

Supporting Information

Synthesis of Highly Uniform and Composition Controlled Gold-Palladium Supported Nanoparticles by Continuous Flow

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Figure S1: Principle of operation of the I-shape connector geometry, which was found to be optimal in this work.

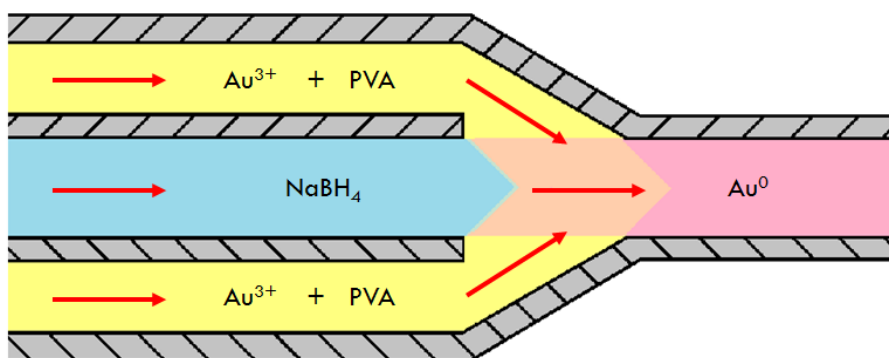
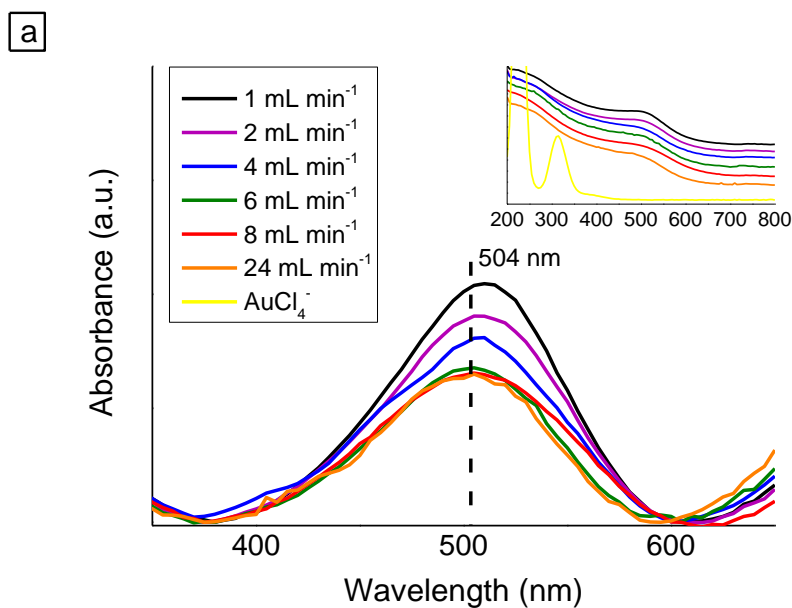
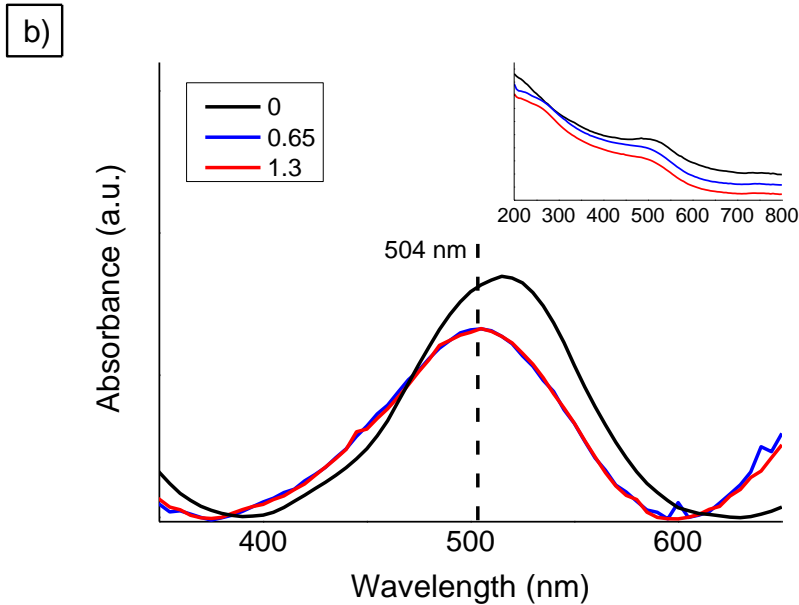


