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Infrared thermography of thermal spray coating processes as quality monitoring tool

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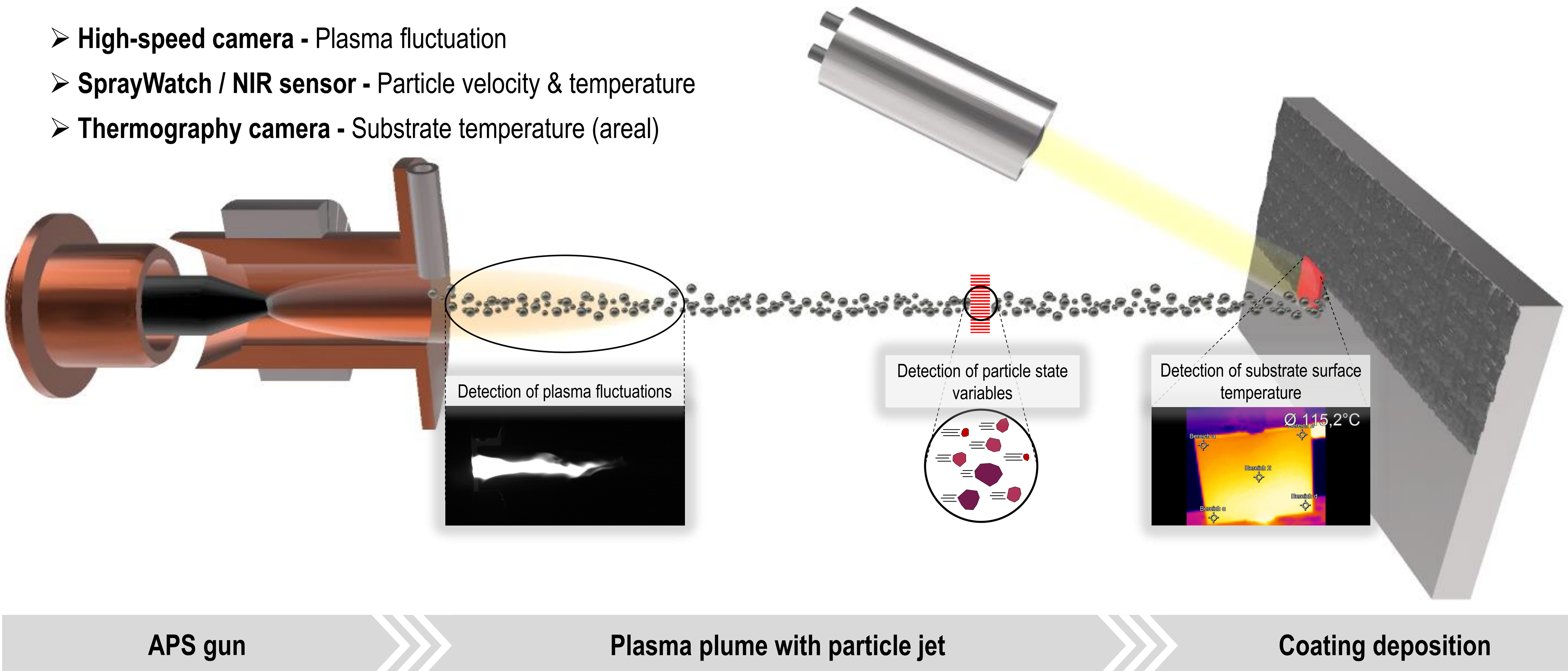
abstract

The evolution of substrate surface temperature during coating deposition is a decisive property-determining factor in thermal spraying. Local heat development is influenced by various factors such as thermal conductivity and substrate thickness. High fluctuations in surface temperatures promote the formation of residual stresses in the coating layers during cooling. Therefore, the risk of oxidation, cracking, or delamination increases. Moreover, limiting the surface temperature appears beneficial for quality assurance. Infrared (IR) thermography offers the possibility to determine the surface temperature in the coating process without contact. Determining factors in temperature evolution during the thermal spray process were identified. The interaction between the substrate and coating material was taken into account. Furthermore, application limits for IR thermography (Optris XI80) in comparison to thermocouple measurements for the temperature range of 0–250 °C were determined. For this purpose, the stainless steel AISI 316L was coated on aluminum and steel sheets by atmospheric plasma spraying (APS).

