

Optical Characterization of Paint Droplet Composition in Sprays

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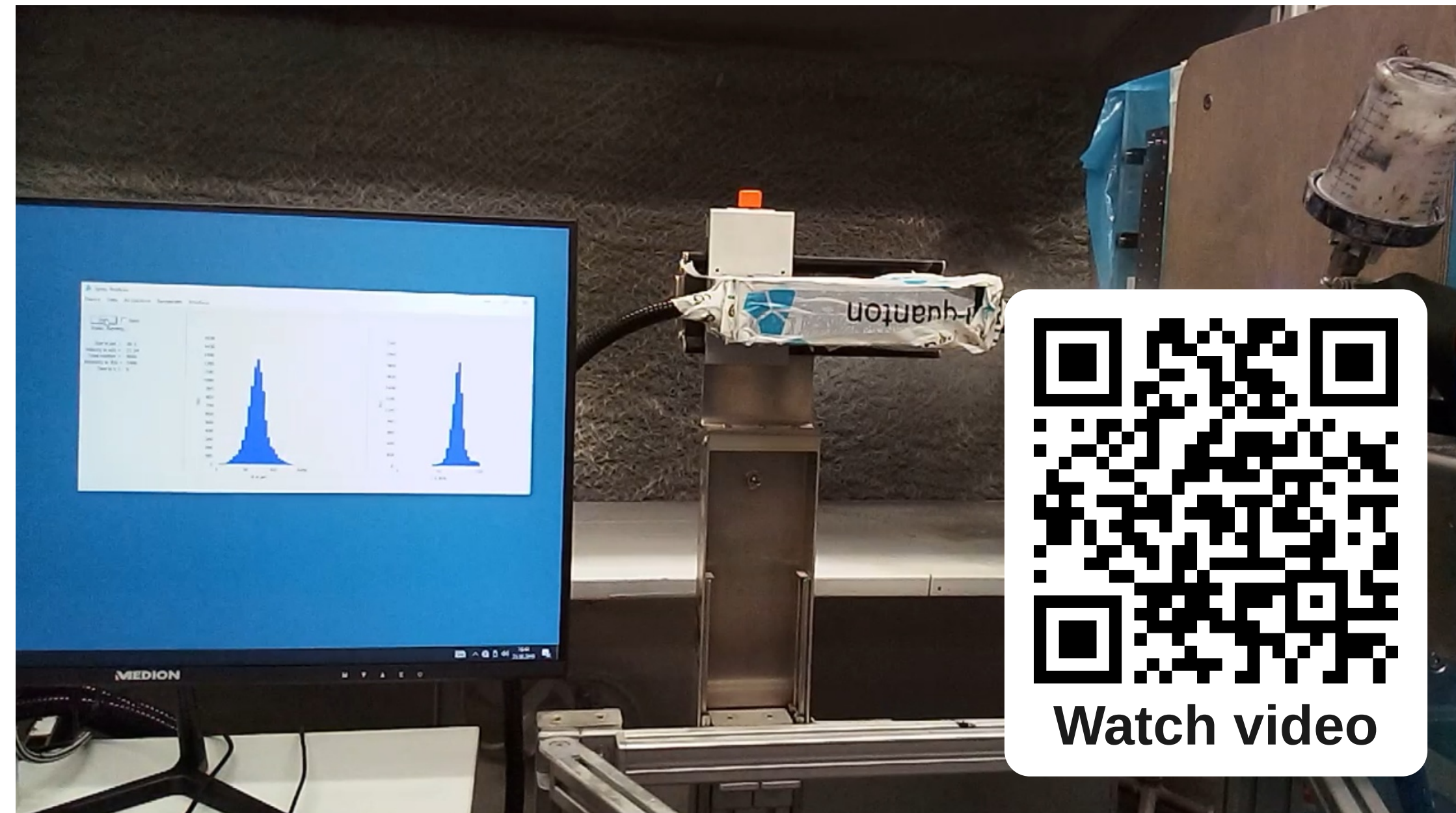


Figure 1: Measurement probe and pneumatic atomizer.

1 Motivation

The quality of a spray-painted coating depends strongly on the composition of the paint droplets formed during atomization: it determines the homogeneity, color tone and surface structure of the final product. Despite the high degree of automation in modern coating processes, there is currently no suitable method for **monitoring the composition of individual paint droplets in flight toward the substrate**.

We present a novel, patent-pending optical method and a corresponding device [1] that characterize the droplet composition from its time-resolved light scattering signals.

