

COATING QUALITY CONTROL WITH SNAPSHOT HYPERSPPECTRAL IMAGING

Our whitepaper *SiO₂ thickness detection on silicon wafers* showed that a single snapshot returns a full-field oxide thickness map, matching nominal values to a few percent; the physical principle and its validation are set out there and are not repeated here. This note reports what has changed since, and puts the improved setup to work on spin-coated polymer films.

WHY FULL-FIELD, FOR A COATING

Spin-coated films are not uniform by default: airflow over the spinning substrate, edge effects and solvent-evaporation gradients produce edge beads, radial thickness trends and striations [1, 2]. Uniformity is nevertheless usually verified with **point tools** – reflectometry, ellipsometry or a stylus profilometer, at a few sites. A handful of points cannot show the *pattern* of a deviation, and the pattern is what separates a radial airflow trend from a local blemish.

WHAT CHANGED IN THE SETUP

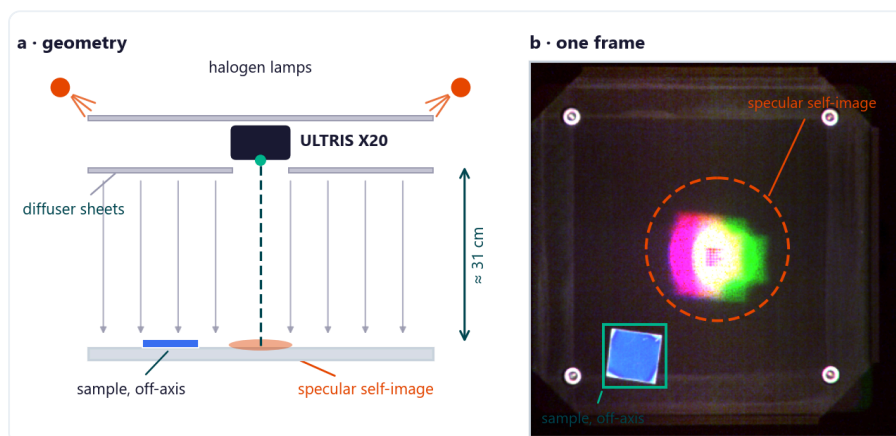


Figure 1 · The measurement setup. (a) The camera hangs between two diffuser sheets lit indirectly by halogen lamps and views the sample through an aperture in the lower one; incidence is normal, so no angle correction is needed and the sample is placed off the optical axis. (b) One recorded frame – the specular self-image sits at the centre of the field, and the coupon is placed clear of it.

The camera looks straight down. The wafer study tilted it about 5° so that it would not image itself in the mirror-like oxide, and carried a $\cos \theta \approx 0.998$ correction through the analysis. Here the camera hangs vertically between two diffuser sheets and views the sample through an aperture in the lower one (Fig. 1a): incidence is normal, $\cos \theta = 1$, and no angle correction enters the calculation.

The self-image does not disappear – it moves to the centre of the frame, where the mirror-like sample reflects the camera straight back into the lens (Fig. 1b). Pieces of a few centimetres are placed off-axis,

clear of it. Suppressing it for large samples, with an improved diffuser and a movable stage, also allows the ULTRIS XMR to be operated at nadir; that arrangement is the subject of a follow-up study.

A different camera, the same read-out. These measurements used a **Cubert ULTRIS X20** — 410 × 410 pixels, 164 spectral channels from 350 to 1000 nm, recorded in one exposure with no scanning axis [3] — where the wafer study used a **Cubert ULTRIS XMR** with 61 bands from 430 to 910 nm. The X20 samples every 4 nm rather than every 8 nm and begins at 350 rather than 430 nm, so more interference detail falls inside the band. That the same read-out works unchanged on both instruments is the second point of this note: the method belongs to the measurement, not to the camera, and the camera can be chosen to fit the application.

