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Hydrophobic and hydrophilic silica shells on metal nanoparticles via plasma-enhanced in-flight coating process

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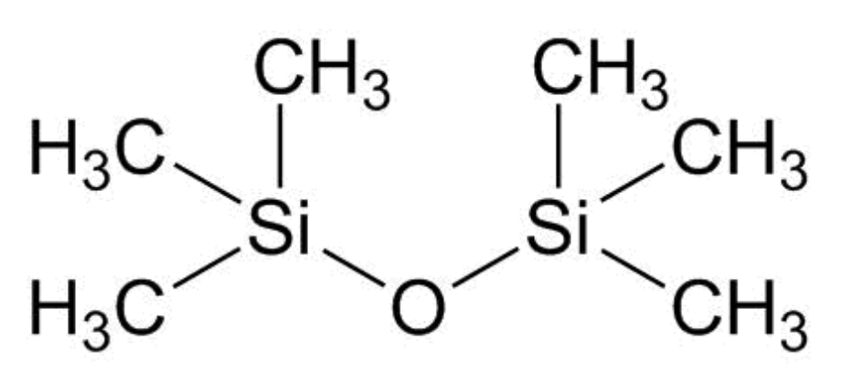
Introduction

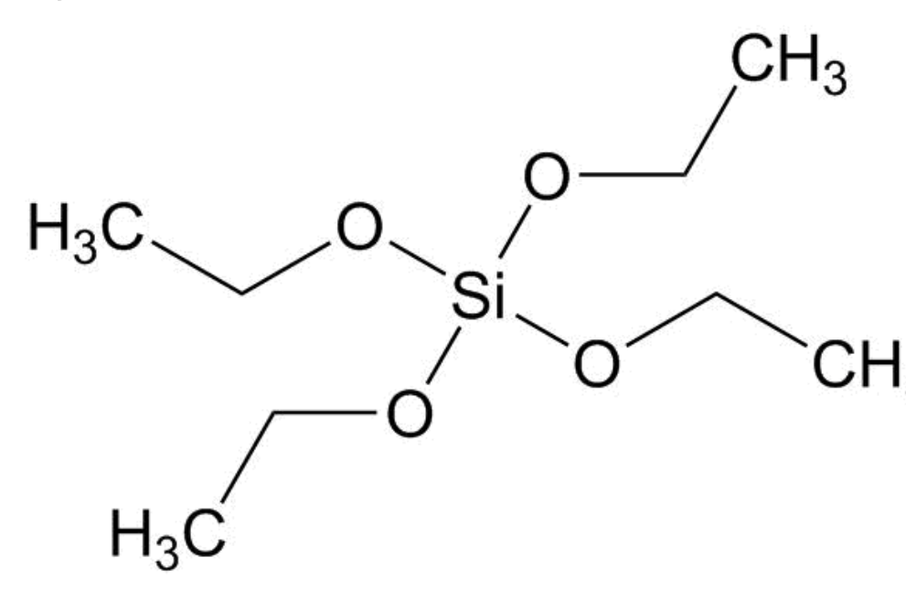
Coated nanoparticles have a wide variety of applications in modern material science because of their interesting properties. TiO_2-nanoparticles for example are used in sunscreen, because of their photocatalytic activity. The goal of this work is to produce silica shells with metal and TiO_2 as core-materials for a targeted creation of hydrophilic and hydrophobic layers. SiO_2 is the here desired shell material because of its chemical inertness and optical transparency. This is archived with a modified method of an in flight plasma-enhanced-chemical-vapor-deposition (PECVD) using a non-thermal dielectric barrier discharge. Tetryethyl orthosilicate (TEOS) and hexamethyldisiloxane (HMDSO) were used as precursors. The coated particles are studied via x-ray photoelectron spectroscopy (XPS). Results show a hydrophilic silica-organic material on platinum using HMDSO, while the deposition of TEOS on TiO_2 results in a hydrophobic, inorganic silica shell.

