Pendant drop technique for the characterization of homogeneous and Janus gold 2-nm nanoparticles.

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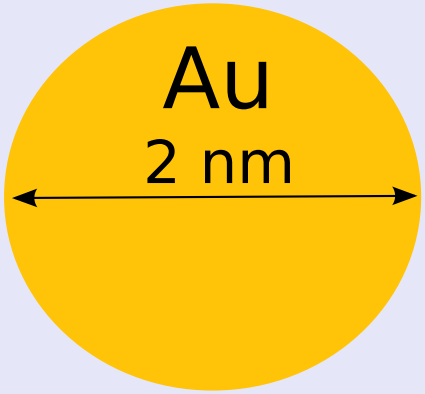
Janus particles

January is named after Janus, facing the past and the future.

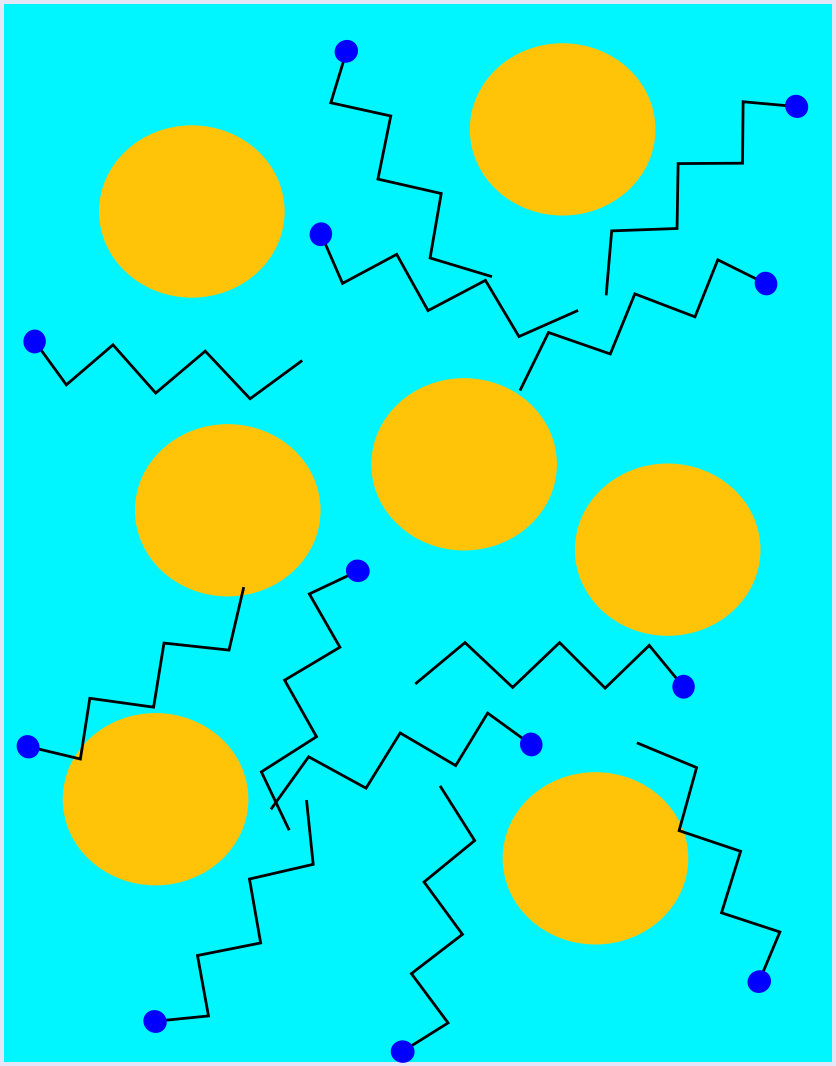
Homogeneous and Janus particle synthesis

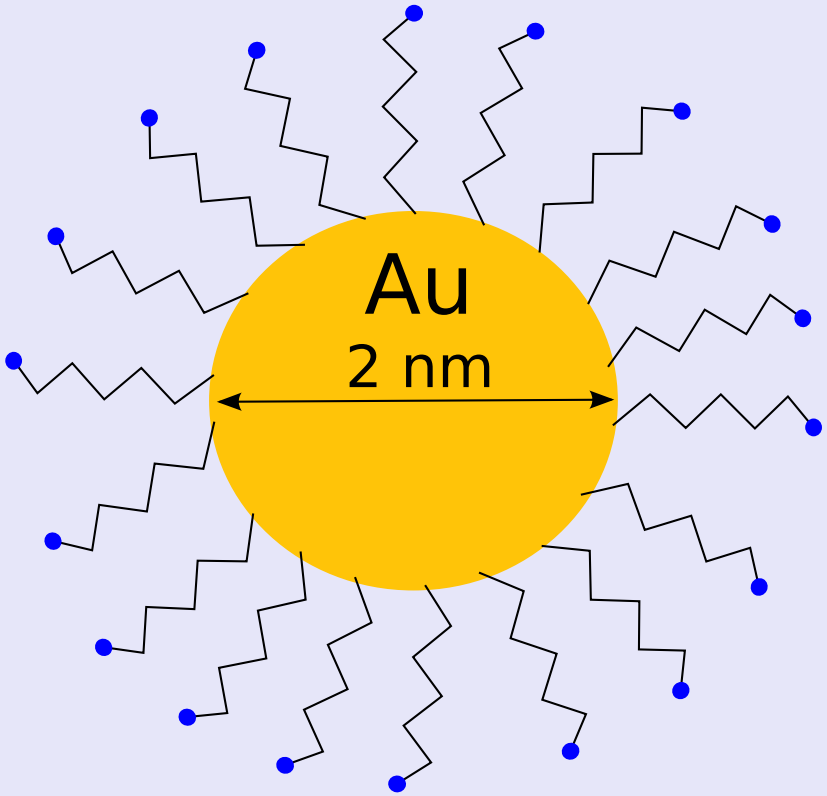
[Pradhan et al., 2007, Adv. Funct. Mater.]
[Pradhan et al., 2009, J. Nanopart. Res.]