methods

Diagnostic tools for process monitoring of the thermal spray process

- **High-speed camera -** Plasma fluctuation
- **SprayWatch / NIR sensor -** Particle velocity & temperature
- **Thermography camera -** Substrate temperature (areal)



Thermography of the substrate temperature

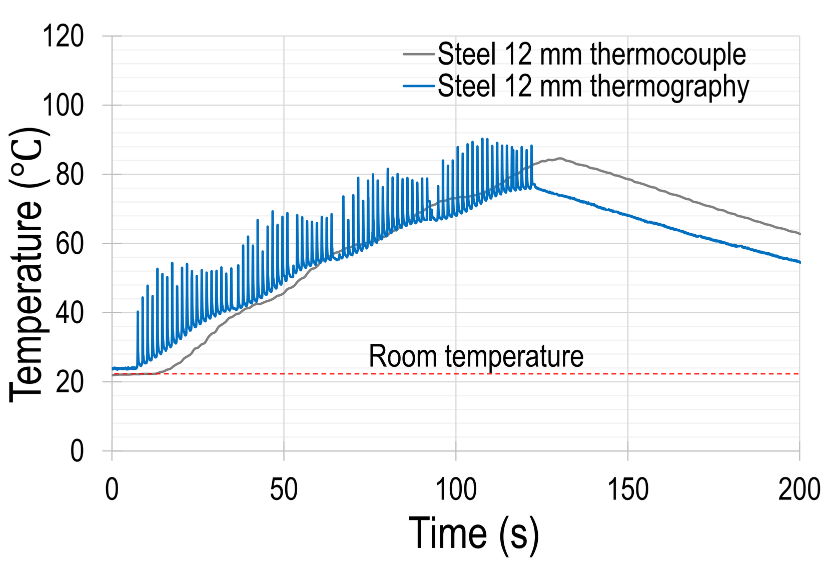
Possible Benefits

- Captures **substrate influence** (previously neglected)
- Considers **material type** and **thickness** (thermophysical properties)
- Enables **thermal history tracking**, **online monitoring**, and **process control**
- Provides **local temperature distribution** (identifies hot spots)
- Allows **process visualization** – did the spray process perform correctly?
- Detects **delamination risks** early (thermal anomalies)
- Supports understanding of **local properties**, e.g., **corrosion behavior**

Currently not common practice in industry – …yet highly promising!

