

Spray-on-Screen

Bringing solution-processed coatings into the few-nanometre regime

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<15
nm

Film thickness achievable

10×7
cm²

Demonstrated coating area

▶▶ EXECUTIVE SUMMARY

A scalable solution-based route to homogeneous coatings below 15 nm

Spray-on-Screen (SoS) is an innovative solution-based deposition technology developed at IUMAT (Hasselt University / Imec) that enables the reproducible deposition of ultra-thin functional coatings in the few-nanometre thickness range over centimetre scale areas.

While established thin-film deposition methods can produce excellent coatings, they typically require trade-offs between thickness control, process complexity, material consumption, substrate compatibility and scalability. SoS offers a process window that delivers homogeneous functional layers in the few-nanometre range, deposited without vacuum processing and using standard solution-processable materials. It has been demonstrated with both aqueous and alcohol-based formulations, operates without vacuum infrastructure, and is architecturally compatible with continuous roll-to-roll (R2R) manufacturing.

Scaling layer thickness down offers significant practical advantages beyond device performance. For costly functional materials, reducing film thickness down to 15nm substantially lowers material consumption. Furthermore, avoiding vacuum infrastructure and high-temperature processing unlocks new possibilities for flexible and temperature-sensitive substrates and for future continuous manufacturing. The process has been experimentally validated across diverse material systems, including PEDOT:PSS, PEIE, and

ZnO-PEIE, demonstrating successful incorporation into functional OLED architectures. The technology is currently implemented via an automated laboratory-scale research platform accommodating substrates up to 7 x10 cm offering a streamlined path toward industrial scale-up.

