Stabilizer residue in inks found to inhibit conductivity in 3D printed electronics

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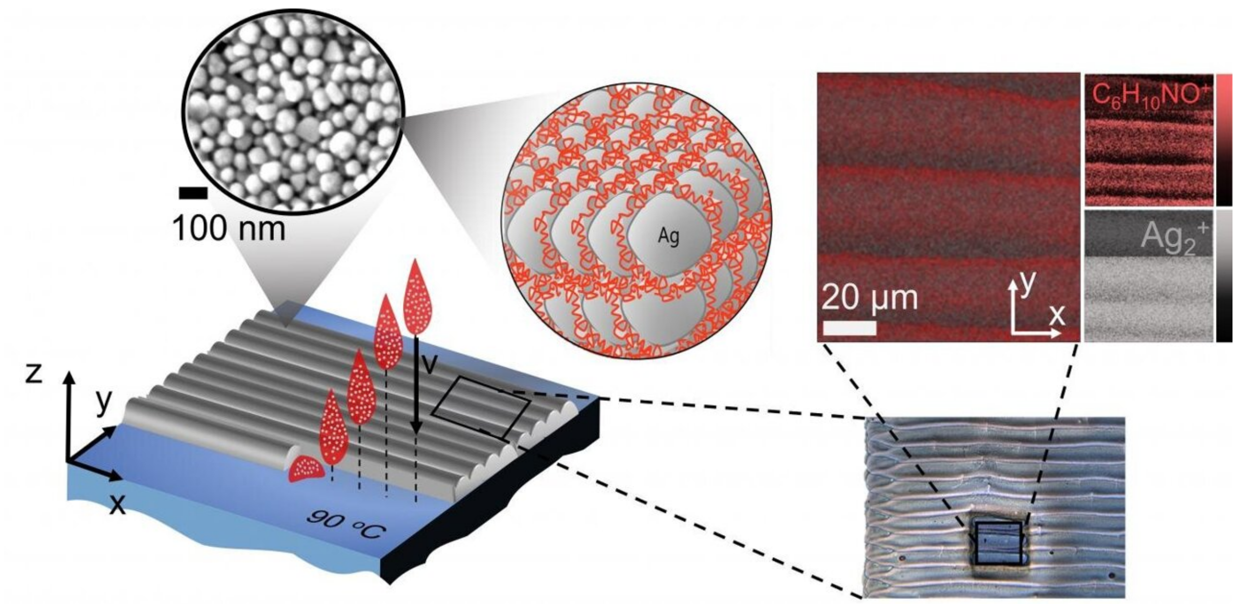


(left) Digital inkjet printing of inks containing metal nanoparticles with in-situ solvent evaporation (pinning). (right) Optical and chemical images of a printed layer of silver nanoparticles showing organic residues at the surface Credit: Gustavo Trindade

Inks containing metal nanoparticles are among the most commonly-used conductive materials for printed electronics. Ink-jetting layers of MNP materials allows for unprecedented design flexibility, rapid processing and