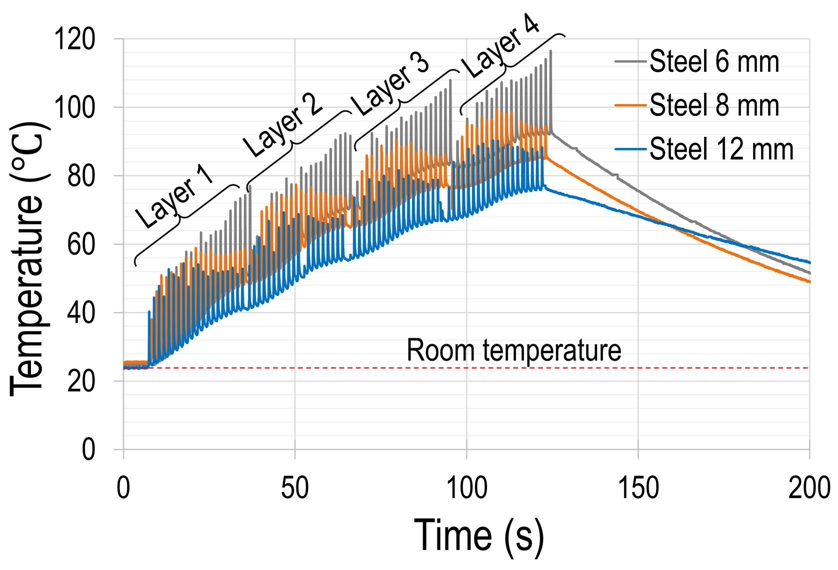
results

Thermography vs. Thermocouple



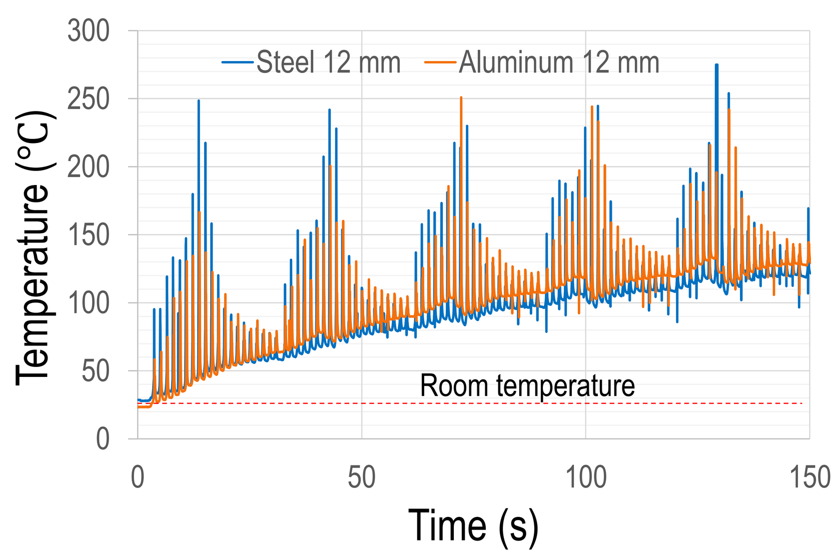
>> only heat input via plasma plume – no particles fed <<

Substrate thickness

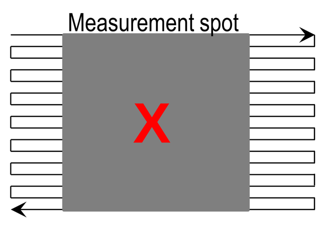


>> only heat input via plasma plume – no particles fed <<

Material type

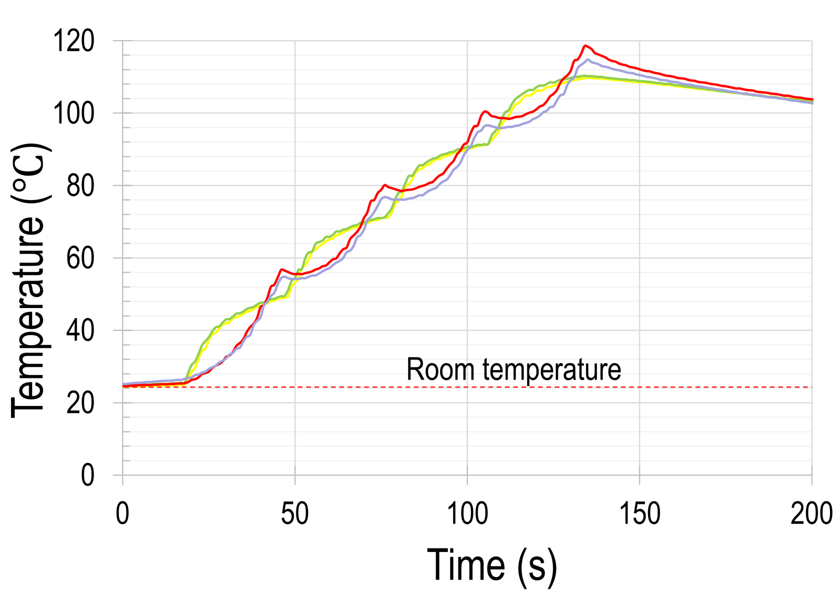


>> heat input via plasma plume and spray particles <<

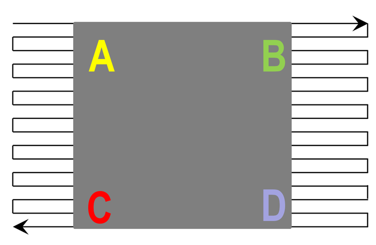


- Thermography: **precise, full-field surface data**
- Thermocouples: **slower response**, limited surface insight
- Thinner substrates: **highest temp rise & cooling rate**
- **Heat accumulation** with multiple passes
- **Aluminum** show **higher heating** due to lower volumetric heat capacity **than steel**