Precursors

Hexamethyldisiloxane (HMDSO)



Tetryethyl orthosilicate (TEOS)



Experimental setup

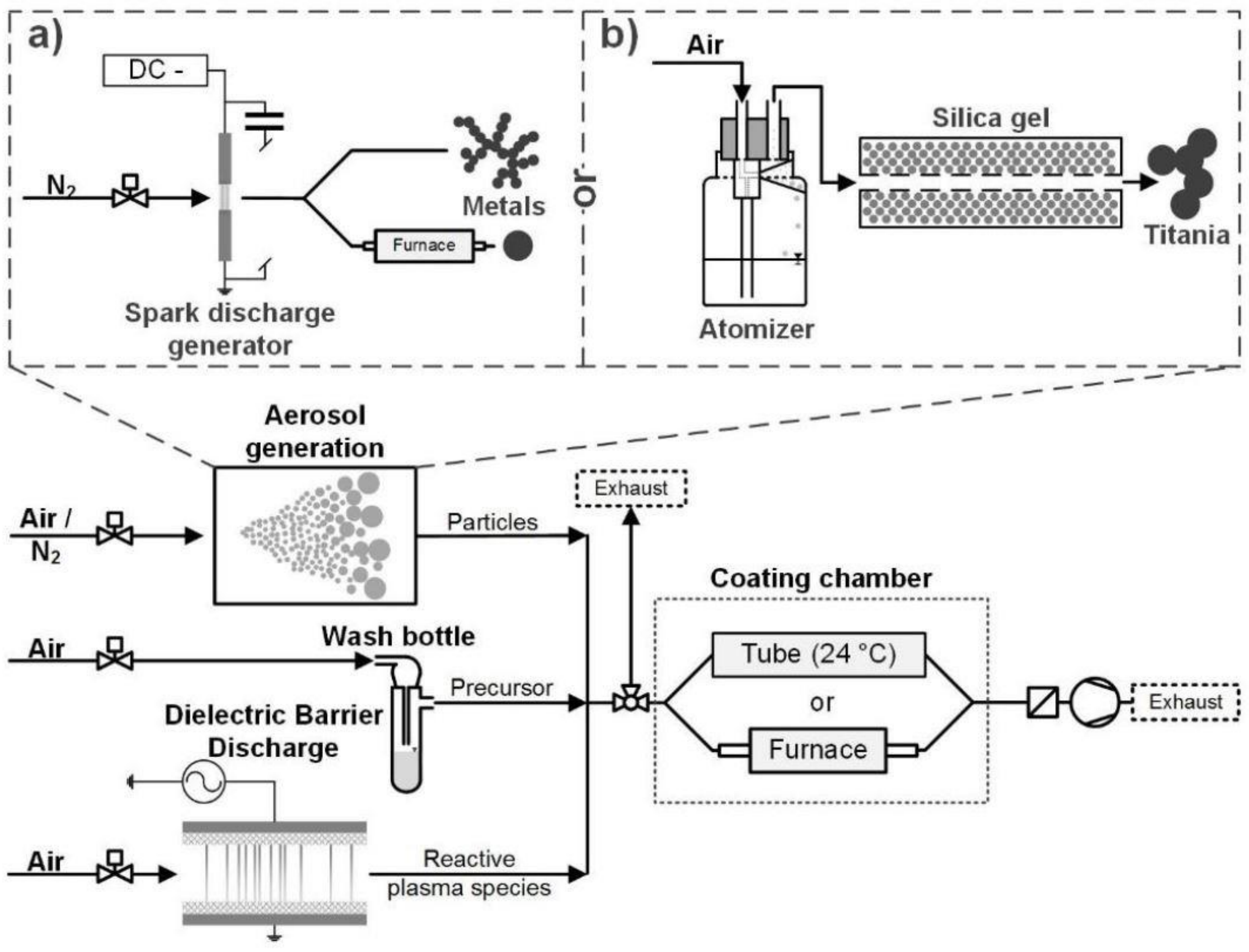


Fig. 2: Experimental setup of the plasma-enhanced in-Flight coating process [1]

- ❖ Nanoparticle production and coating in the gas phase as continuous aerosol process
- ❖ Different aerosol generators: a) Spark discharge generator (SDG) for metal particles; b) Atomizer for titania particles
- ❖ Precursor in a wash bottle with gas inlet and outlet
- ❖ Reaction occurs in post-discharge environment via reactive plasma species
- ❖ Ambient pressure and variable temperature (up to about 300°C) of the post-discharge species