Figure S2: All the UV-vis spectra shown here have been processed by baseline subtraction from the original spectra (seen in the inset). The apparent absorption after 600 nm is simply a mathematical artefact caused by the subtraction of a straight line (baseline) and has no scientific meaning.

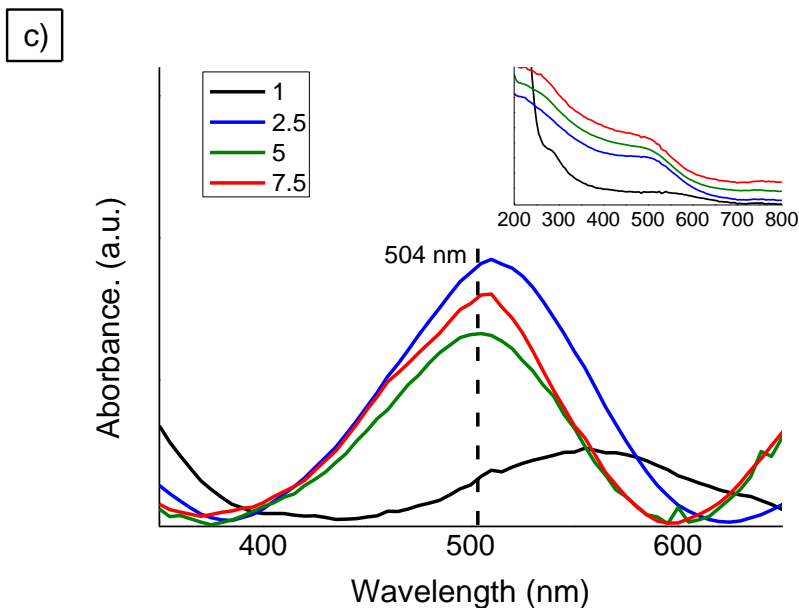
a) UV-vis analysis showing the plasmon resonance feature at different flow rates. The insets show the entire UV-vis spectra and the spectrum of the unreduced metal precursor. The data was recorded using the *in-line* UV-vis flow-cell positioned 50 cm downstream from the T-connection where the Au precursor, PVA and NaBH₄ first come into intimate contact.



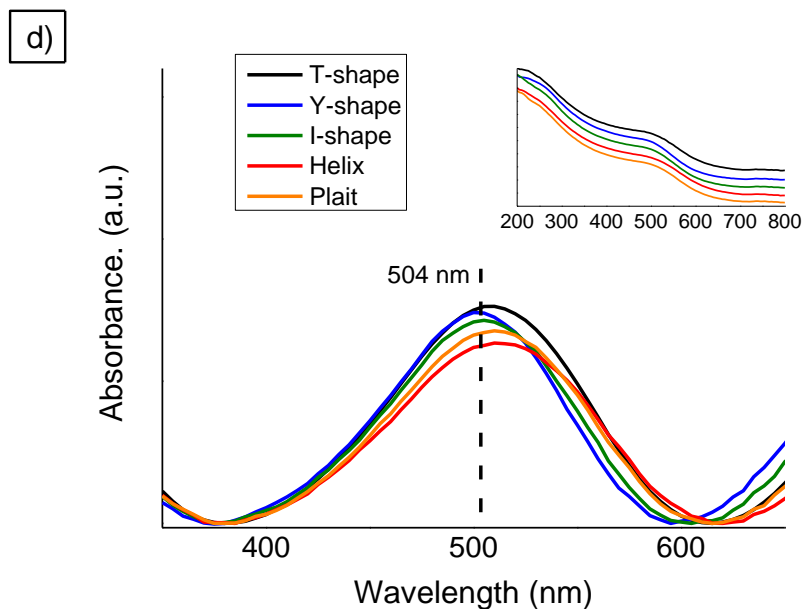
b) UV-vis analysis showing the plasmon resonance for different PVA/Au weight ratios. The insets show the entire UV-vis spectra. The data was recorded using the *in-line* UV-vis flow-cell positioned 50 cm downstream from the T-connection where the Au precursor, PVA and NaBH_4 first come into intimate contact.



