A universal method for preparing highly dispersed bimetallic nanoparticles: the case of Pd–Fe

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Methods

Textural characteristics were measured by low-temperature adsorption-desorption of nitrogen on an automatic analyzer of specific surface area and porosity Tristar 3020 (Micromeritics, USA). Device error $= \pm 5\%$.

X-ray fluorescence analysis (XRF) was performed on the Lab Center XRF-1800 spectrometer (Shimadzu, Japan) equipped with a 4 kW X-ray tube with a rotation capability of up to 60 rpm. Device error $= \pm 1\%$.

X-ray diffraction (XRD) was performed on an XRD-6000 (Shimadzu, Japan) equipped with a Cu X-ray tube with a long fine focus and a power of 2.2 kW at a step of 1 °/min according to the Bragg-Brentano scheme.

Transmission electron microscopy (TEM) studies were performed on a JEM-2100F (JEOL, Japan) microscope equipped with an electron gun based on a Schottky thermopole kathode.

Scanning electron microscopy (SEM) studies were performed on a Vega 3 SBH microscope (Tescan, Czech Republic) equipped with a tungsten cathode electron gun with thermionic with an energy dispersive microanalysis system Aztec Live Lite Xplore 30 with the possibility of magnification x1000000.

X-ray photoelectron spectroscopy (XPS) analysis was performed on the X-ray photoelectron spectrometer PHI 5000 VersaProbe II (Ulvac-PHI, Japan) with a monochromatized AlKα X-ray source equipped with a charge neutralization system. The internal standard is the C1s line at 280.05 eV.

Experimental data

Table S1 Specific surface area (BET) and pore characteristics of samples and the support.

Sample	S_{BET}, m^2/g	V_{pore}, cm^3/g	D_{pore}, nm
Al$_2$O$_3$	137.7	0.30	6.1
3Pd-1Fe	136.1	0.28	5.9
10Pd-1Fe	136.4	0.27	5.8
20Pd-1Fe	136.4	0.27	5.9

S_{BET} – specific surface area (BET);
V_{pore} – pore volume;
D_{pore} – average pore size.
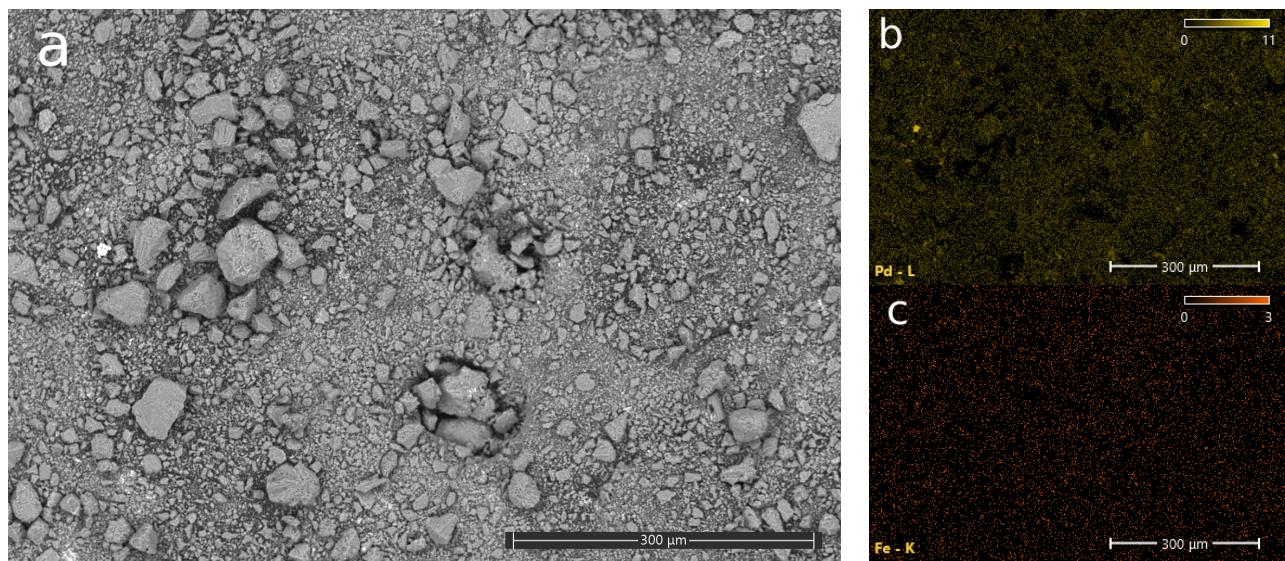
Figure S1 SEM micrograph (a) and EDX maps of Pd (b) and Fe (c) of 3Pd-1Fe sample.