Summary

- ❖ TEOS and HMDSO were used to coat titania and metal nanoparticles
- ❖ An in-flight process utilizes an aerosol mixture of precursor, nanoparticles and reactive plasma species
- ❖ The coated particles show different carbon compounds a different wettability depending on the precursor proven via XPS

Results of XPS-Analysis

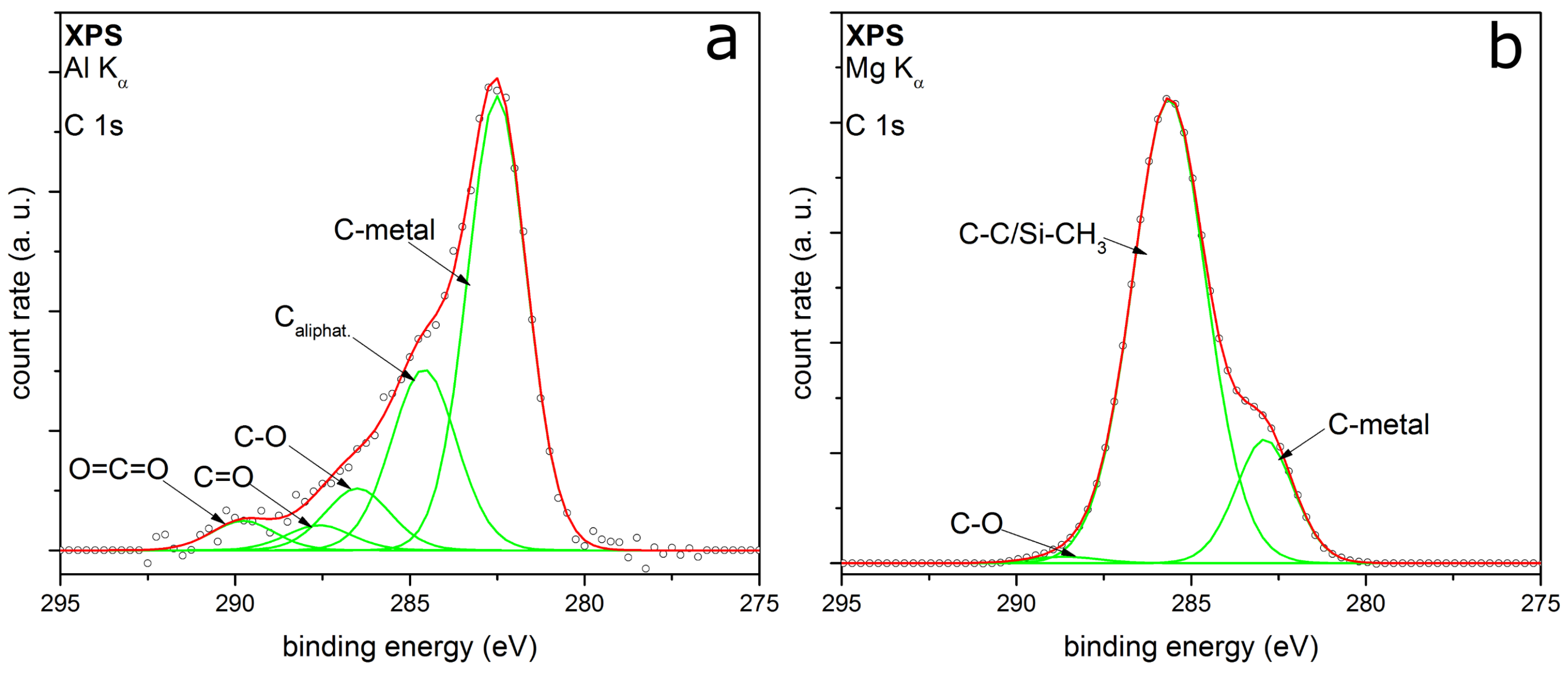


Fig. 1: C1s detail spectra of the coated nanoparticles: (a) titania with TEOS; (b) Pt with HMDSO [1]

❖ Peak-ratio (a) : (b) = 1 : 5,5

(a)
- ❖ Metal-C-peak is due to sample holder
- ❖ The C 1s-peak shows only the organic by-products of TEOS
- ➢ by-products can easily be removed in UHV