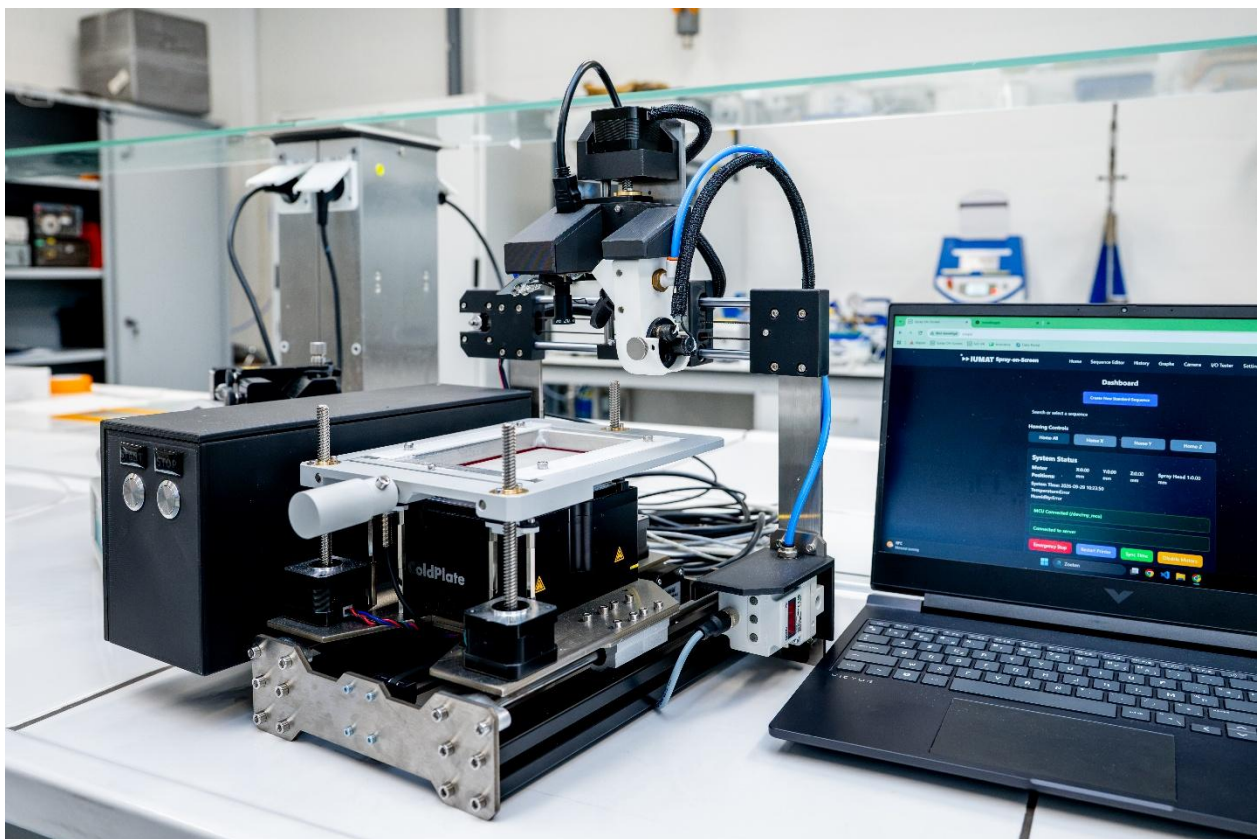


Figure 1. The StreamCoat automated research platform for Spray-on-Screen deposition. The system integrates an ultrasonic spray nozzle (top) for controlled microdroplet generation and a screen mesh (centre) that converts the microdroplets into a uniform liquid film through coalescence and forced dynamic wetting. The platform supports substrates up to 7 × 10 cm.μ

►► INTRODUCTION

The need for precise ultra-thin functional coatings

Thin-film device performance relies heavily on controlling functional and interfacial layers within a narrow nanometre-scale thickness window. For instance, charge-transport layers measuring just a few nanometers are essential in organic electronics to optimize charge injection, transport, and interfacial energetics[1]. Similarly, ultra-thin interlayers in photovoltaics can suppress interfacial recombination and improve charge-selective contacts [2]. In thin-film sensors, coating thickness can strongly influence analyte transport, surface interaction and ultimately sensitivity [3].

In addition the device performance, reducing coating thickness significantly decreases costly material consumption, particularly when using specialty polymers, nanoparticles or other high-value formulations. At very low wet-film volumes, dewetting, evaporation-driven flow and incomplete surface coverage can rapidly compromise film uniformity, often forcing extensive reformulation of the ink or process. As device architectures demand tighter control over interfaces, while manufacturers seek to reduce material use and energy-intensive processing, reliable deposition in the nanometre regime becomes increasingly important. However, reliably producing continuous, homogeneous films in this thickness regime remains challenging for conventional wet-coating techniques.

►► HOW IT WORKS

The Spray-on-Screen process in detail

The SoS deposition process consists of four sequential steps, each critical to achieving a homogeneous ultra-thin coating. Figure 2 provides a schematic cross-section overview of each step, while Figure 3 shows how strongly film quality depends on release timing: a difference of only a few seconds separates droplet formation from mesh imprinting under these processing conditions. Rather than depositing the final film directly droplet by droplet, SoS uses the screen as an intermediate liquid-handling interface where droplets first coalesce on the mesh before the liquid is transferred and thinned on the substrate.

Step 1: Microdroplet generation and mesh wetting

The ultrasonic spray coater generates microdroplets that deposit onto the screen mesh. Where they coalesce into milli-droplets that sit on, fill, and hang beneath the mesh openings, forming a continuous liquid reservoir.

Step 2: Mesh contact and substrate wetting

Upon pressing the wetted mesh against the substrate, the applied force causes the microdroplets to spread, while attraction forces simultaneously draw the ink through the mesh onto the substrate surface. Together, these effects produce a homogeneous, uniform wetting of the entire substrate area.

Step 3: Controlled drying through the mesh

The mesh remains in contact with the substrate while the solvent evaporates homogeneously through the mesh openings. The mesh acts as a template that regulates evaporation uniformity across the coated area.