Table S2 Elemental analysis by the SEM-EDX method in several areas of the 3Pd-1Fe sample.

Area No.	Pd, at. %	Fe, at. %	Pd/Fe (at.)
1	1.5	0.5	3.0
2	1.6	0.6	2.7
3	1.4	0.6	2.3
4	1.6	0.6	2.7
5	1.6	0.7	2.3
6	1.4	0.3	4.7
Average			2.9

Table S3 Peak areas and their ratio, measured by the XPS method.

Sample	Pd state	$3d_{5/2}$	$3d_{3/2}$	Ratio
Pd	Pd^0	2930	1948	1.50
	Pd (II)	1363	896	1.52
3Pd-1Fe	Pd^0	867	578	1.50
	Pd (II)	580	387	1.50
10Pd-1Fe	Pd^0	808	539	1.50
	Pd (II)	1543	1023	1.51
20Pd-1Fe	Pd^0	1172	782	1.50
	Pd (II)	1067	706	1.51
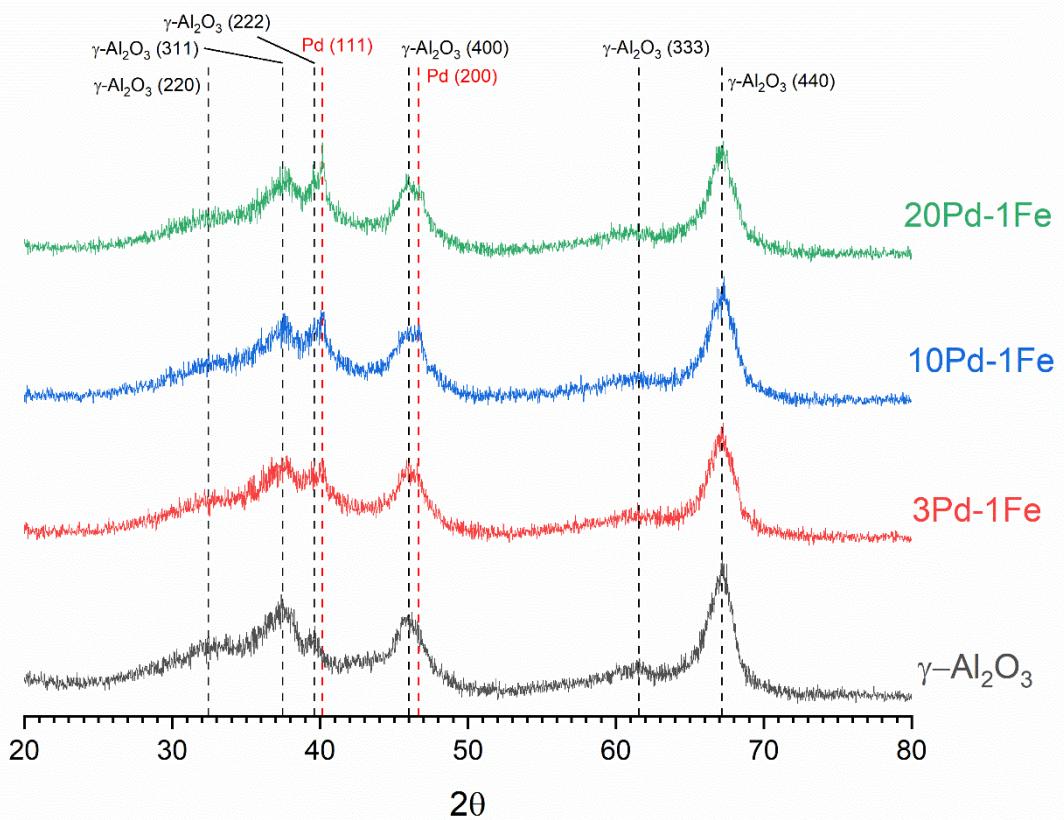
Figure S2 XRD patterns for γ-Al₂O₃ and Pd-Fe samples.