c) UV-vis analysis showing the plasmon resonance for different NaBH_4/Au molar ratios. The insets show the entire UV-vis spectra. The data was recorded using the *in-line* UV-vis flow-cell positioned 50 cm downstream from the T-connection where the Au precursor, PVA and NaBH_4 first come into intimate contact.



d) UV-vis analysis showing the plasmon resonance with different connector/reactor geometry combinations. The insets show the entire UV-vis spectra. The data was recorded using the *in-line* UV-vis flow-cell positioned 50 cm downstream from the connection where the Au precursor, PVA and NaBH₄ first come into intimate contact.



e) UV-vis analysis showing the plasmon resonance with the batch, semi-continuous and continuous synthesis routes. The insets show the entire UV-vis spectra. The data was recorded using the in-line UV-vis flow-cell positioned 50 cm downstream from the T-connection where the Au precursor, PVA and NaBH₄ first come into intimate contact.

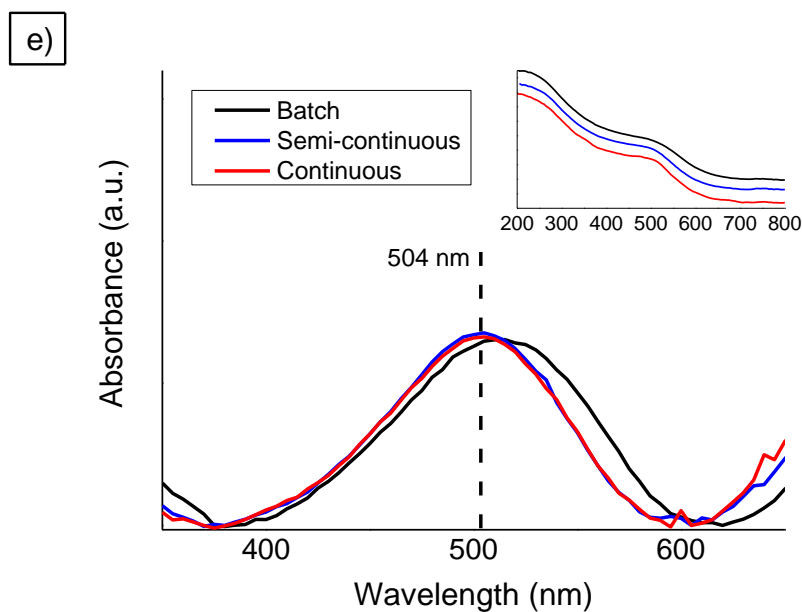


Figure S3: a) Representative DF-STEM image of the Au/TiO₂ *batch* catalyst with b) its corresponding particle size distribution. c) Representative bright field TEM image of the AuPd/TiO₂ *batch* catalyst with b) its corresponding particle size distribution.

