

## Introduction

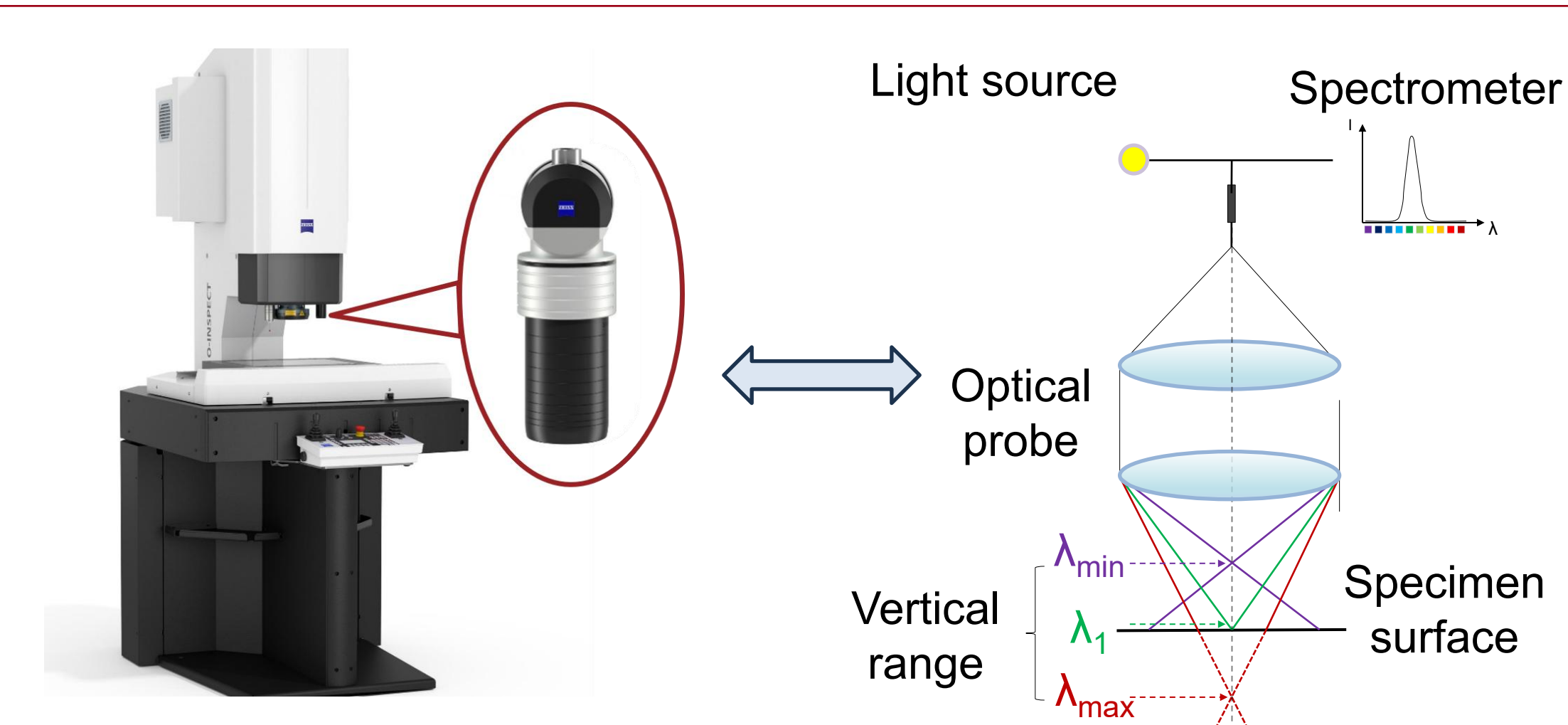
- **Optical metrology** plays a key role in modern industry due to demand for fast, precise, non-contact measurements.
- Chromatic confocal sensors provide nanometric resolution and sub-micrometric accuracy, but their **performance is challenged on non-cooperative surfaces** (i.e. reflective, complex geometry, colour, rough).
- The study assesses the **metrological performance** of a chromatic confocal sensor, focusing on the impact of surface properties and characteristics.