- Hexanethiol [-CH_3 terminal group].
- 2-(2-mercapto-ethoxy)ethanol (MEA) [-OH terminal group].

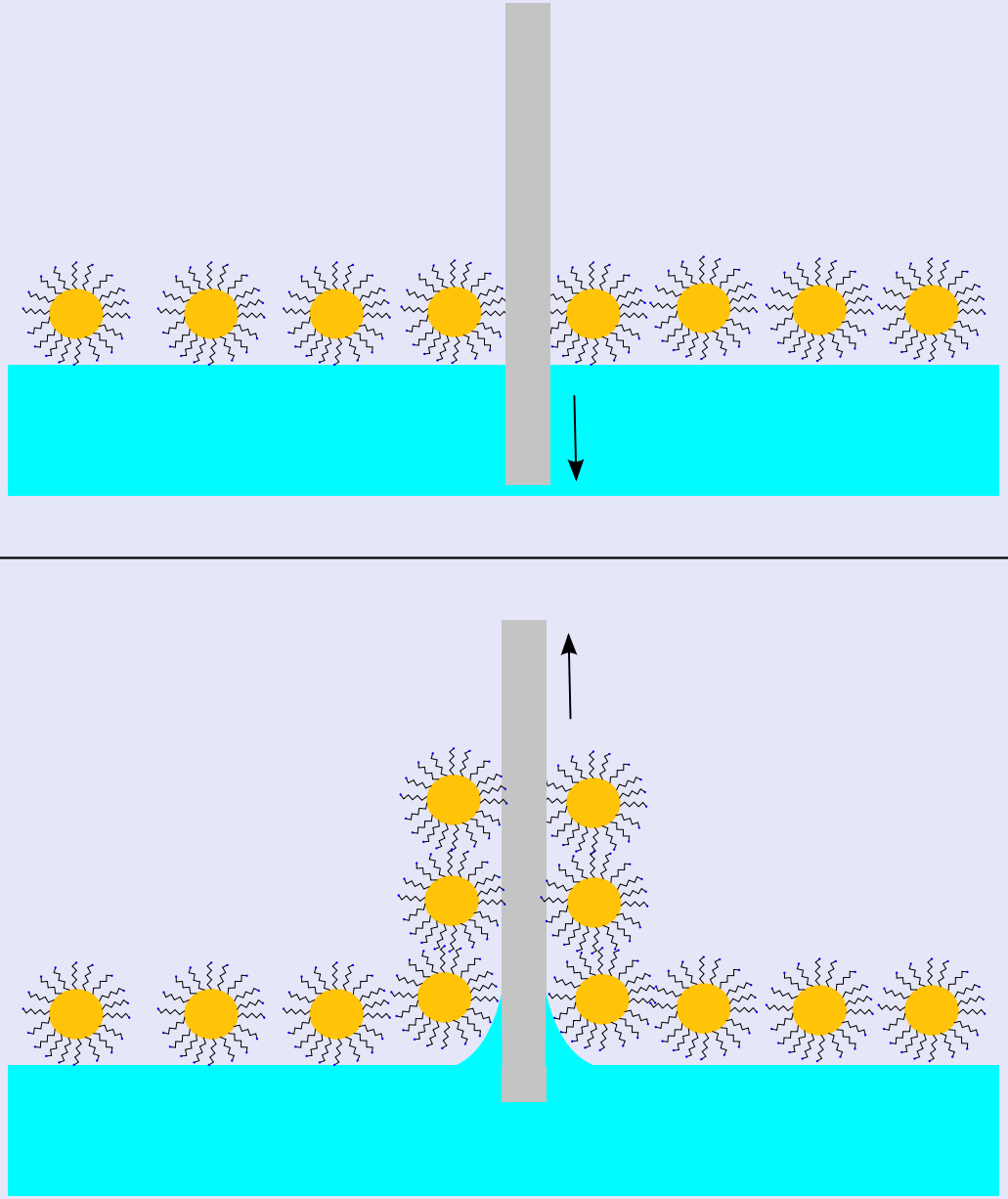
Homogeneous particles (HPs)



