-free inks with diverse rheological properties for various printing and coating methods. Depending on the selected 2D material, thin and thick, conductive, semiconductive (with different bandgaps), or insulating films can be deposited on almost all substrates, using freely selectable solvents, while no post-treatment (e.g., sintering or high-temperature thermal treatments) is required.

Background

Printing and wet coating methods are widely used for commercial production of electronics. Usually conventional inks contain enormous amounts of additives such as binders and surfactant, which drastically degrade the electronic properties of the functional materials. To remove the additives and recover the electronic properties, high-temperature post-treatments (>300°C) are required, limiting the choice of materials (e.g., no heat-sensitive material). Furthermore, conventional 2D material inks (e.g., graphene inks) are usually produced using hazardous solvents (e.g., NMP) and have low solid contents that complicates the fabrication process and increases the production cost and time.
In this regard, the new high-solid-content, additive-free inks produced in green solvents without the need for additional post-treatment (except for drying) can offer a vast range of possibilities for functional printing/coating and are highly desirable for commercial production of electronics.

Advantages

These new inks are based on a high concentration of pristine 2D materials (e.g., graphene, 2D single element materials, 2D alloys, 2D supercrystals), in which – contrarily to diluted dispersion – a solvent is dispersed in the solid without the need for additives. These inks show high colloidal stability, exhibit exceptional adhesion to a wide range of substrates, and are producible using almost any solvent (including green solvents). These inks can be optimized for all common printing techniques as rheological properties can be easily adjusted over a wide range. Graphene inks are significantly cheaper than metallic inks (e.g., silver or copper) and are chemically inert/stable. Since no heat treatment is needed to achieve full functionality, printing and coating on heat-sensitive substrates (e.g., Paper, PET, PLA, etc.) or layers (e.g., perovskites) are possible. Being additive-free, our printed/coated films are highly porous (porosity level is adjustable), which is desirable for sensing and energy storage applications, new possibilities may arise by functionalizing the inks with biomolecules.

Applications

The inks can be applied in all fields of printed electronics where conductive, semiconductive or isolating features with low temperature processing is needed or desired. A specific application may be

1. Energy storage and conversion (e.g., batteries, supercapacitors, solar cells, fuel cells, etc.);
2. Sensors (e.g., chemical, temperature, pressure, etc.);
3. Electromagnetic interface (EMI) shielding;
4. Thermal interface material (both in solid and gel form).

The inks are specifically suited for extrusion- and screen-printing. Further specific applications are in the field of stretchable wires and interconnects, embedded electronics, self-healing circuits, conformal electrodes, heat transfer systems, and thermal cooling and heating designs.

Ownership

Empa, Swiss Federal Laboratories for Materials Testing and Research, Überlandstrasse 129, CH-8600 Dübendorf; Patent pending

References

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Homogeneous emulsions and suspensions of 2-dimensional materials, Patent application EP3848420A1

Keywords

2D materials, Printing and Coating, Printed electronics,
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