## Objective

Quantify the performance of a chromatic confocal sensor focusing on:

- Limit angle of acquisition**
- Influence of colour**
- Influence of surface roughness**

## Materials and Methods

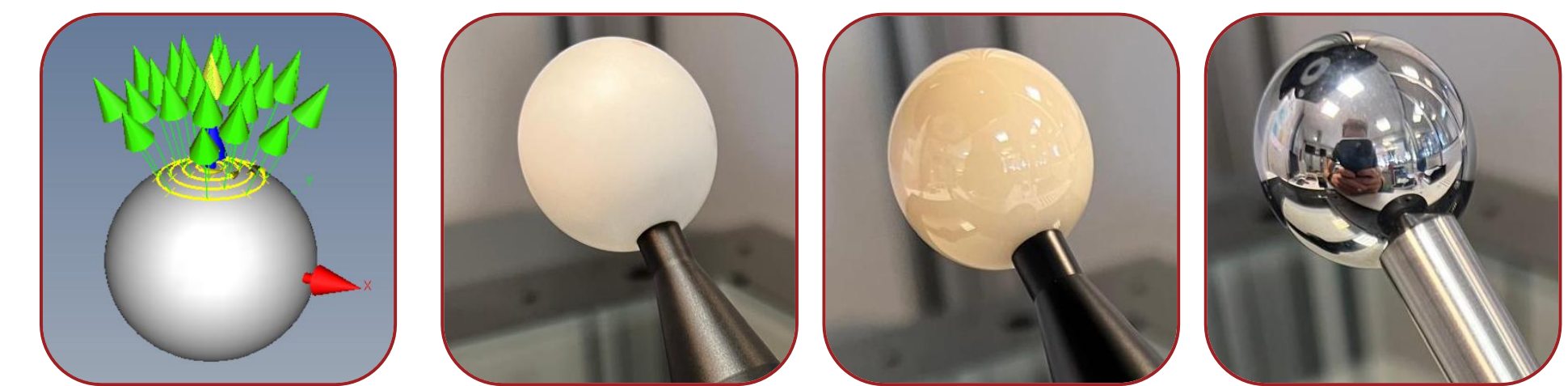


**Fig. 1.** Use of a chromatic confocal sensor mounted on a multisensor CMM ZEISS O-Inspect 322. Schematic representation of the working principle of the chromatic confocal probing system

The performance of the chromatic confocal sensors were assessed with direct comparison with tactile measurements, considered as reference for their superior accuracy and repeatability.

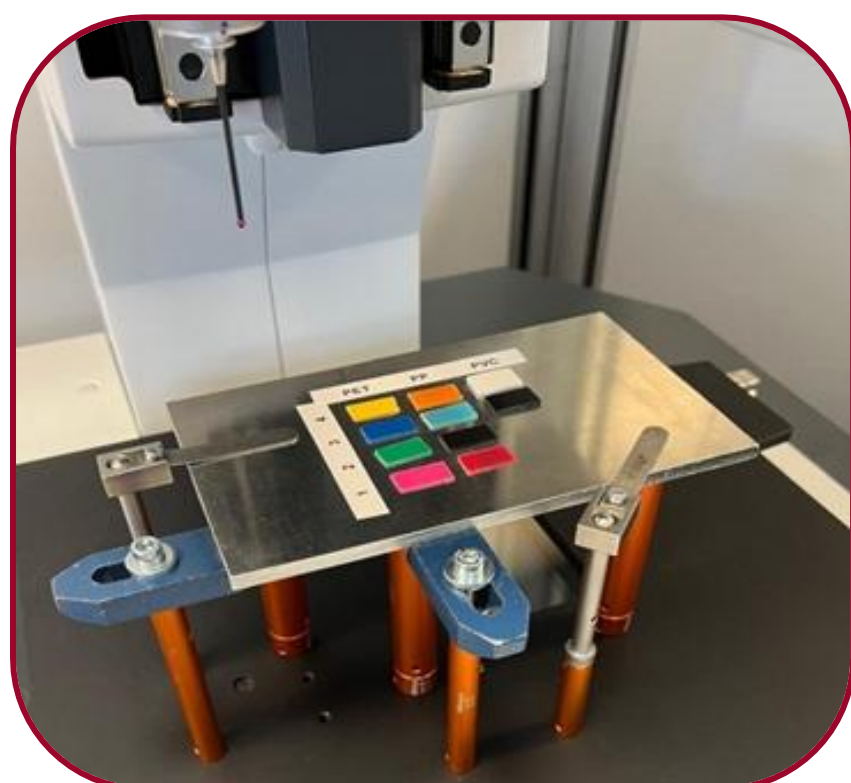
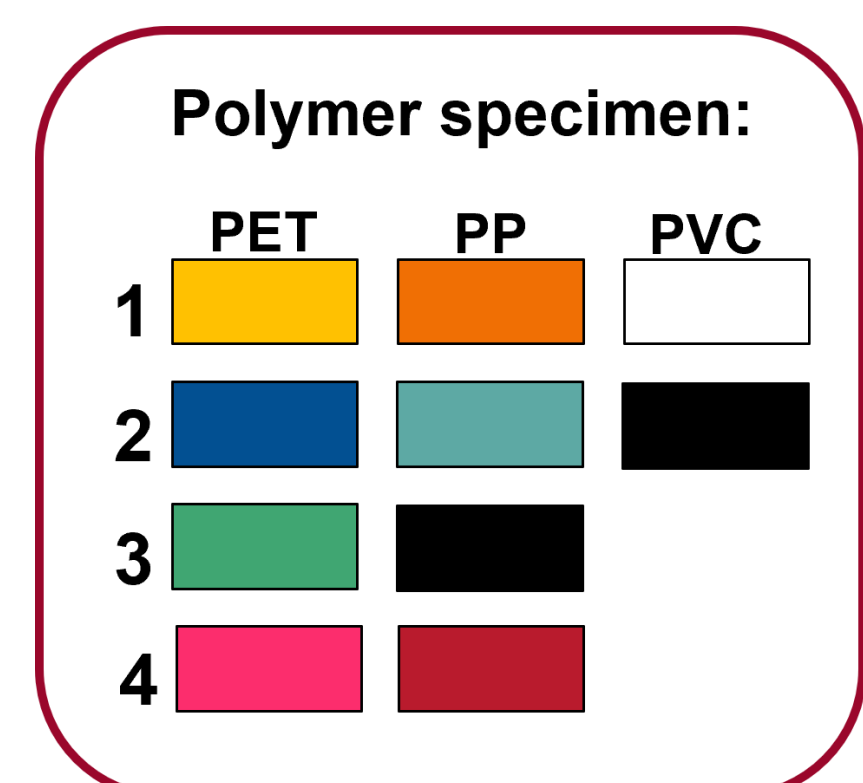
### a) Study of the sensor's limit angle of acquisition and influence of material properties:

