Bifunctional Au-Sn-SiO_2 catalysts promote the direct upgrading of glycerol to methyl lactate

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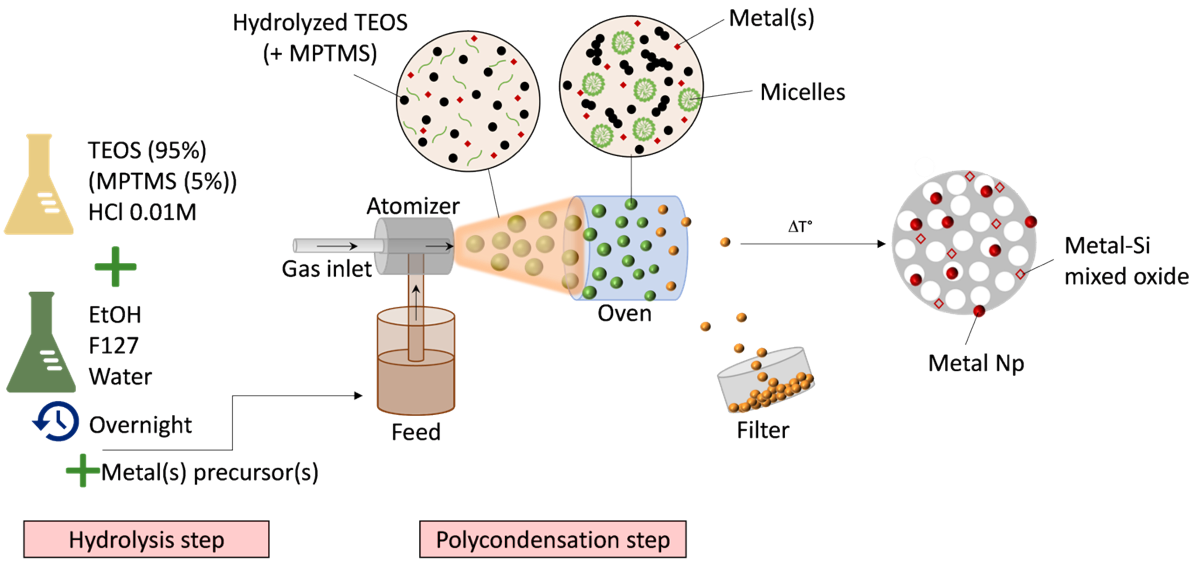
Supplementary information



Scheme S1: Schematic view of the aerosol-assisted sol-gel process

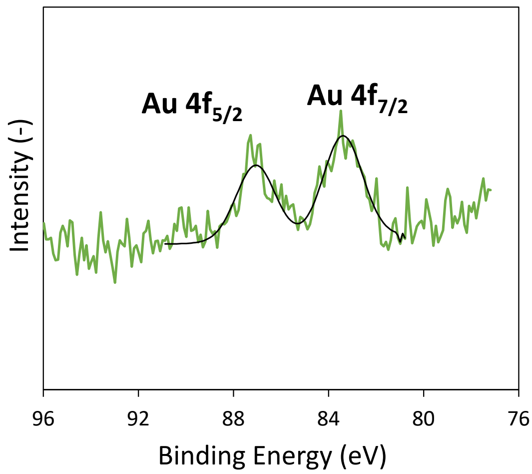


Figure S1: XPS spectra of the Au4f region of $AuSiO_2$. The theoretical binding energy of $Au4f_{7/2}^0$ is 84.3 eV.