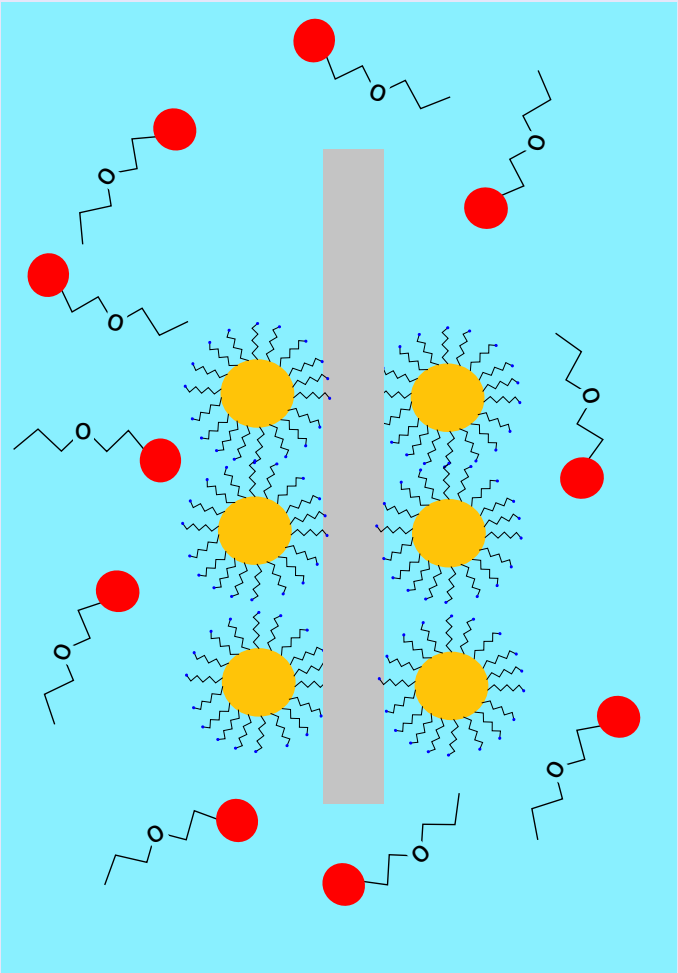


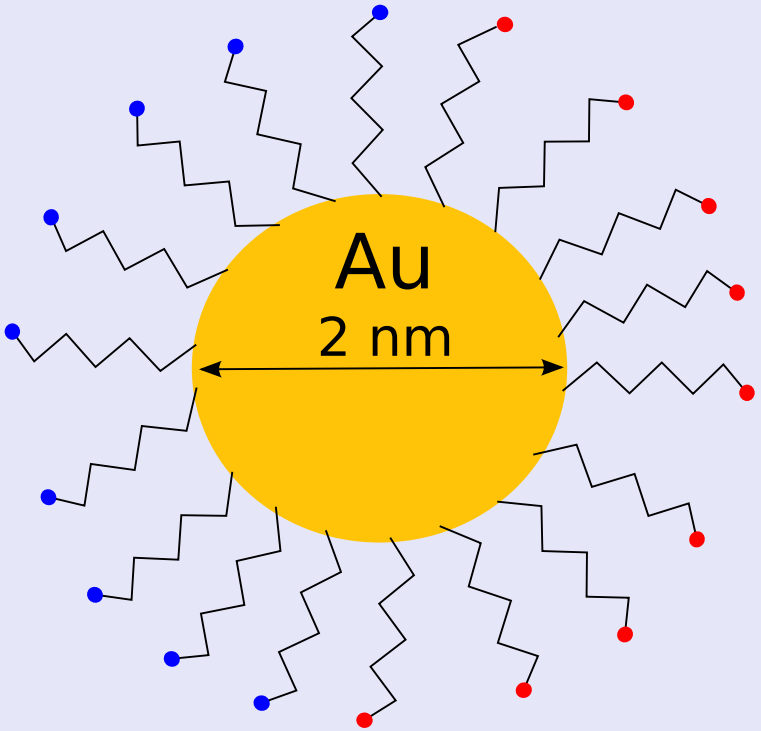
Hexanethiol functionalization of gold nanoparticles.