- Three calibrated spheres were tested:
- Two ceramic ( $\varnothing$  25 mm): matte and glossy finish
  - One metallic ( $\varnothing$  30 mm): glossy finish
- Results were compared with tactile reference, and the limit value  $\alpha_L$  (i.e. the acquisition angle at which the optical sensor error exceeds the maximum permissible error (MPE) of the instrument) was calculated.



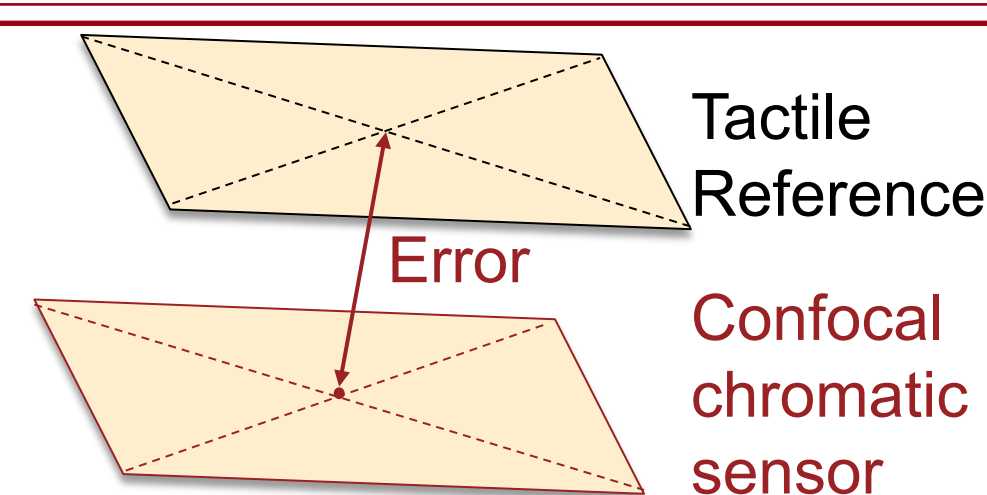
**Fig. 2.** Schematic representation of the measurement strategy and of the three reference spheres employed.

### b) Determination of the material colour influence:



**Fig. 3.** Representation of the polymeric test sample with multiple colors and materials

- Plate with different polymeric inserts (PP, PVC, PET) was measured.
- Both achromatic and chromatic colours were investigated.