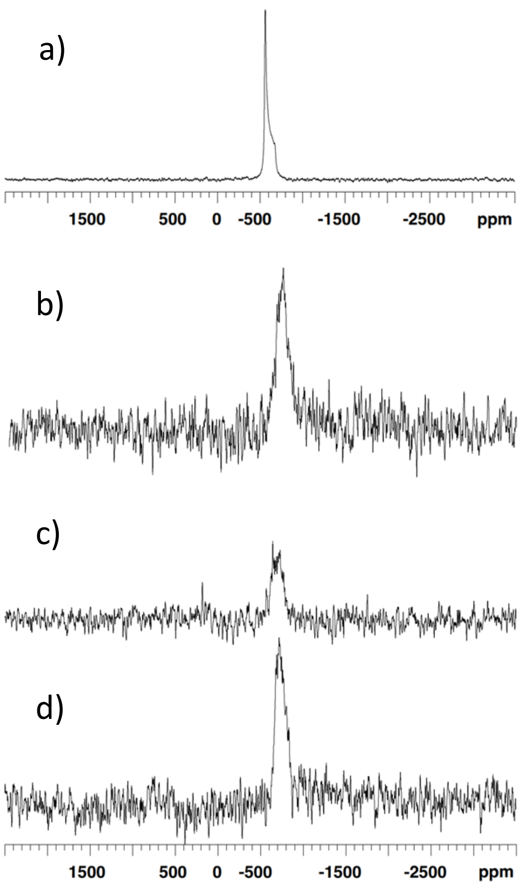


Figure S2: Solid state ^{119}Sn static NMR spectrum of (a) pure SnO_2, (b) Au(1)$SnSiO_2$ calcined, (c) fresh Au(1)$SnSiO_2$ and (d) $SnSiO_2$ calcined.

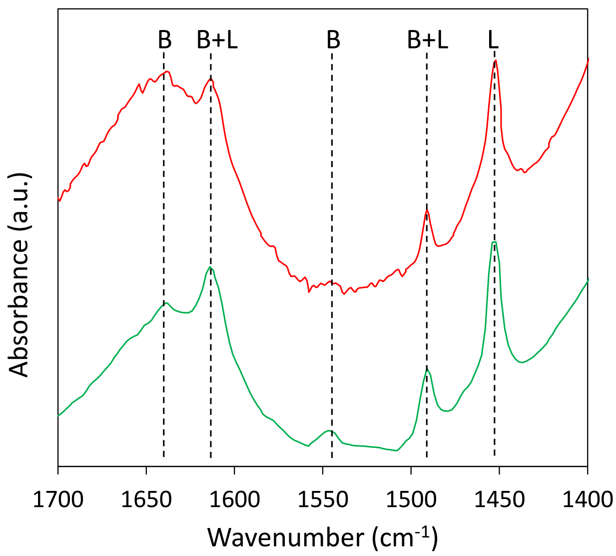


Figure S3: FTIR spectra after pyridine adsorption and desorption at 150 °C for 2 hours of $SnSiO_2$ (bottom green curve) and Au(1)$SnSiO_2$ (top red curve). B = band corresponding to Bronsted acid sites; L = band corresponding to Lewis acid sites.