2 Measurement principle

A paint droplet passing through a shaped light beam produces a temporal sequence of scattered-light intensities, which is recorded by two or more detectors. The order of the signal maxima reveals whether a droplet is **semi-transparent** or **non-transparent**. Statistical evaluation of many such events yields the relative number of semi-transparent droplets N_{rel} , which allows conclusions about the droplet composition.

$$I(x, y, z) = \frac{2 P_0}{\pi w_x(z) w_y(z)} \text{Exp} \left\{ -\frac{2x^2}{w_x^2(z)} - \frac{2y^2}{w_y^2(z)} \right\} \xrightarrow{y \rightarrow \infty, z \rightarrow 0} I(x) = I_0 \text{Exp} \left\{ -\frac{2x^2}{w_{x0}^2} \right\} \xrightarrow{v = x/t} S(t) = \sum_p^{\{0, 1, 2, 1, \dots\}} S_p \left\{ -\frac{2(t - t_p)^2}{\sigma^2} \right\}$$

Intensity distribution of the Gaussian beam Profile along the flight direction in the focus Time signal as a sum of Gaussian peaks

3 Validation and results

For validation, paint droplets from spray materials with different mass ratios of base coat and color concentrate ($C_m = 3, 5, 11, 13, 17$ and 23%) were classified by their degree of transparency and counted. The resulting frequencies give N_{rel} , which is compared with the mixing ratio C_m .

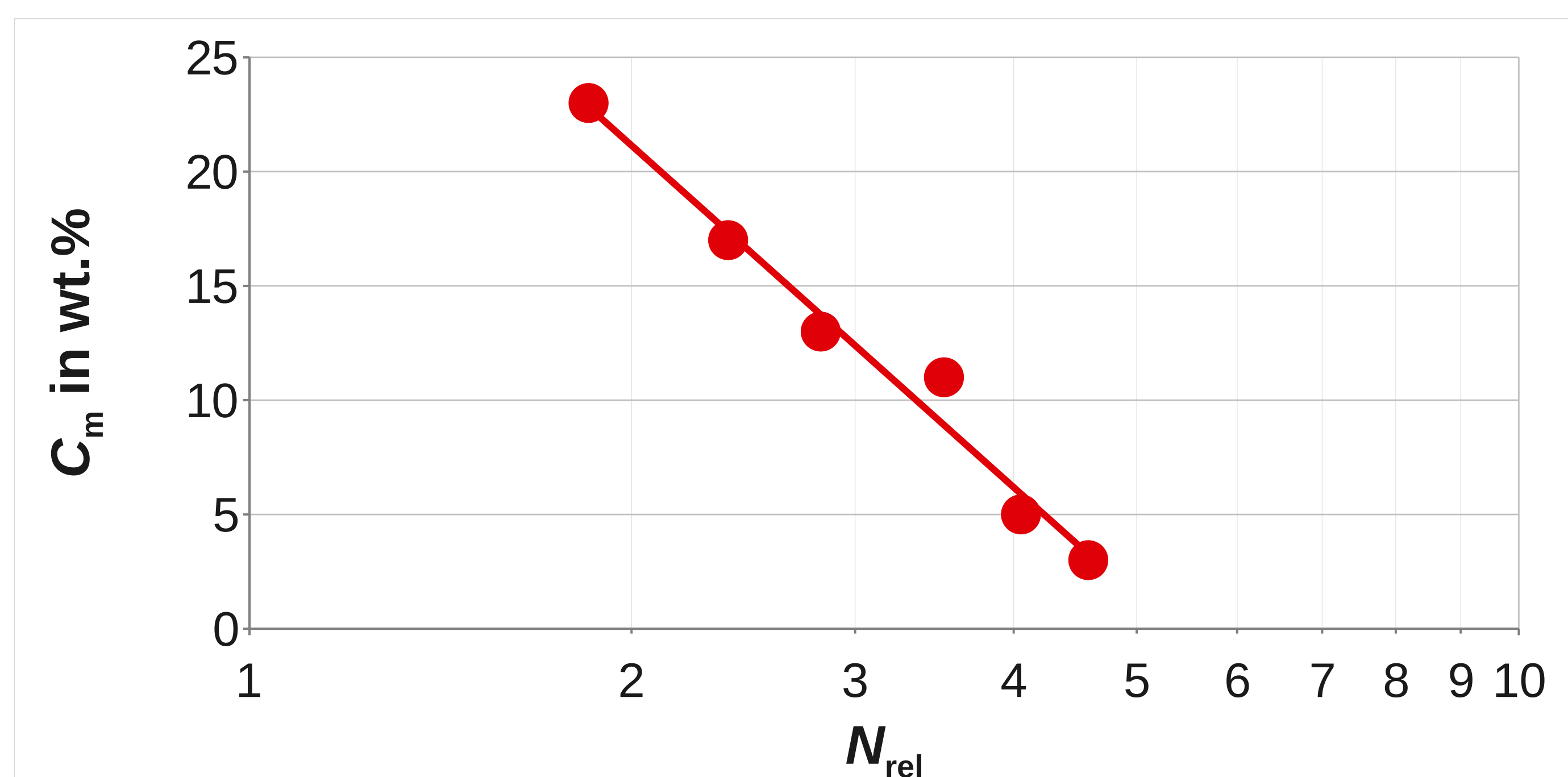


Figure 2: Correlation between C_m and N_{rel} (logarithmic fit: $C_m = -21.6 \cdot \ln N_{rel} + 36.1$; $R^2 = 0.98$). The number of semi-transparent paint droplets increases with decreasing fraction of color concentrate.