**Fig. 4.** Schematic representation of the measurement strategy. Error defined as the difference between the coordinates of the least-squares planes created on the tactile and optical measurements, respectively.

### c) Determination of the surface roughness influence:

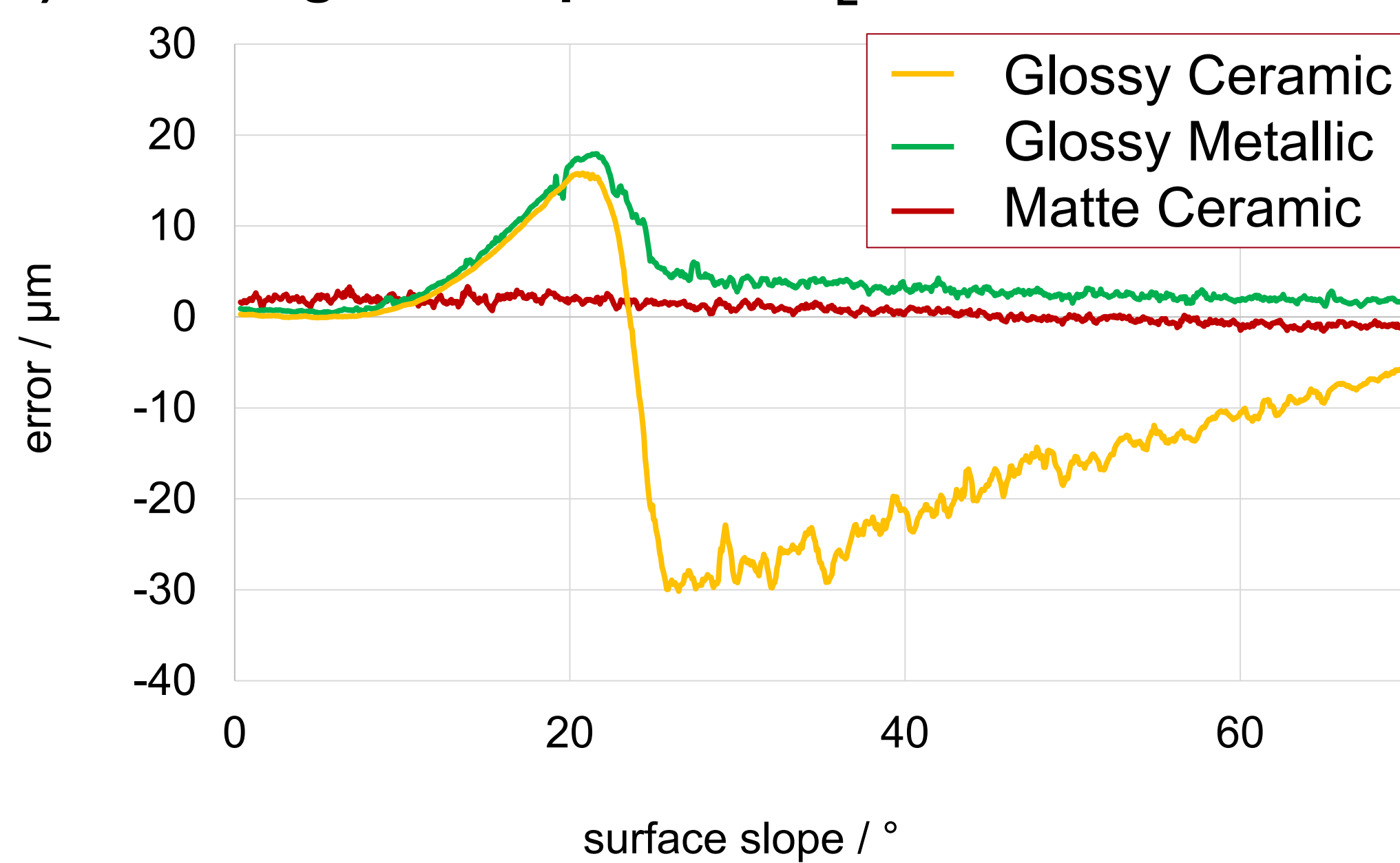


**Fig. 5.** Roughness test specimens with different machining and range of surface roughness levels

- Roughness specimens made of different machining processes (i.e. polishing, grinding, milling, spark erosion).
- 29 test surfaces were investigated with Ra ranging from 0.0125 to 50  $\mu\text{m}$ .