PARAMETER	VALUE
Camera	Cubert ULTRIS X20 (410 × 410 px, 164 spectral channels)
Spectral window	350–1000 nm (VIS–NIR)
Geometry	normal incidence, camera at nadir — no angle correction
Working distance	≈ 31 cm
Illumination	halogen lamps → two diffuser sheets (indirect, diffuse)
Exposure	45 ms per snapshot

The X20 has fixed optics, so the imaged area follows from the working distance alone: ≈ 18 × 18 cm here, ≈ 22 × 22 cm at about 38 cm. The pieces in this study are a few centimetres across and fill only a small part of that frame, which is why they look coarsely sampled — a property of the samples, not of the setup, which takes in a 220 × 220 mm wafer whole.

SEEING COATING QUALITY DIRECTLY

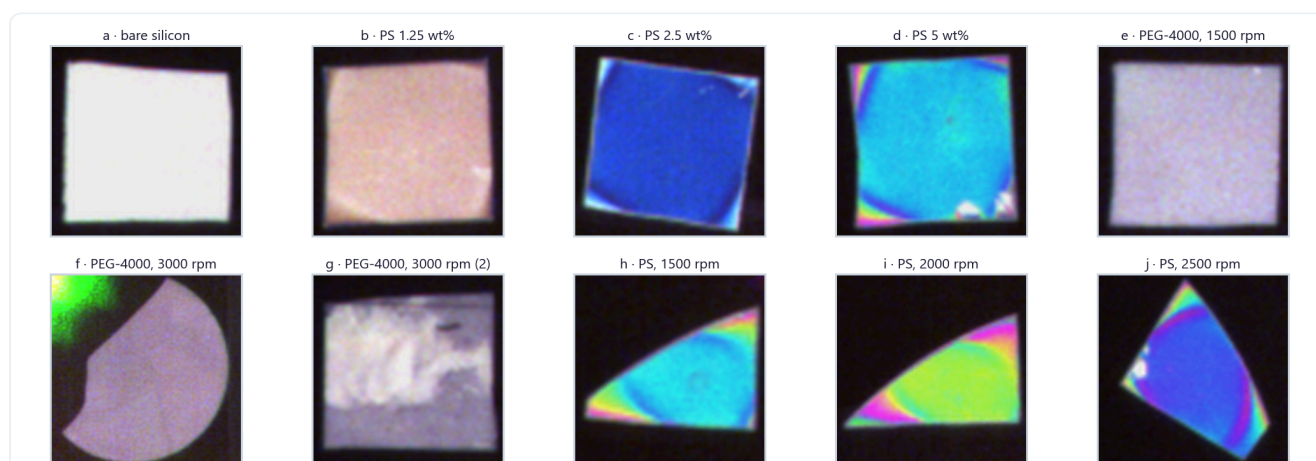


Figure 2 · Ten coated silicon pieces, one 45 ms exposure each. The interference colour is the film thickness — an even colour is a uniform run, a colour that changes is not. Panel (d) shows an edge bead; (f) and (g) carry the same nominal recipe and spin speed. PS — polystyrene from xylene; PEG-4000 — polyethylene glycol 4000 from chloroform.

The colour *is* the measurement: a transparent film on silicon produces optical interference whose colour follows the film thickness. A uniform run reads as one even colour; a run that went wrong shows its gradient as a colour that changes across the piece – a judgement that needs no model, no refractive index and no fitting.

Bare silicon (a) carries no film and stays neutral. The polystyrene films (b–d) are even across their interiors, and the rainbow band around the rim of (d) is an **edge bead**, resolved as a pattern rather than sampled as a number. The wedges (h–j) were spun at 1500, 2000 and 2500 rpm: each sweeps in colour toward its curved edge, and their interior colours differ, so the process setting is legible directly. The pair (f) and (g) is the one to look at twice – both polyethylene glycol 4000, 10 wt% in chloroform, at the same nominal 3000 rpm, yet one is even and the other strongly mottled over its whole area. A few sampled points could well have returned comparable averages for the two; one exposure separates them at a glance.