Langmuir balance deposition on solid substrate



Janus particles (JPs)

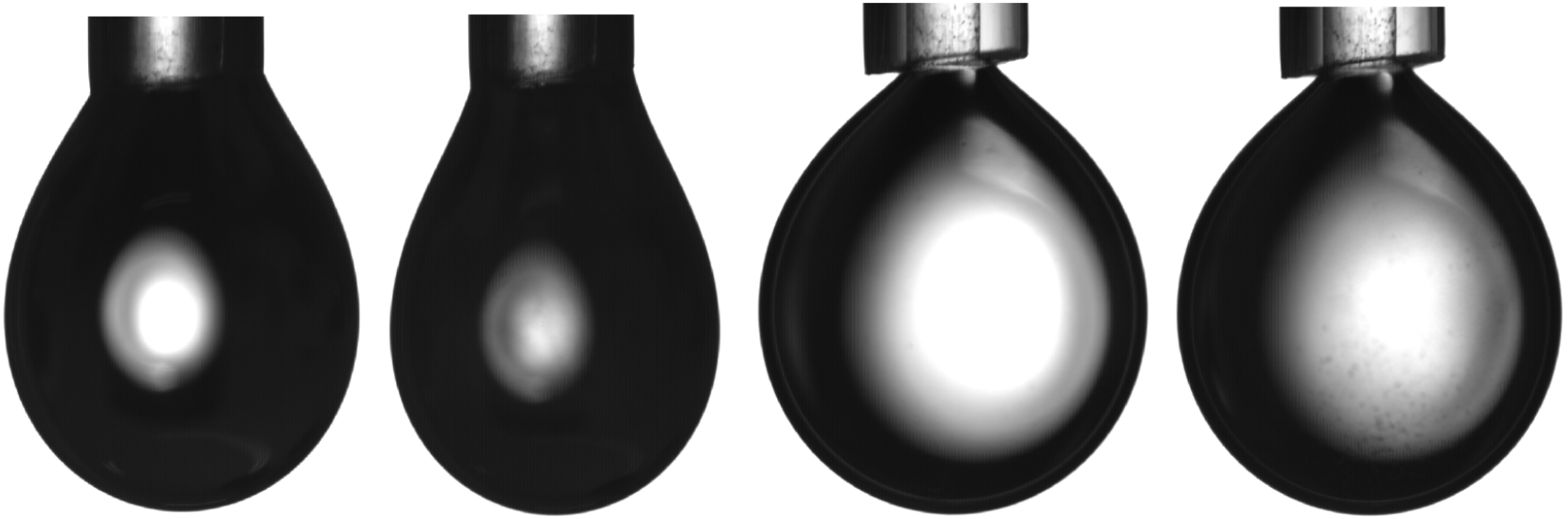




- MEA functionalization.
- Low quantities of JPs synthesized by this method.
- Reported values of contact angle for solids covered with these particles: $\sim 48.5\,^{\circ}$ for the hexanethiol face and $58.5\,^{\circ}$ for the MEA face.

Pendant drop

- Low quantities of JPs, insufficient for traditional Langmuir balance experiments and even for adsorption from the pendant drop bulk → Direct deposition.
- Measure of the interfacial properties by growing and shrinking pendant drop volume of MilliQ water (ADSA-P) [Montes Ruiz-Cabello et al., 2011, J. Adhes. Sci. Technol.].