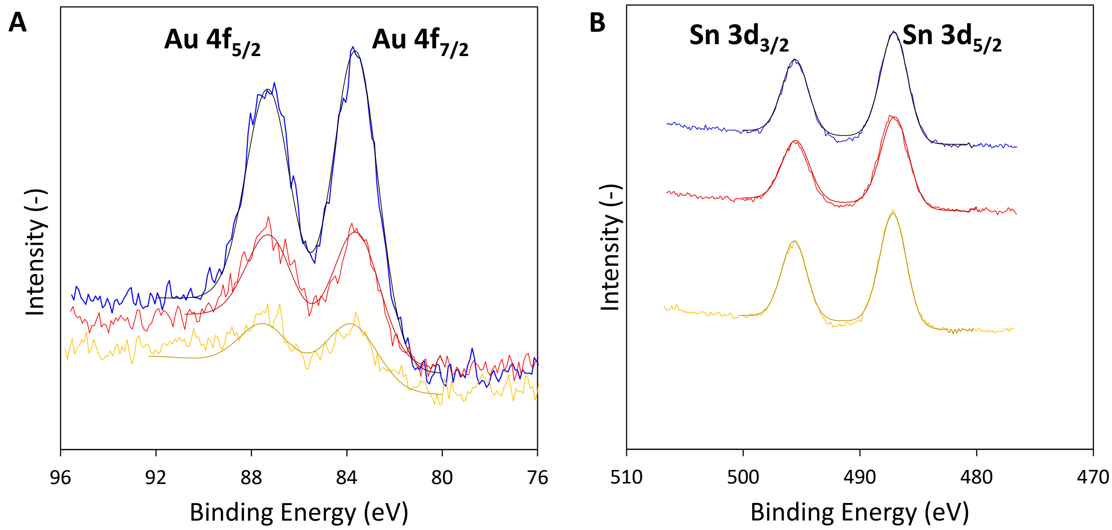


Figure S4: XPS spectra of the (A) the Au4f region and (B) Sn3d region of Au(x)SnSiO2(x = 0.5% (-), 1% (-), or 2% (-)). The theoretical binding energy of Au4$f_{7/2}{}^{0}$ and Sn3$d_{5/2}$ in Sn4+ state are respectively 84.3 eV and 487.2 eV.

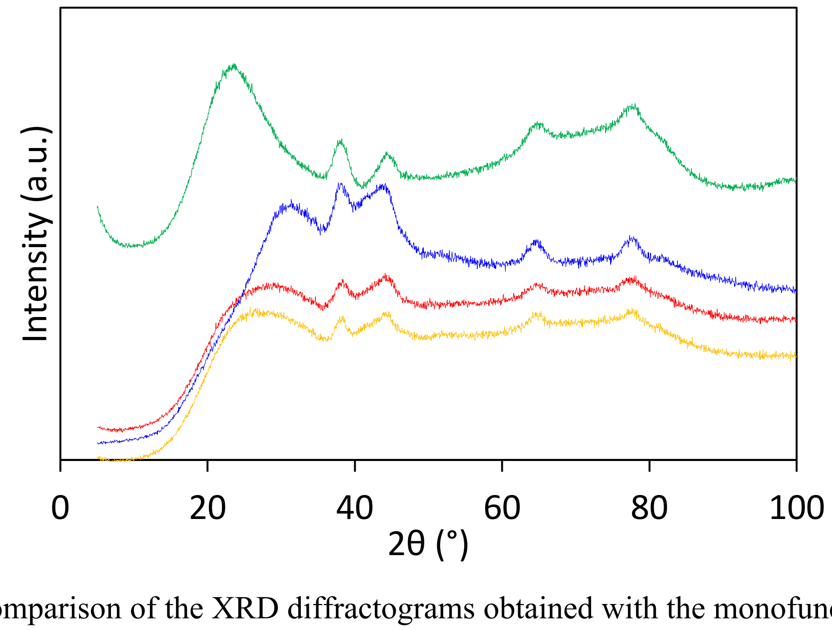


Figure S5: Comparison of the XRD diffractograms obtained with the monofunctional AuSiO_2 catalysts and the bifunctional Au(x)SnSiO_2 catalysts (x = 0.5% (-), 1% (-), or 2% (-)). The presence of the small shoulder at ~41° in the bifunctional catalyst is noticed but can not be interpreted at this stage.