Positional influence

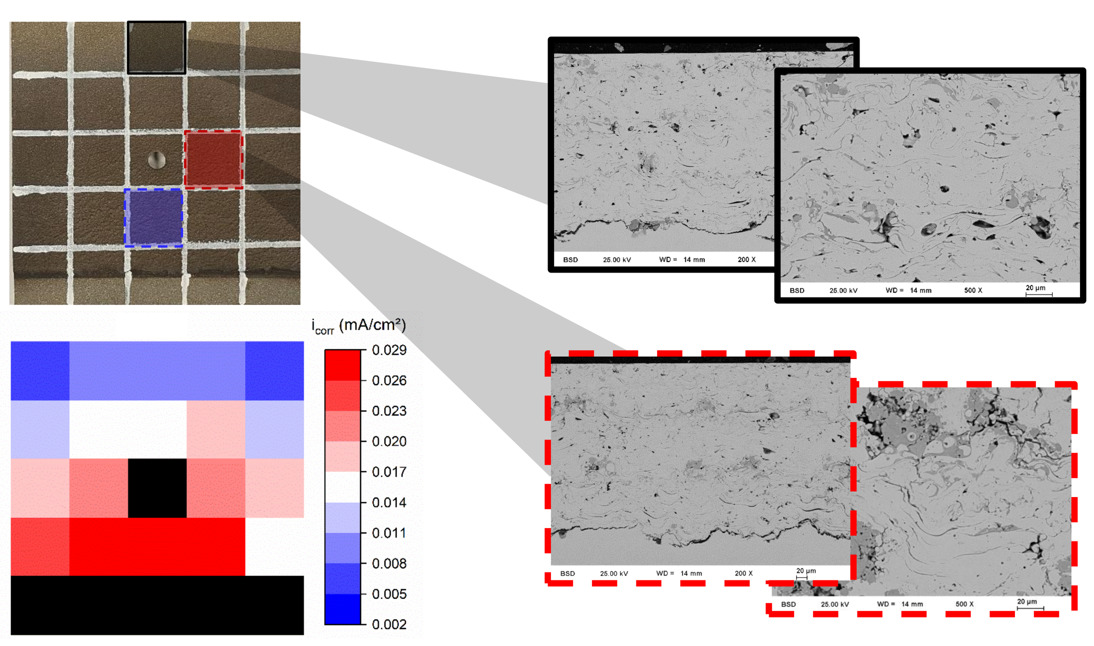


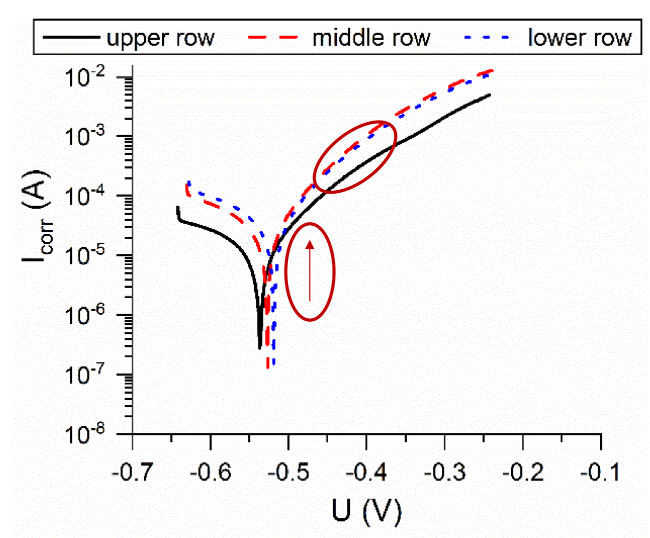
>> only heat input via plasma plume – no particles fed <<



- **Thermal spreads** within the substrate surface
- **Preheating** effect for areas coated later
- **Peak temperature** at the end point of spraying

Local properties - Corrosion resistance





- Oxide formation in high-temperature zones
- Reduced corrosion resistance

summary

The influence of substrate thickness was evaluated. A correlation between the temperature history during the coating process and the corrosion properties was established. Current density measurements using gel electrolytes were used for this purpose. Clear correlations between the development of the surface temperature and the resulting coating properties were derived.