Step 4: Timed mesh release

Precise retraction of the mesh is critical to obtain a smooth, uniform coating. When retracting too early, the film is still too wet, so droplets form on the surface and the resulting flow instabilities produce an inhomogeneous coating. When retracting too late, the film has already dried onto the mesh, leaving a thickness imprint of the screen's relief pattern as alternating thick and thin zones. Only at the optimal moment, while the film is still slightly wet, does rapid and homogeneous evaporation yield a smooth, uniform layer.

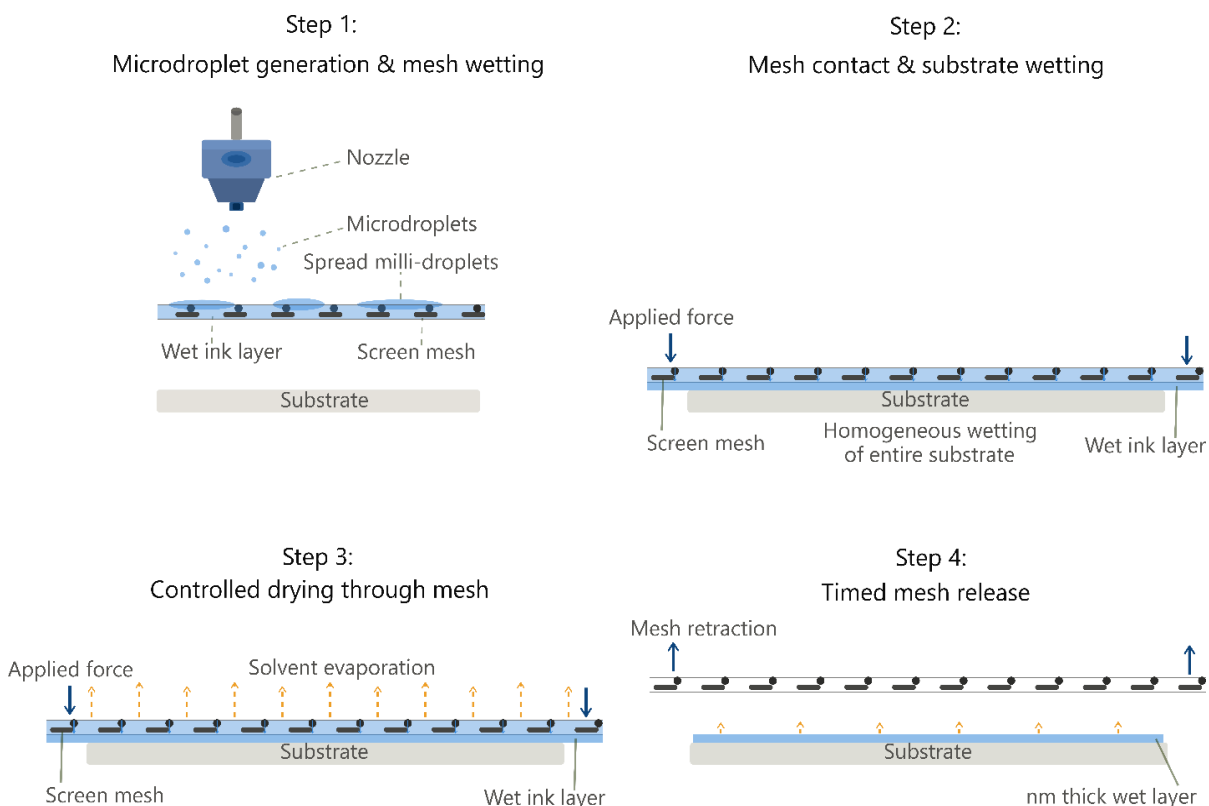


Figure 2: Schematic cross-section overview of the four sequential steps of the Spray-on-Screen (SoS) deposition process: (1) microdroplet generation by the nozzle and coalescence into milli-droplets on, (2) mesh contact with the substrate, driving lateral spreading of the liquid film through applied pressure, (3) controlled solvent evaporation through the mesh openings while the mesh remains in contact; and (4) timed mesh retraction leaving a homogeneous ultra-thin coating on the substrate.