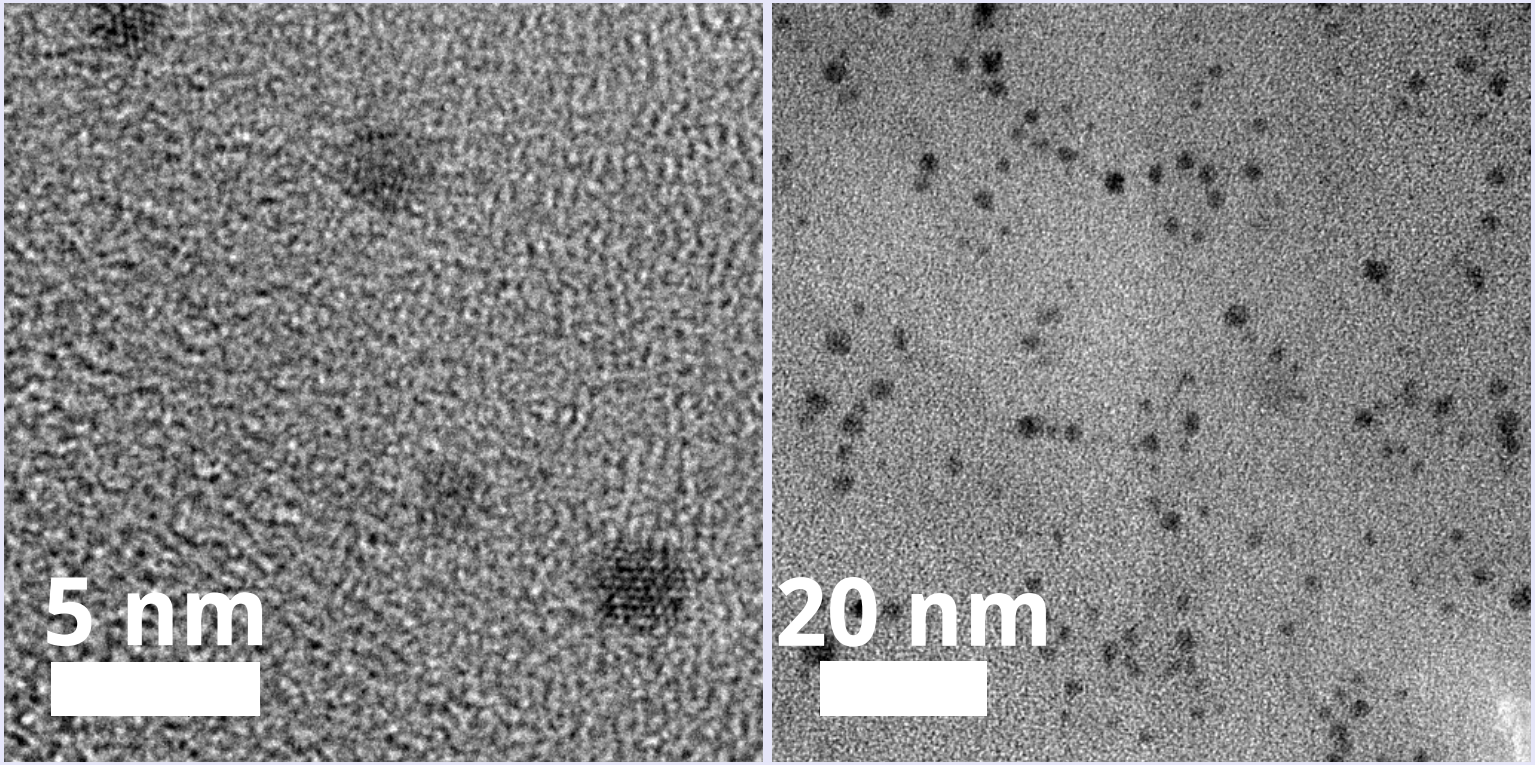


(a) $1.7{\cdot}10^{12}$ JPs in water/air (b) $17{\cdot}10^{12}$ JPs in water/air (c) $1.7{\cdot}10^{12}$ JPs in water/decane (d) $17{\cdot}10^{12}$ JPs in water/decane

Pendant drops with different particle concentration. The pendant drop volumes are 20 μl and 30 μl for the water/air and water/decane interfaces, respectively.