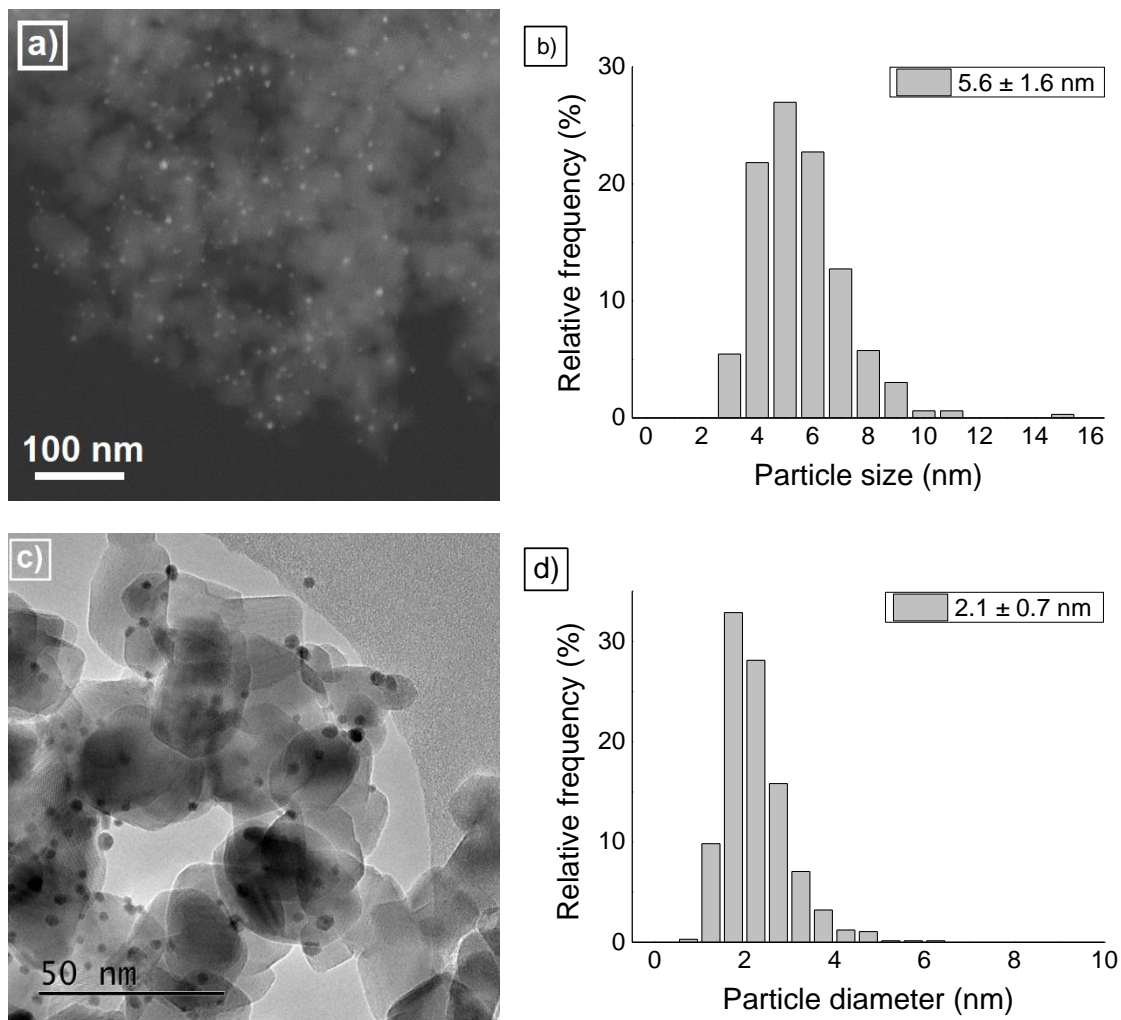


Figure S4: Diffuse reflectance UV-vis analysis of the Au/TiO₂ catalysts prepared via the conventional *batch*, *semi-continuous* and *continuous* production methods.