WHEN A NUMBER IS NEEDED

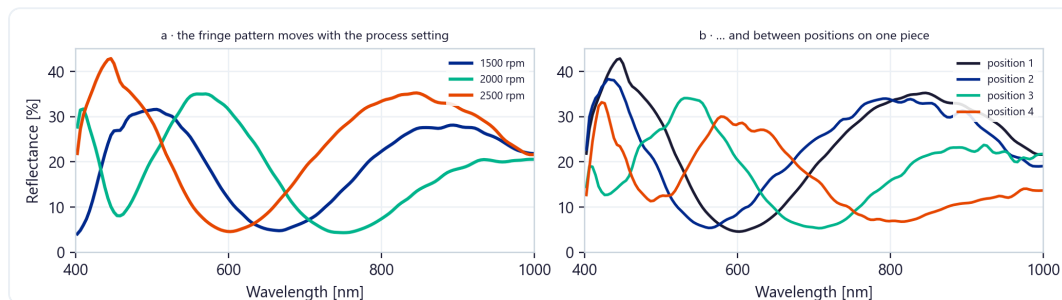


Figure 3 · Reflectance spectra. (a) The fringe pattern shifts with spin speed. (b) It shifts just as clearly between four positions on one and the same piece – the spectral form of the non-uniformity seen in Figure 2.

Every pixel carries a full reflectance spectrum, and that is where the qualitative picture becomes quantitative. Interference between the reflections at the air/film and film/silicon interfaces makes that spectrum oscillate with wavelength [4, 5]; the pattern shifts with spin speed (Fig. 3a) and between positions on a single piece (Fig. 3b). Two adjacent maxima at $\lambda_1 > \lambda_2$ then give the film thickness from

$$d = 1 / (2 \cdot n \cdot (1/\lambda_2 - 1/\lambda_1))$$

with no $\cos \theta$ term, because the camera is at nadir. The relation needs the coating's refractive index n , for polymers taken from published dispersion data [6]. Thicknesses are deliberately not evaluated here – this note is about the quality decision, and the wafer study carries the thickness treatment.

LIMITS

Absolute thickness requires n , or one reference sample to calibrate against; without either, the measurement still gives *relative* thickness across a piece, which is what a uniformity check needs. Like any fringe method it has a **thin-film floor**: below roughly two fringes in the band, peak spacing no longer applies. For the highest absolute precision on very thin films, point **ellipsometry remains the reference**

method and the snapshot does not replace it. The spatial sampling is coarse next to a stylus profilometer, so striation-scale detail is not resolved. And the specular self-image is always present at normal incidence.

CONCLUSION

This setup was built for mirror-like samples, wafers first of all, and Cubert continues to extend its wafer and semiconductor application experience. Two properties make it useful for routine quality work. It is **designed for repeatability**: every sample is measured in the same fixed geometry under the same illumination, which removes the largest source of run-to-run variation. How far that carries over weeks depends on lamp ageing, camera and positioning stability and the calibration interval, and we have not yet validated it over that span. And it is **quick** – thirty 200 × 200 mm wafers, loaded and measured by hand, took under 30 minutes.

What is shown here on spin-coated films is not restricted to spin coating: the read-out is the interference fringe, not the deposition process. Dip, slot-die and blade coating, and CVD or PVD layers on reflective substrates, are within reach – **provided the deposited layer is sufficiently transparent and produces measurable thin-film interference**. That proviso is not a formality: an opaque metallic film returns no fringes and is not this measurement. Together with the wafer study, the approach spans a centimetre-sized coupon and a 200 mm wafer with one method. One step is deliberately not shown here: automating the interpretation, which is being built on Cuvis.AI, Cubert's open-source framework for hyperspectral AI pipelines (github.com/cubert-hyperspectral/cuvis-ai , accessed 25 August 2026).

Work with us. Cubert runs a feasibility study on your own coated samples – your material, your substrate, your thickness range – documenting repeatability and the calibration needed for absolute thickness. Send reference samples or arrange a technical discussion at sales@cubert-gmbh.de.

REFERENCES

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