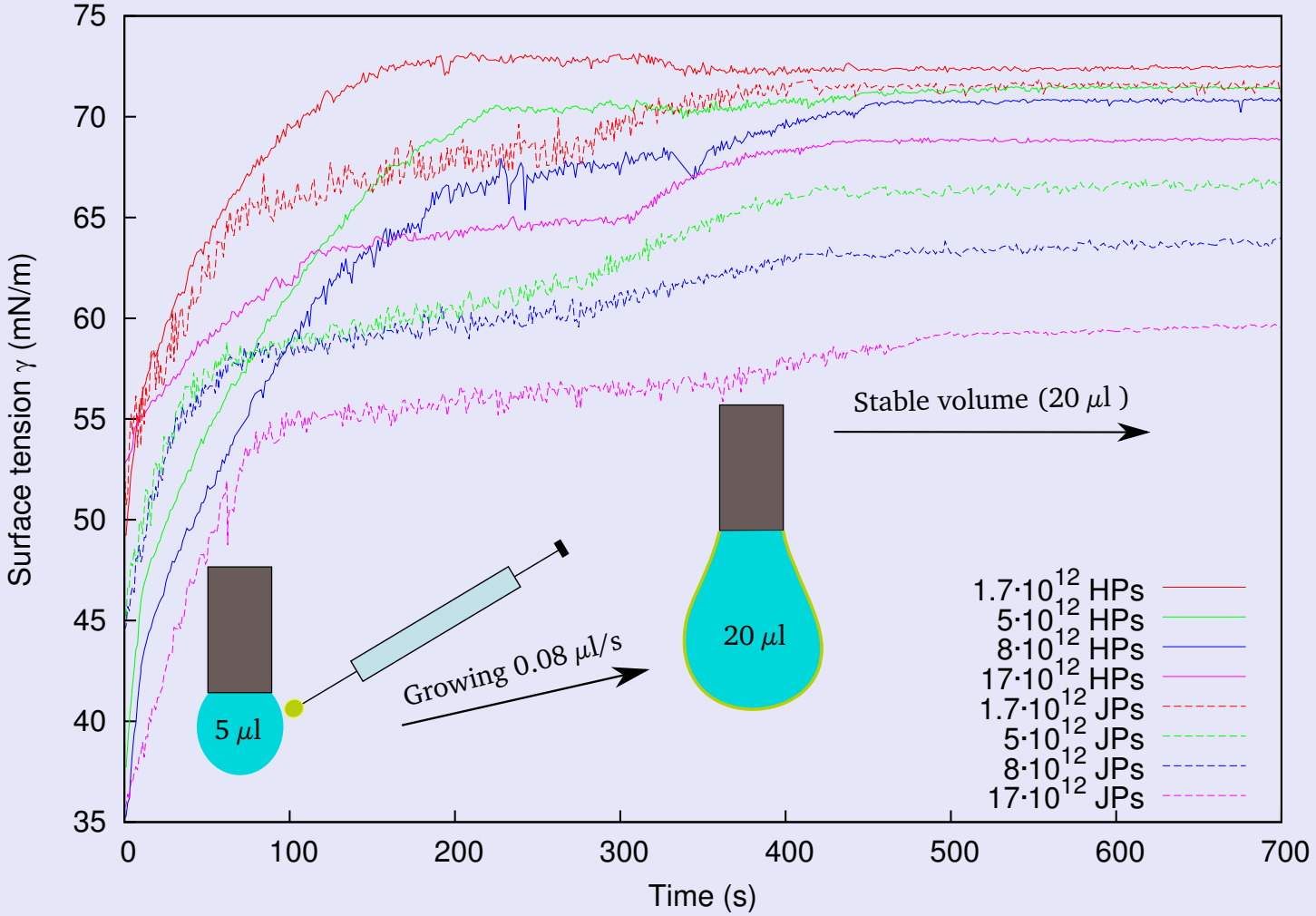
Nanoparticle characterization

- Electrophoretic mobility measured in $10^{-2}\,M$ sodium citrate MilliQ water solution: $\mu_{e,HP} = (-1.1 \pm 0.7)\,\mu m \cdot cm/(V \cdot s)$ and $\mu_{e,JP} = (-3.2 \pm 0.6)\,\mu m \cdot cm/(V \cdot s)$.
- HRTEM.



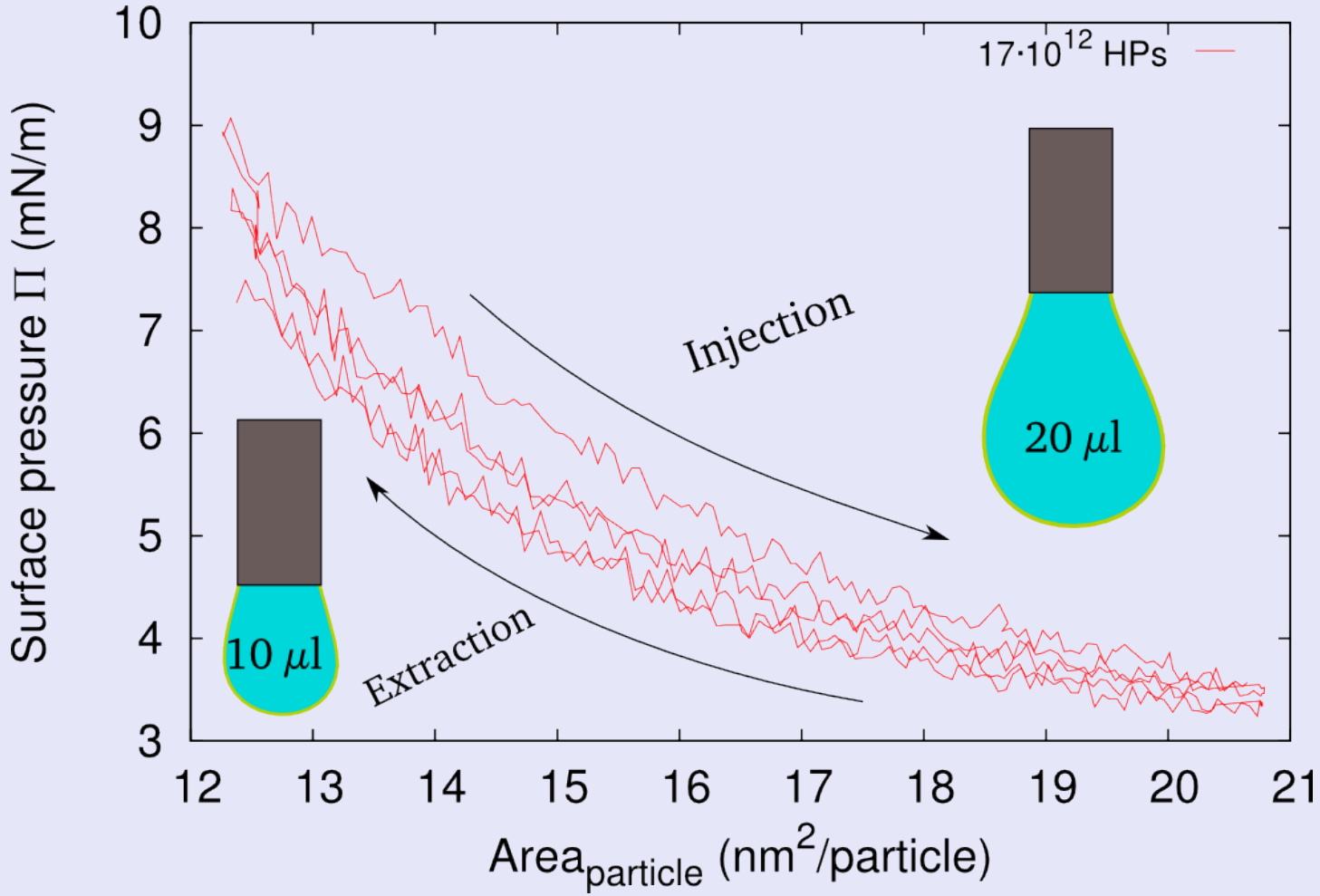
The particle size distribution of the JPs was determined by transmission electron microscopy: $3.5 \pm 0.9\,nm$.