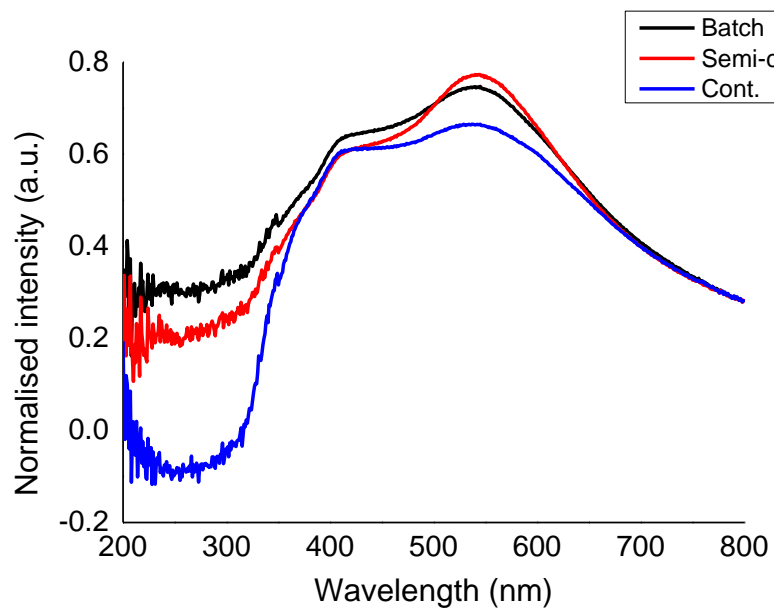
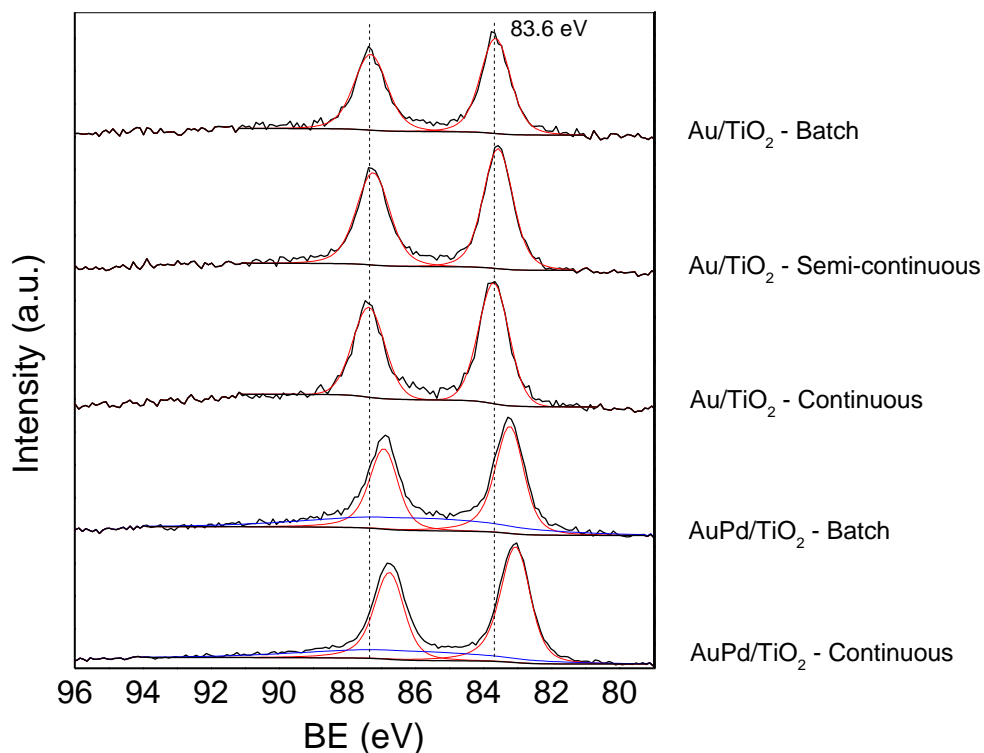


Figure S5: a) Au 4f_{7/2} XPS spectra obtained from the Au/TiO₂ and AuPd/TiO₂ materials prepared by the *batch*, *semi-continuous* and *continuous* production methods.



b) Pd 3d_{5/2} XPS spectra of AuPd/TiO₂ materials prepared by the conventional *batch* and *continuous* production methods.