Figure 3: Optical microscopy images (Keyence) of PEDOT:PSS coatings deposited from aqueous solution, illustrating the effect of mesh release timing. **(a)** Too early : film still wet, causing droplet formation and inhomogeneous coating . **(b)** Too late : film fully dried against mesh, leaving a periodic thickness imprint of the screen relief. **(c)** Optimal timing: homogeneous, featureless coating (scale bar: 1000 μm).

DEMONSTRATED PERFORMANCE

Validated results

SoS has been validated with several functional material systems, including PEDOT:PSS, PEIE and ZnO–PEIE, on both ITO and glass substrates. Minimum demonstrated film thicknesses range from approximately 5 to 16 nm, with RMS surface roughness values between 0.3 and 2.6 nm (Table 1). For PEIE, homogeneous coatings were demonstrated over areas up to $5 \times 5 \text{ cm}^2$.

Material	Min. Thickness	Roughness (RMS)	Substrates Tested
PEDOT:PSS (aqueous solution)	$15.8 \pm 0.6 \text{ nm}$	1.1 nm	ITO glass, Super Yellow polymer, $5 \times 5 \text{ cm}^2$
PEIE (IPA)	$4.8 \pm 0.1 \text{ nm}$	0.3 nm	ITO glass, Super Yellow, $5 \times 5 \text{ cm}^2$
ZnO–PEIE nanocomposite (IPA)	$15.3 \pm 0.6 \text{ nm}$	2.6 nm	ITO glass, Super Yellow polymer, $5 \times 5 \text{ cm}^2$

Table 1: Overview of material systems deposited by SoS, with minimum achieved thickness, surface roughness (RMS), and substrate compatibility[4].