Surface tension evolution for different JPs concentrations.



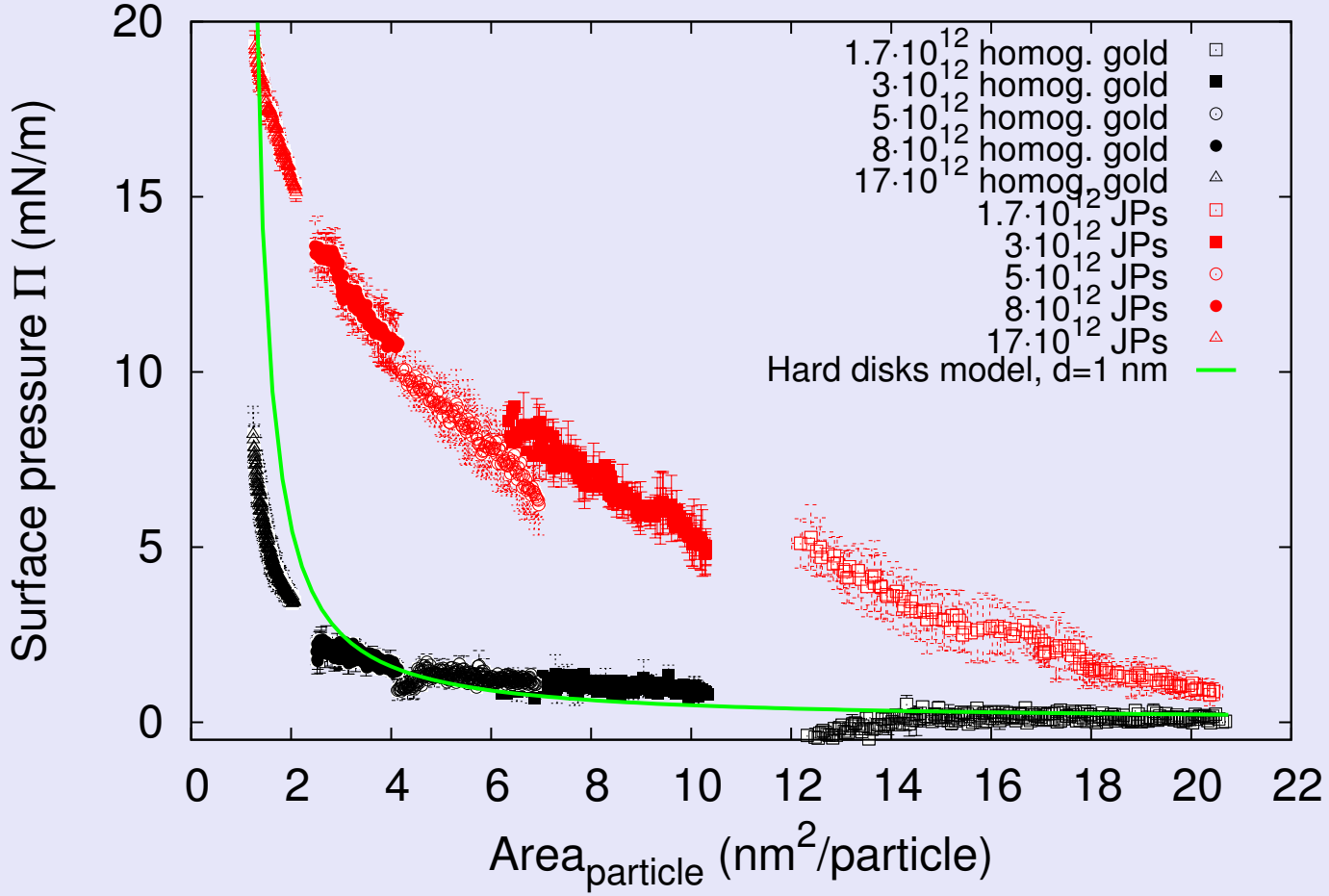
Surface tension evolution after different numbers of JPs and HPs deposited at the MilliQ water-air pendant drop interfaces. The surface tension remained stable when the spreading solvent (tetrahydrofuran) was fully evaporated.

Pendant drop growing and shrinking experiments.