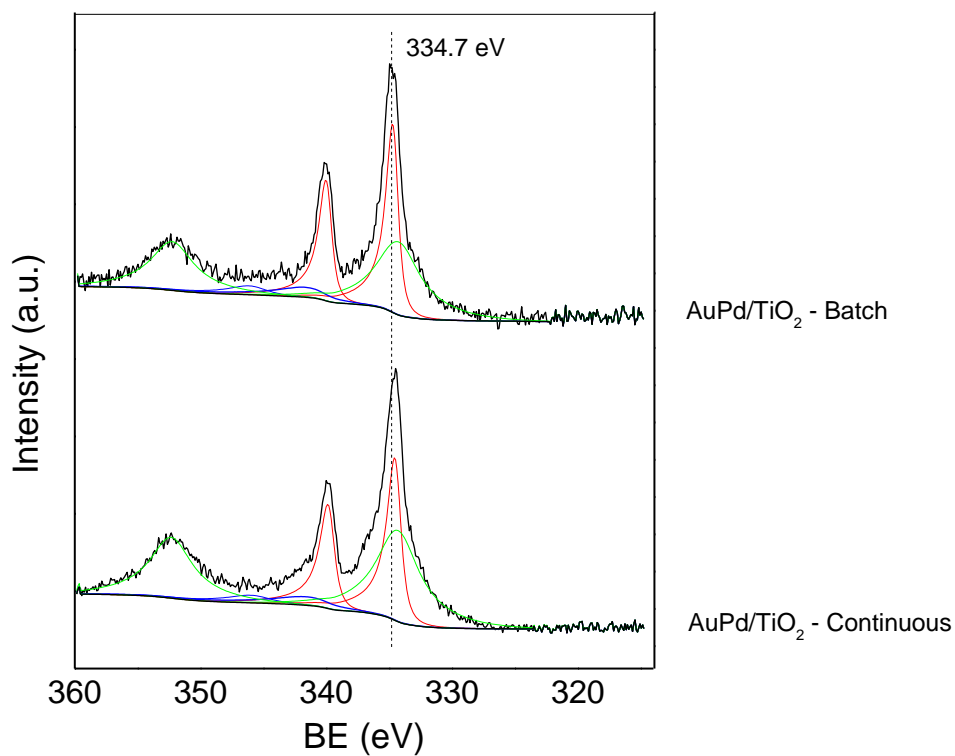
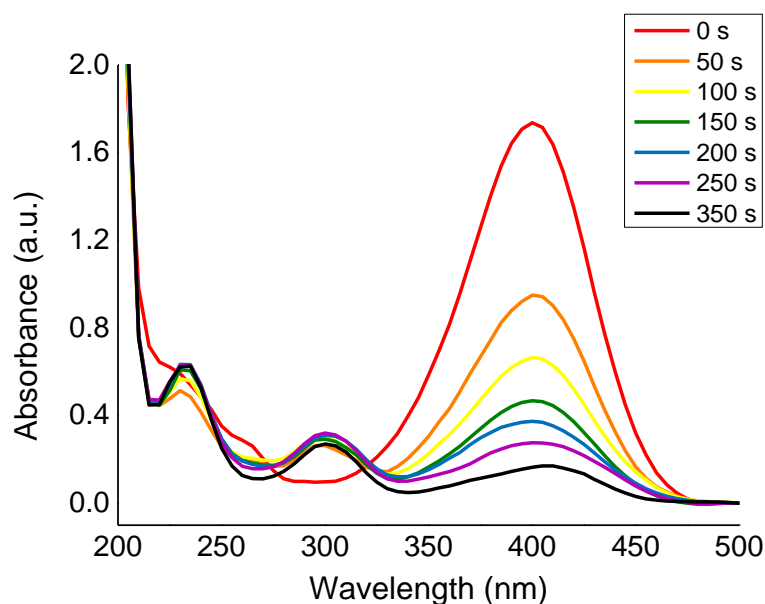


Figure S6: a) Typical time sequence UV-vis spectra following the catalytic reduction of 4-NPH reduction (and more generally of NAR reduction) over Au/TiO₂ made using the *continuous* preparation method with an excess of NaBH₄ at room temperature. Molar ratios of Au : NAR : NaBH₄ are 1 : 2.5 : 250.



b) Typical plots of C_t/C_0 (black line) and $-\ln(C_t/C_0)$ (red line) versus the reaction time for the reduction of NAR catalysed by Au/TiO₂ made using the *continuous* preparation method with an excess of NaBH₄ at room temperature. Molar ratios of Au : NAR : NaBH₄ are 1 : 2.5 : 250.