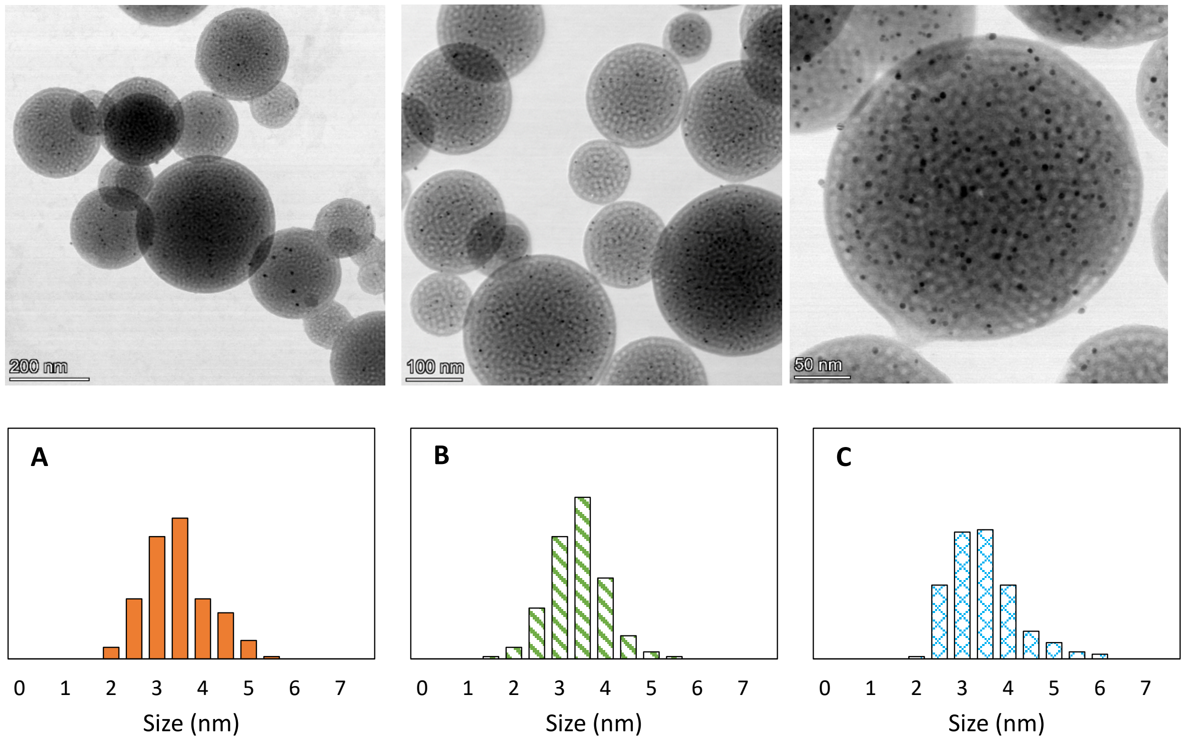


Figure S6: Gold nanoparticles size distribution of (A) Au(0.5)$SnSiO_2$, (B) Au(1)$SnSiO_2$ and (C) Au(2)$SnSiO_2$. TEM micrographs are shown as representative images of the samples used to count and measure nanoparticles size; the size distribution was estimated by measuring ~200 nanoparticles.

