COMMUNICATION

Supporting Information

New neodymium-phosphine compound for supercapacitors with long-term cycling stability

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Experimental Section

2.1 Materials

Triphenylphosphine, Neodymium(III) chloride hexahydrate, KOH and EtOH were purchased from Aladdin and used without any further purification, and activated carbon (AC) was purchased from Nanjing Xfnano Company. All the aqueous solutions were freshly prepared with high purity water.

2.2 Synthesis of Nd-$(Ph)_3P$

Firstly, triphenylphosphine (0.525 g) was dissolved in 20 mL ethanol (EtOH) with stirring at room temperature. Then, neodymium(III) (0.358 g)chloride hexahydrate (dissolved in 10mL EtOH) was slowly added to the beaker and heated to 50 ℃ for 8 h in water bath. After that, they crystallized at room temperature for 48 h. The as-obtained crystals were dried under vacuum at 60 ℃ for 12 h.

2.3 Characterizations

The phase analysis of the Nd-$(Ph)_3P$ was determined by a X-ray diffraction (XRD) pattern recorded on Rigaku Ultima IV with Cu radiation of 1.5418 Å. The morphology of Nd-$(Ph)_3P$ was taken on a Hitachi S4800 instrument, transmission electron microscopy (TEM) images were captured on a TECNAI G2 F20 instrument. Also, fourier transform infrared (FTIR) transmission spectra of the Nd-$(Ph)_3P$ was performed by a Nicolet iS50 IR spectrophotometer. Furthermore, the surface species of the Nd-$(Ph)_3P$ was examined using a X-ray photoelectron spectroscopy (XPS) measurements (ESCALAB 250). The elemental analysis of the Nd-$(Ph)_3P$ was examined by Inductively coupled plasma-atomic emission spectrometry. (PerkinElmer Optima 8000).

2.4 Electrochemical measurements

The electrochemical performance was conducted by using a standard three-electrode system. About counter and reference electrodes, we chose a platinum foil electrode and a Hg–HgO electrode, respectively. The working electrode material was made by grinding the mixture of 70 wt% active material, 20 wt% acetylene black and 10 wt% PVDF, and soaking the mixture on a 1×1 cm nickel foam, The mass loading of the nickel foam was about 3 mg. Furthermore, the electrolyte was a 6 M KOH aqueous solution. Cyclic voltammetry (CV), galvanostatic charge–discharge (GCD) and electrochemical impedance spectroscopy (EIS) measurements of materials were conducted on an electrochemical workstation (Zahner, IM6).

2.5 Fabrication of the PVA/KOH all-solid-state supercapacitors

Preparation of the PVA-KOH gel electrolyte as follows: 1.52 g of PVA was dissolved in 15 mL water and the solution stirred for about 3 h at 80 ℃, then the solution of 5 M KOH (5 mL) was dropwisely added to the as-obtained gel solution under stirring. Based on the charge balance theory ($q^+ = q^-$), the mass ratio of Nd-$(Ph)_3P$ and AC was calculated to be 1:3. Moreover, the solid-state hybrid devices were prepared as follows: The negative and positive electrodes were soaked into PVA/KOH gel electrolyte, then pressed together to form a sandwich structure after the extra water to gasify. After that, the as-obtained device was sealed in an aluminium pouch using an capper.[36]

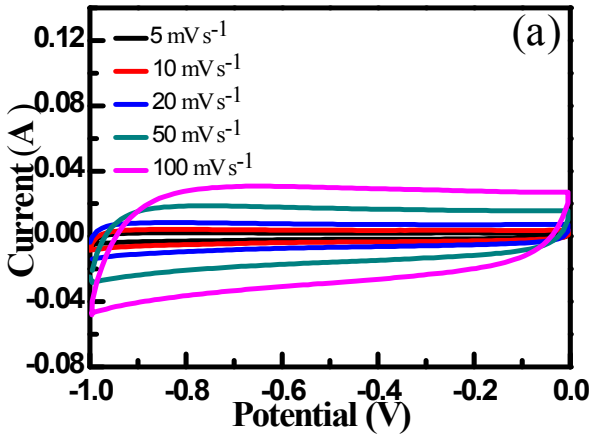

Fig. S1 CV curves of the AC electrode at different scan rates.

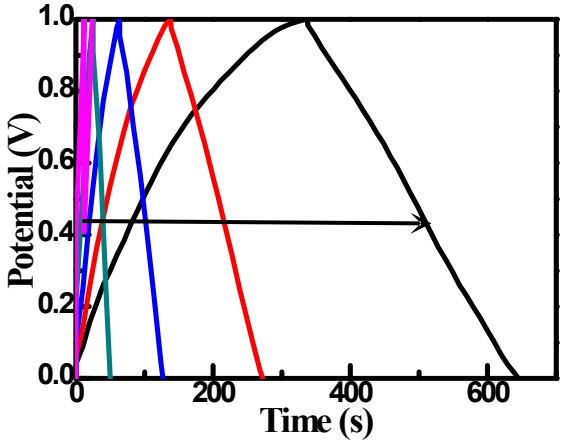

Fig. S2 Galvanostatic charge–discharge profiles of the AC electrode at different current densities.