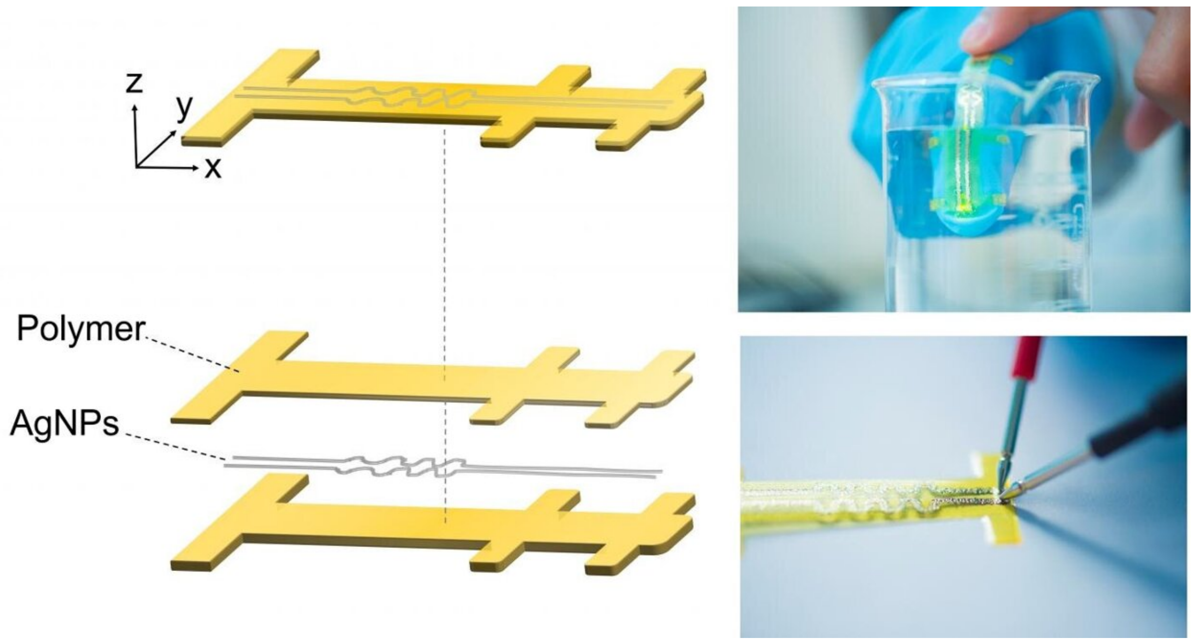
3D printing of functional electronic devices such as sensors, solar panels, LED displays, transistors and smart textiles.

Inkjet 3D printing of metals typically form a solid printed object via a two-step process: solvent evaporation upon printing (pinning) and subsequent low-temperature consolidation of nanoparticles (sintering). The low temperature is important as in many applications the nanoparticles are co-printed with other functional/structural organic materials that are sensitive to higher temperatures.

However, layers produced by inkjet printing of metal nanoparticles have different electrical conductivity between horizontal and vertical directions. This effect is known as functional anisotropy and is a long-standing problem for the 3D printing of functional electronic devices, preventing its use for advanced applications.

It was previously thought that reduced vertical conductivity through a printed device is mainly caused by shape and physical continuity problems at the interfaces of the constituent nanoparticles (at the very small micro and nanoscale). However, Nottingham researchers used silver nanoparticles to show, for the first time, that it is caused by organic chemical residues in the inks.

These residues, which are added to the inks to help stabilize the nanomaterials, lead to the formation of low-conducting, very thin nanoscale layers which interfere with the electrical conductivity of the printed sample in the vertical direction.



A multi-material inkjet 3D printed prototype of an encapsulated strain sensor used in the study Credit: Gustavo Trindade

With a clearer understanding of the distribution of residual organic additives within printed layers, the researchers hope to go on to define new techniques and develop new ink formulations to overcome functional anisotropy of inkjet-based 3D printed electronics.

Lead author, CfAM Research Fellow Dr. Gustavo Trindade, said, "The conductivity of inkjet-printed metal nanoparticles is known to be dependent on processing temperature and have been previously attributed to changes in the shape and porosity of clustered nanoparticles, with the role of organic residues being only speculated."

"This new insight enables the development of routes to overcome functional anisotropy in inkjet-based nanoparticles, and will therefore improve uptake of this potentially transformational technology, making it competitive with conventional manufacturing. Our approach is transferable to other nanomaterial-based inks including those containing graphene and functionalised nanocrystals, and will enable the development and exploitation of both 2-D and 3D printed electronics like flexible and wearable sensors, solar panels, LED displays, transistors and smart textiles."

The study was carried out by the Centre for Additive Manufacturing (CfAM), under the £5.85m EPSRC-funded Programme Grant, Enabling Next Generation Additive Manufacturing. Their findings are published in a new paper 'Residual polymer stabilizer causes anisotropic electrical conductivity during inkjet printing of metal nanoparticles' in the Nature journal *Communications Materials.*

The researchers used the unique chemical sensitivity of a state-of-the-art 3D orbiSIMS instrument owned by the University of Nottingham. The Nottingham orbiSIMS—the only one at a UK university—allows label-free 3D chemical imaging of materials with very high resolution, revealing insights that have informed this study.

More information: Gustavo F. Trindade et al. Residual polymer stabiliser causes anisotropic electrical conductivity during inkjet printing of metal nanoparticles, *Communications Materials* (2021). DOI: 10.1038/s43246-021-00151-0

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