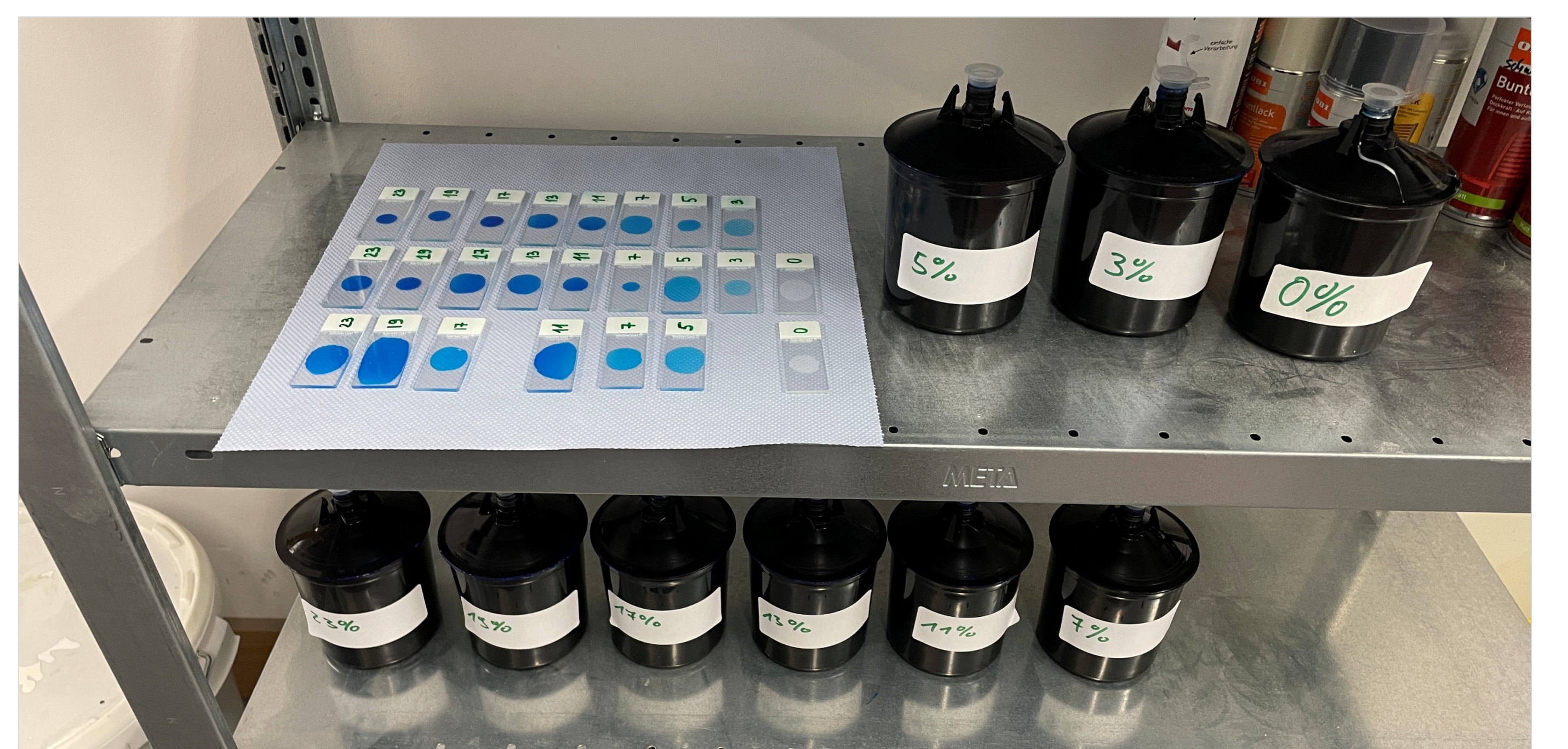


Figure 3: Paint samples of the investigated materials with different C_m . The visible differences in the transparency of the droplets enclosed between microscope slides result from slight variations in the spacing between the slides.

Conclusion

- Time-resolved light scattering signals distinguish semi-transparent from non-transparent paint droplets in flight.
- N_{rel} correlates clearly with C_m (3 to 23 %): the less color concentrate, the more semi-transparent droplets.
- The method is suited for the quantitative characterization of the droplet composition in the coating process.

[1] A. Hänsel, M. Rößler, W. Schäfer (inventors); ai-quanton GmbH, Duale Hochschule Sachsen (applicants): Verfahren und Vorrichtung zur Messung der Zusammensetzung dynamischer Lackteilchen für die Überwachung eines Beschichtungsprozesses in der Spritzlackierung [Method and device for measuring the composition of dynamic paint particles for monitoring a coating process in spray painting]. German patent application DE 10 2025 100 487 A1 (file no. 10 2025 100 487.0), filed 8 January 2025, published 9 July 2026.
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