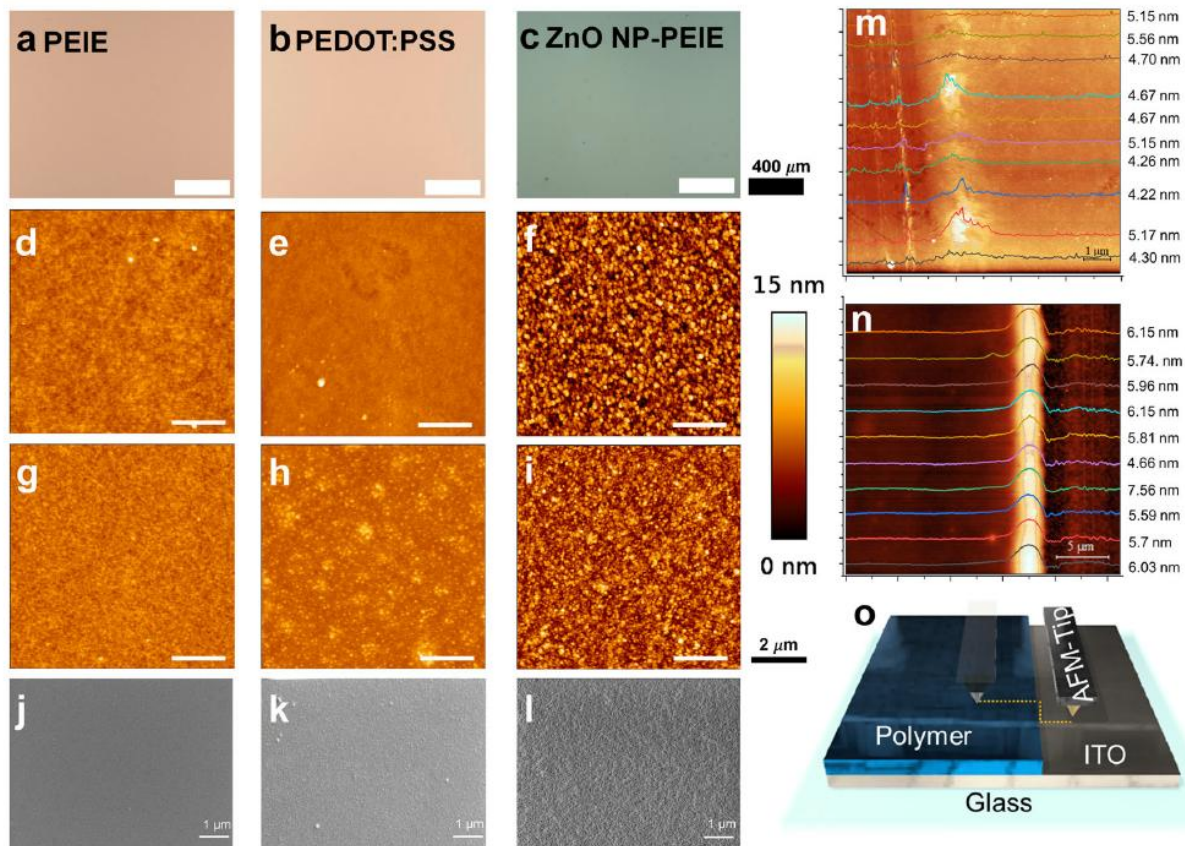


Figure 4: Optical microscopy, AFM and SEM characterisation of SoS-deposited PEDOT:PSS, PEIE and ZnO-PEIE coatings on ITO and polymer substrates, demonstrating uniform film formation and nanometre-scale thickness control. Adapted from [4].

▶▶ OLED APPLICATION PROOF POINT

The quality of the deposited films was also validated at device level. SoS-deposited PEDOT:PSS and ZnO-PEIE layers were integrated into organic light-emitting diodes. Devices reached an external quantum efficiency of 5.6%, comparable to spin-coated reference devices, while a luminous efficacy of approximately 24 lm/W was obtained compared with approximately 20 lm/W for devices using a vacuum-evaporated calcium electron-injection layer. The process was also demonstrated in $5 \times 5 \text{ cm}^2$ OLEDs showing homogeneous large-area emission [4].

THE PLATFORM

StreamCoat: an automated research platform for Spray-on-Sceen

StreamCoat translates the Spray-on-Screen process into a compact, automated research platform designed for reproducible process development. The system supports substrates up to 7 × 10 cm, operates between 20 and 100 °C and is compatible with glovebox environments. No vacuum infrastructure is required. Its modular architecture also provides a platform for investigating future scale-up of the SoS deposition principle.

Specification	Detail
Maximum substrate size	Up to 7 × 10 cm
Coating thickness range	5–30 nm (sub-nm regime in development)
Substrate temperature	20–100 °C — compatible with heat-sensitive polymers
Vacuum required	None
Glovebox compatible	Yes — compact tabletop footprint
Scale-up pathway	Deposition principle inherently R2R-compatible

APPLICATIONS

Where SoS creates value

So far, SoS has been successfully demonstrated with functional layers relevant to organic electronics, including charge injection and transport layers for OLED devices. This unique capability, to control solution-processed films in the few-nanometre regime, holds strong potential for other thin-film technologies requiring precisely controlled interfaces, such as photovoltaics, sensors and emerging energy devices. Future work will focus on extending the material set and validating these application-specific process windows.

TECHNOLOGY STATUS AND IP

Patented. Validated. Ready to collaborate.

Spray-on-Screen originates from research at IUMAT, and has since been developed into the StreamCoat research platform through continued process and application validation. The technology is protected by granted European and US patents, including EP4184601B1. Current development focuses on expanding the compatible material set, validating additional applications and exploring pathways toward larger-area and continuous processing.

IUMAT is open to collaborative research agreements, joint development projects, licensing discussions and contract research engagements. We are actively seeking industrial partners to co-develop application-specific process parameters and explore scale-up pathways.

HELP SHAPE THE FUTURE OF PRINTED ELECTRONICS

Hasselt University (UHasselt) is exploring the development of professional education and training opportunities in Printed Electronics. As the field continues to evolve across sectors such as healthcare, energy, smart packaging, wearables and advanced manufacturing, industry input is essential to ensure that future training programmes address real needs.

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