- ❖ Aliph. carbon chains bound to oxygen
- ❖ No Si-C-component, which indicates the bonding of silicon directly to oxygen ⇒ SiO_2

- ➢ **Hydrophilic behaviour**

(b)
- ❖ Remnants form short carbon chains
- ❖ In comparision to (a), by-products are not easily removed in UHV
- ➢ HMDSO not to reacts completely to SiO_2

- ❖ Si-CH_3-component indicates the presence of a silicon based organopolymer

- ➢ **Hydrophobic behaviour**

Wettability

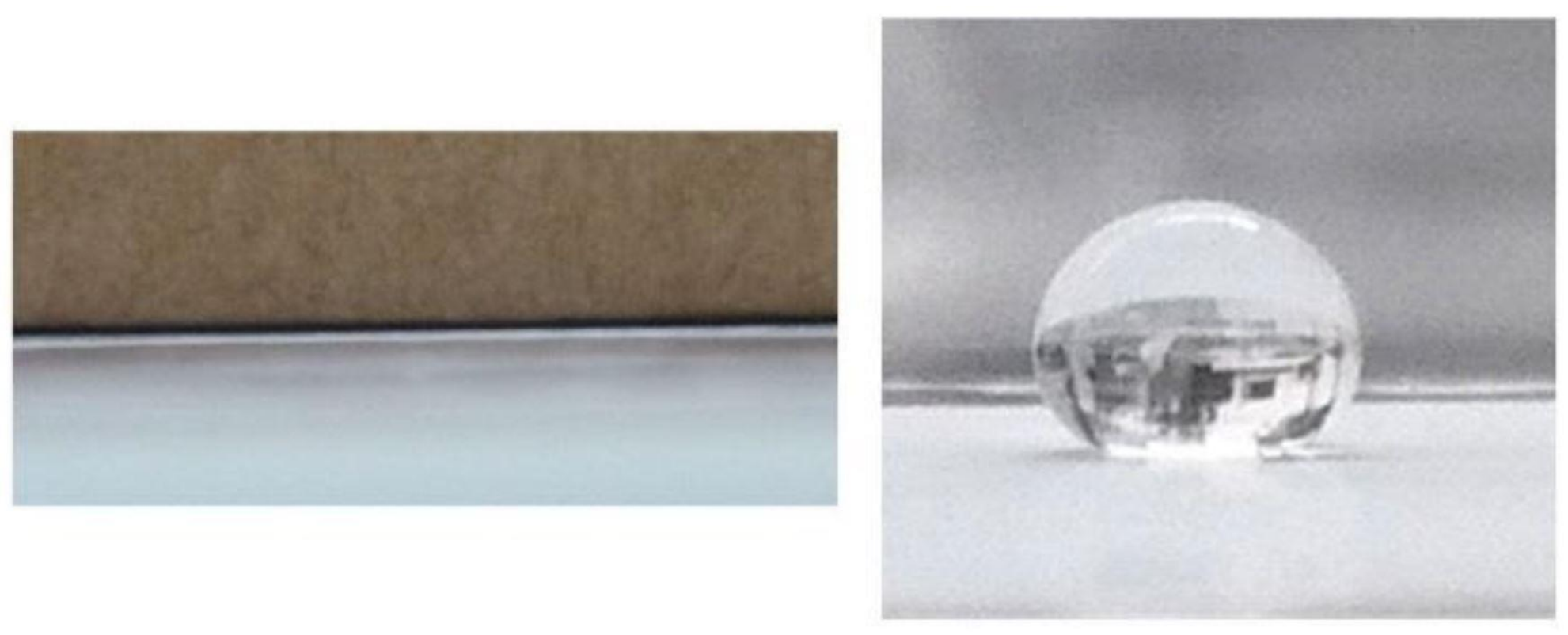


Fig. 3: Water droplet on uncoated (left) and via HMDSO coated titania particles (right) demonstrating the reduced wettability [1]

References

[1] P. Post, L. Wurlitzer, W. Maus-Friedrichs und A. Weber, „Characterization and Applications of Nanopatricles Modified in-Flight with Silica or Silica-Organic Coatings", Nanomaterials 8 (2018) 10.3390/nano8070530.

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