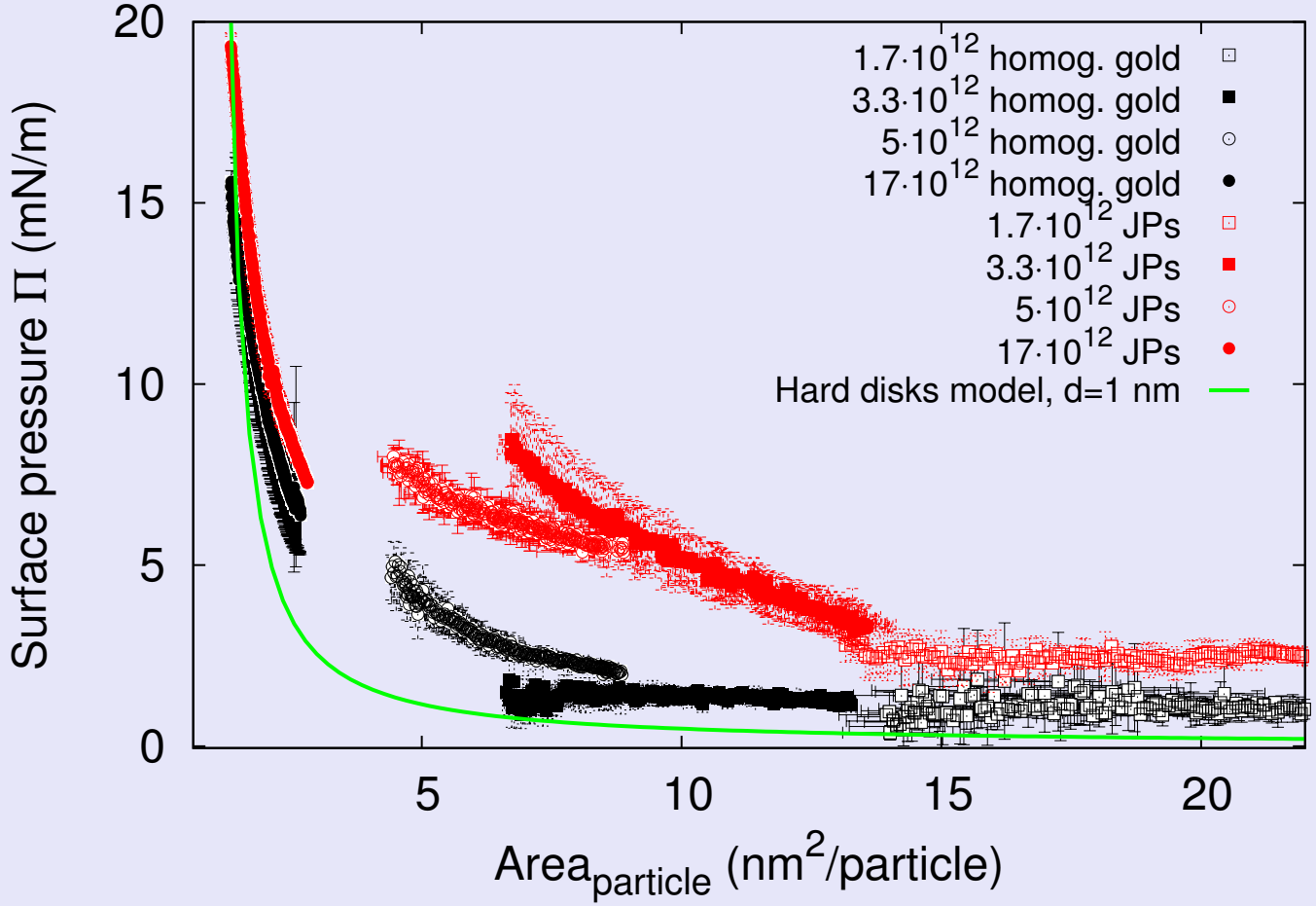
Pendant drop growing and shrinking experiment diagram for a water/decane interface with JPs deposited at the interface (and after fully evaporation of the spreading solvent).

Growing and shrinking experiments: water/air interface



- $$\Pi(A_{particle}) = \frac{k_B \cdot T}{A_{particle} \cdot \left(1 - \frac{\pi \cdot d^2}{4 \cdot A_{particle}}\right)^2}.$$

Pendant drop growing and shrinking experiments: water/decane interface



- $$\Pi(A_{particle}) = \frac{k_B \cdot T}{A_{particle} \cdot \left(1 - \frac{\pi \cdot d^2}{4 \cdot A_{particle}}\right)^2}.$$

Conclusions

- We have characterized the size and charge of homogeneous 2-nm gold nanoparticles (capped with hexanethiol) and Janus 2-nm gold nanoparticles (capped half with hexanethiol and half with MEA) by electrophoretic mobility measurement and TEM.
- We used the pendant drop tensiometer with direct deposition of the nanoparticles at the interface, requering low quantity of nanoparticles.
- We have explored and compared the interfacial activity of both nanoparticles using the pendant drop growing and shrinking technique.
- We performed pendant drop experiments in water/air and water/decane interfaces for different nanoparticle concentrations, pointing out a compression isotherm.
- The hard disk model reasonably fitted the HPs results and underestimated the JPs results. Possibly because it neglects the interactions between the Janus nanoparticles.

Thank you

Thank you for your attention.

Acknowledgements

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