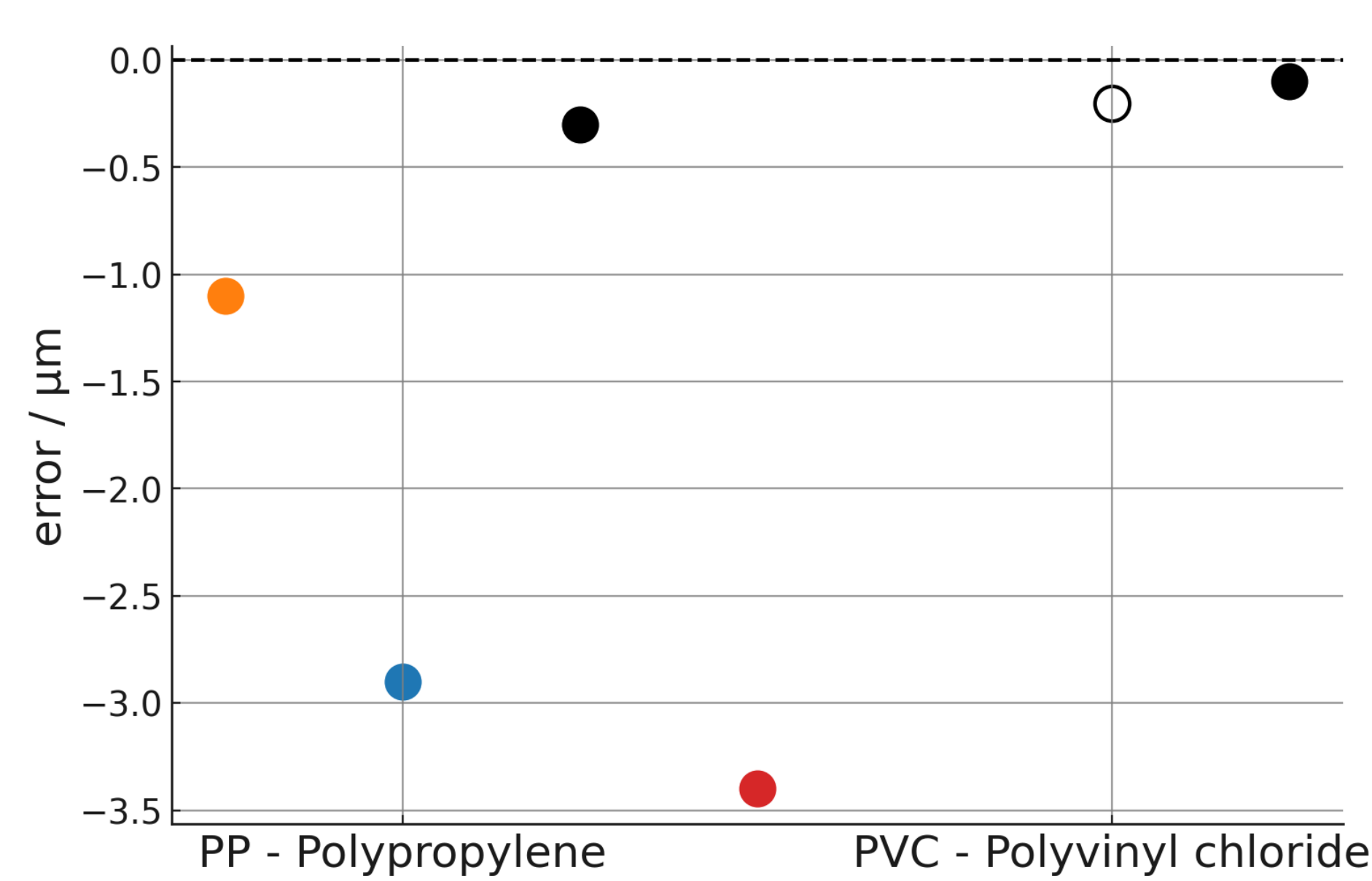
## Results

### a) Limit angle of acquisition $\alpha_L$



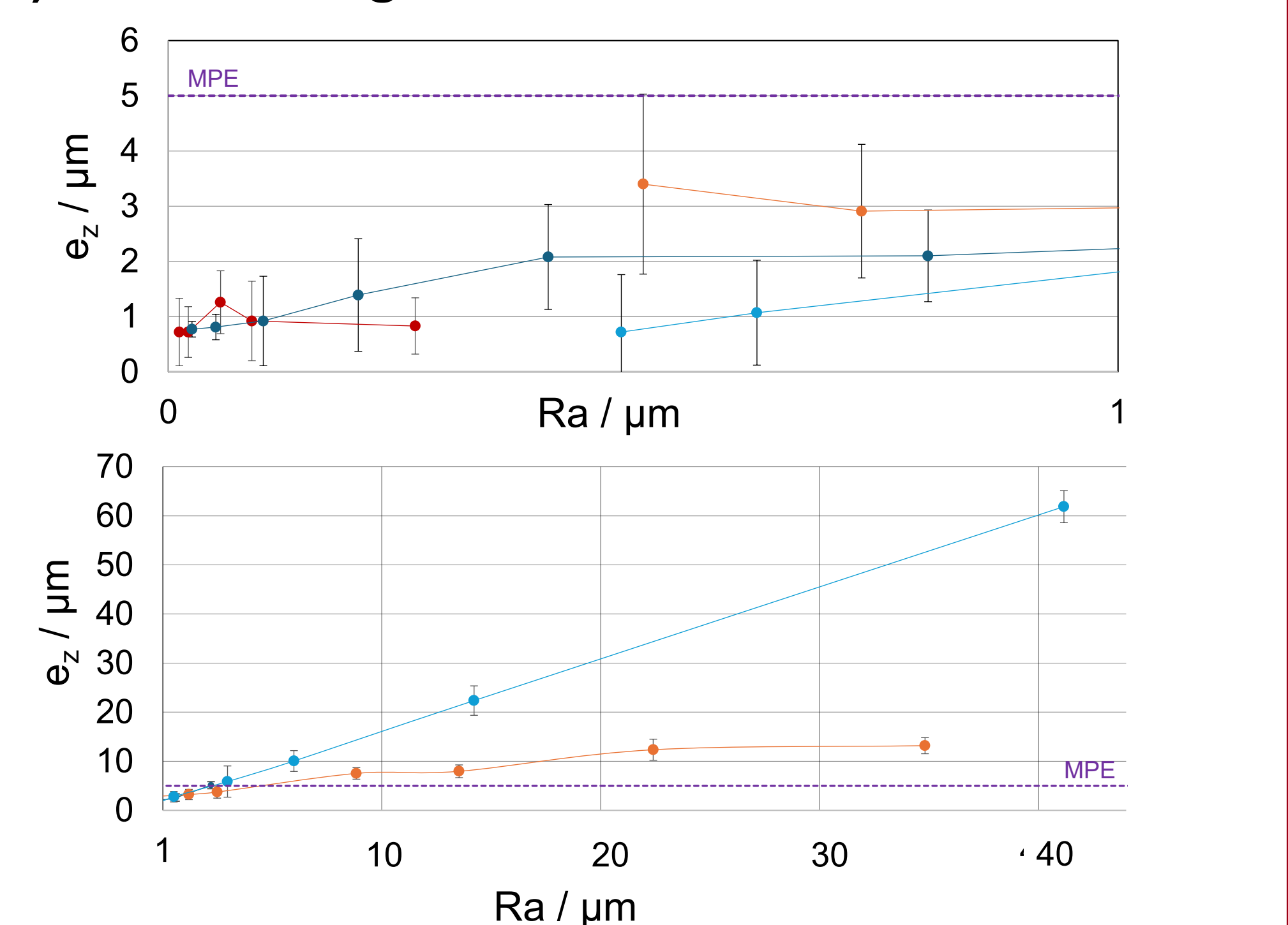
- Matte surface: stable sensor's performance within specifications up to  $\alpha_L \approx 70^\circ$ . No critical issues occurs.
- Glossy materials: for both ceramic and metallic surfaces the limit angle  $\alpha_L \approx 13^\circ$ . For higher  $\alpha$ , measurement error is higher than the MPE.

### b) Material colour influence



- In achromatic surfaces, a sub-micron measurement error is observed.
- Chromatic surfaces exhibit measurement errors in the order of a few microns.

### c) Surface roughness influence



- The higher the roughness value, the higher the measurement error.

## Conclusions

- **Measurement accuracy is significantly influenced by surface properties and characteristics**, highlighting the **importance of understanding sensor-surface interactions** to potentially model or compensate for systematic deviations.
- Future work will address the uncertainty assessment and explore the integration of the findings into digital twins and virtual CMM models to enable predictive and more reliable measurements.

### Acknowledgements

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