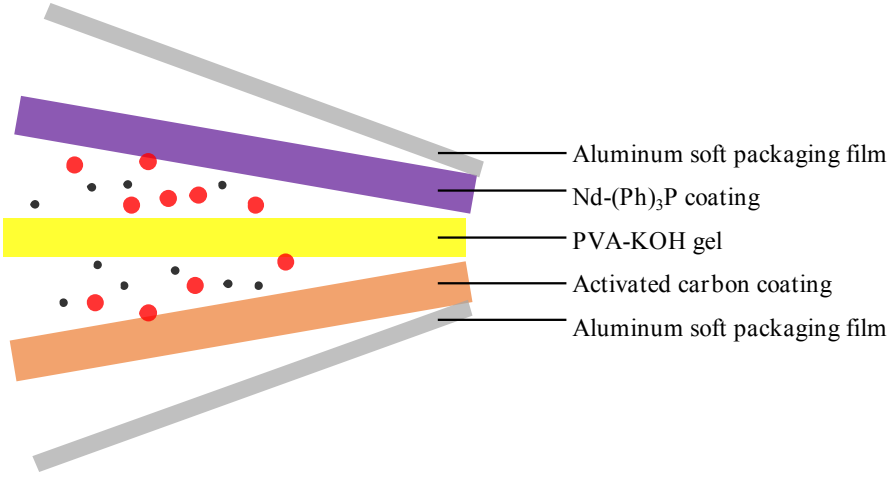

Fig. S3 Schematic diagram of the device structure for all-solid-state supercapacitors.

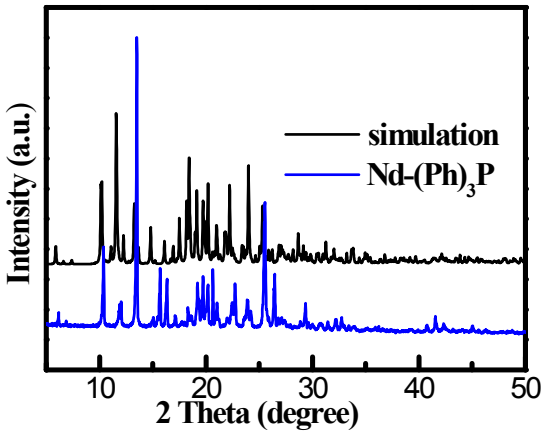

Fig. S4 XRD patterns of the simulation and Nd-$(Ph)_3$P sample.

Table S1. The molar ratio of elements in Nd-$(Ph)_3P$ determined by ICP analysis.

Elemennt	Sample-1	Sample-2	Sample-3
Nd : P	1 : 2.09	1 : 2.06	1 : 2.10

Table S2. Electrochemical performance comparison between recently reported studies and the present work.

Materials	Current density	Specific capacitance	Reference
$La(OH)_3$/GNs	1 A g^{-1}	485 F g^{-1}	Electrochim. Acta, 2018, 281, 329-337
CeO_2	1 A g^{-1}	779 F g^{-1}	Electrochim. Acta, 2016, 222, 773–780
CeO_2/N-C	0.5 A g^{-1}	752 F g^{-1}	ACS Sustainable Chem. Eng., 2020, 8, 6675-6681
$Nd(OH)_3$	1 A g^{-1}	820 F g^{-1}	New J. Chem., 2018, 42, 2923-2932
PIn/Nd_2O_3	1 A g^{-1}	401 F g^{-1}	New J. Chem., 2018,42, 5295-5308
Nd_2O_3/Mn_3O_4	5 mV s^{-1}	205 F g^{-1}	J. Alloy. Compd., 2020, 815, 152104-152115
POAP/Nd_2O_3	0.005 mA	379 F g^{-1}	J. Colloid. Interf. Sci., 2017, 495, 102–110
$Tb_2(fma)_2(ox)(H_2O)_4 \cdot 4H_2O$	1 A g^{-1}	510 F g^{-1}	New J. Chem., 2020,44, 11615-11621
$Tb_2(WO_4)_3$	1 mV s^{-1}	336 F g^{-1}	Ultrason. Sonochem., 2018, 45, 189–196
Nd-$(Ph)_3P$	**0.5 A g^{-1}**	**951 F g^{-1}**	**This work**
	10 A g^{-1}	**634 F g^{-1}**	