Supporting information 1

All STEM images for measuring particle size distribution (Catalyst No.1)

(Au+Pd) ion exchange $\rightarrow$ reduction
(Catalyst No. 1 in Table 1)
STEM image 1-1

(Au+Pd) ion exchange $\rightarrow$ reduction
(Catalyst No. 1 in Table 1)
STEM image 1-2
(Au+Pd) ion exchange $\rightarrow$ reduction
(Catalyst No. 1 in Table 1)
STEM image 1-3
All STEM images for measuring particle size distribution (Catalyst No.2)

Au ion exchange $\rightarrow$ reduction $\rightarrow$
Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-1

Au ion exchange $\rightarrow$ reduction $\rightarrow$
Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-2
Au ion exchange $\rightarrow$ reduction $\rightarrow$
Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-3

Au ion exchange $\rightarrow$ reduction $\rightarrow$
Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-4
Au ion exchange $\rightarrow$ reduction $\rightarrow$ Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-5

Au ion exchange $\rightarrow$ reduction $\rightarrow$ Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-6
Au ion exchange $\rightarrow$ reduction $\rightarrow$ Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-7

Au ion exchange $\rightarrow$ reduction $\rightarrow$ Pd ion exchange $\rightarrow$ reduction
(Catalyst No. 2 in Table 1)
STEM image 2-8
Au ion exchange $\rightarrow$ reduction $\rightarrow$

Pd ion exchange $\rightarrow$ reduction

(Catalyst No. 2 in Table 1)

STEM image 2-9
All STEM images for measuring particle size distribution (Catalyst No.3)

Pd ion exchange → reduction →
Au ion exchange → reduction
(Catalyst No. 3 in Table 1)
STEM image 3-1
Pd ion exchange $\rightarrow$ reduction $\rightarrow$ Au ion exchange $\rightarrow$ reduction
(Catalyst No. 3 in Table 1)
STEM image 3-2

Pd ion exchange $\rightarrow$ reduction $\rightarrow$ Au ion exchange $\rightarrow$ reduction
(Catalyst No. 3 in Table 1)
STEM image 3-3