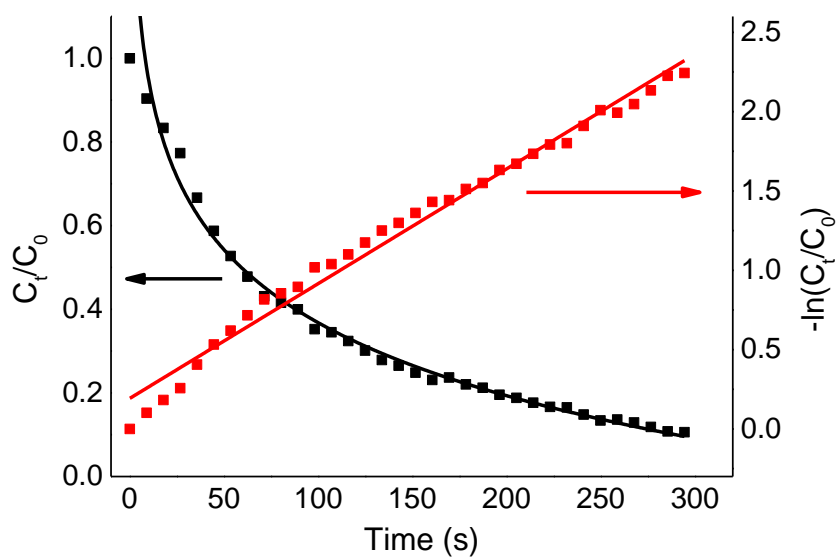


Figure S7: Graphical plot of mean particle size versus flow rate for the continuous production of Au nanoparticles.

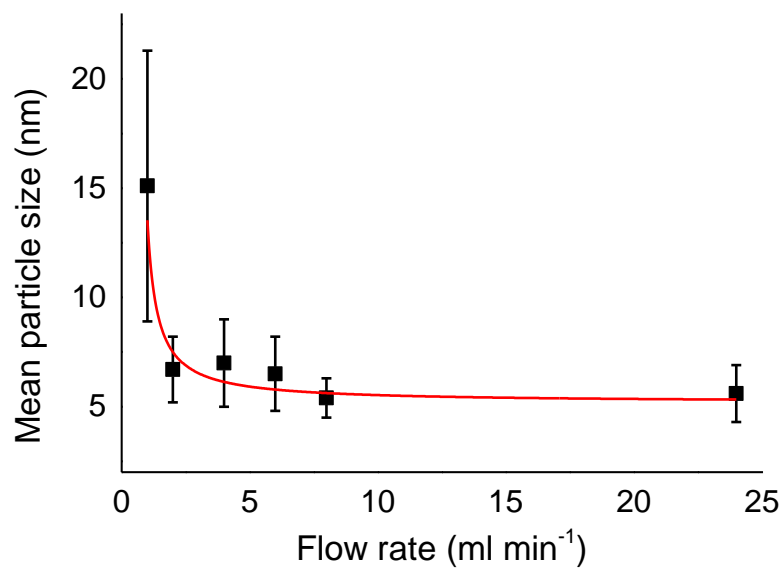


Table S1: Comparison between the *batch* benchmark, *semi-continuous* and *continuous* derived Au/TiO₂ and AuPd/TiO₂ catalysts showing mean particle size, metal loading, and Au 4f_{7/2} and Pd 3d_{5/2} binding energies.

Catalyst	Mean NP size [nm]		Metal loading [wt%]	Binding energy [eV]	
	DLS	DF-STEM		Au 4f _{7/2}	Pd 3d _{5/2}
Au/TiO ₂ - batch	5.6 ± 1.7	5.6 ± 1.6	0.94	83.6	-
Au/TiO ₂ -semi-continuous	6.0 ± 1.7	5.4 ± 0.9	0.92	83.7	-
Au/TiO ₂ - continuous	5.4 ± 1.6	4.5 ± 1.3	0.96	83.6	-
AuPd/TiO ₂ - batch	7.7 ± 2.1	2.1 ± 0.7	0.95	83.2	334.7
AuPd/TiO ₂ - continuous	7.6 ± 2.3	2.0 ± 0.7	0.94	83.0	334.6

References

- 1 T. Aditya, A. Pal and T. Pal, *Chem. Commun.*, **2015**, *51*, 9410–9431.