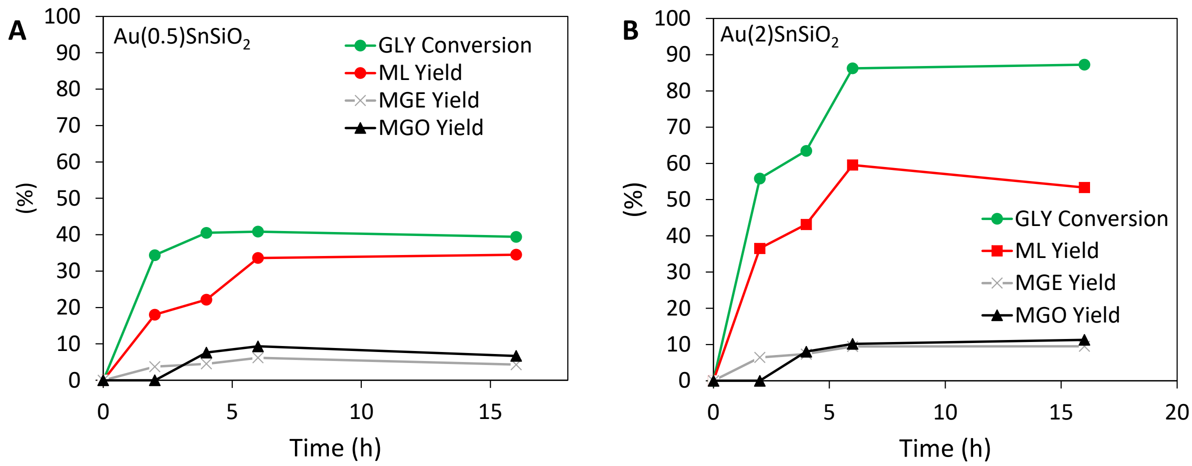


Figure S7: Kinetic study of the transformation glycerol (GLY) to methyl lactate (ML), methyl glycerate (MGE) and methyl glycolate (MGO) with (A) Au(0.5)SnSiO2 and (B)Au(2)SnSiO2. Reaction conditions: T = 160°C, pair = 15 bars, 0.125 M glycerol in methanol, and GLY/Catalyst ratio = 1.15 (w/w). Each measure has an error of ± 5%.

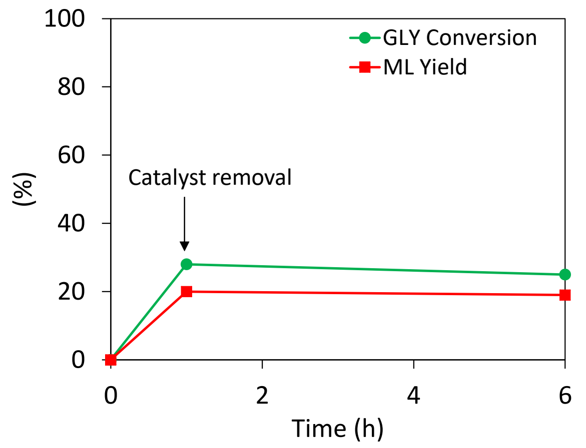


Figure S8: Hot filtration test performed with Au(1)$SnSiO_2$.

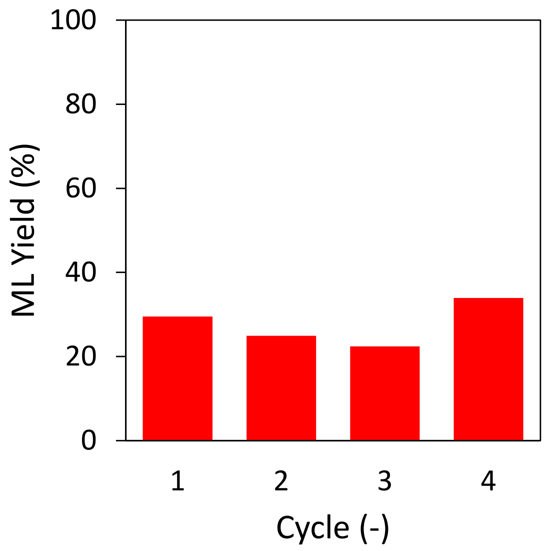


Figure S9: Recycling test performed with Au(1)$SnSiO_2$. The Au/GLY ratio was maintained constant in each cycle.

Table S1: Catalytic performance of Au(1)$SnSiO_2$ on different reaction conditions.

Temperature (°C)	P_{air} (bars)	Gly/Au (w/w)	GLY conversion (%)	ML Selectivity (%)	ML Yield (%)
160	15	1.15	85	73.1	62.2
160	**30**	1.15	77.5	72.9	56.5
160	30	**0.575**	69.5	75.2	52.2
160	30	**2.3**	77.2	67.6	52.2
160	30	**4.6**	54	54.3	29.3

120	30	2.3	5	100	5
140	30	2.3	41.2	66.9	27.7
180	30	2.3	96.4	60	57.8

One parameter is change at the time. Increasing the amount of air (and therefore the amount of oxidant in the reactor) did not improve the catalytic performance of Au(1)$SnSiO_2$. Similarly, increasing the amount of glycerol does not have a significant impact to a certain point (GLY/Au (w/w) = 4.6) where the ML yield starts to decrease. The diminution of temperature leads to the gradual loss of activity, while increasing the temperature reduced the selectivity to ML.

References

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