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Data Article

Data on a highly stable electrocatalyst of NiCoPt/Graphene-dot nanosponge for efficient hydrogen evolution reaction

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ABSTRACT

The data presented in this article are related to the research article entitled "NiCoPt/Graphene-dot Nanosponge as a Highly Stable Electrocatalyst for Efficient Hydrogen Evolution Reaction in Acidic Electrolyte (N.-A. Nguyen et al., 2020) [1]. This article reports a simple method to synthesize NiCoPt/Graphene-dot as an electrocatalyst with low Pt loading but high hydrogen evolution reaction (HER) performance. The morphology of NiCoPt/Graphene-dot was analyzed by scanning electron microscopy (SEM) and high-resolution transmission electron microscopy (HRTEM) techniques. The structural and chemical properties of NiCoPt/Graphene-dot were investigated by using X-ray Powder Diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) techniques.

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Specifications Table

Subject	Physics, Chemistry
Specific subject area	Electrochemical catalysts for hydrogen evolution reaction
Type of data	Table Image Graph Figure
How data were acquired	Evaluation of the characterizations of synthesized electrocatalyst: The structure of obtained samples was investigated by using Powder X-ray diffraction (XRD) measurement with a Cu target (Cu Kα1 = 1.541 Å), (Japan). The measurements were conducted from 15° to 60° with steps of 0.02°. The morphology was observed by scanning electron microscopy (FE-SEM, Hitachi S-4800 with UHR lens) and by high-resolution transmission electron microscopy (HRTEM, JEM-2100F, 200 kV, JEOL LTD., Japan). X-ray photoelectron spectroscopy (XPS) characterization was performed on a Thermo Fisher Theta Probe system equipped with a monochromated Al-K X-ray source with a photon energy of 1486.6 eV. (K-Alpha+, Thermo Fisher Scientific).
Data format	Raw Analyzed Filtered
Parameters for data collection	Data on a synthesis of NiCoPt/Graphene-dot Nanosponge electrocatalyst including its characteristics and electrochemical properties.
Description of data collection	The samples were synthesized by the co-reduction method, then their characteristics were analyzed by XRD, SEM, TEM, and XPS methods. The electrochemical performance was collected by a potentiostat (IViumStat)
Data source location	Chungnam National University City: Daejeon Country: Republic of Korea
Data accessibility	With the article
Related research article	Ngoc-Anh Nguyen, Yousuf Ali, Van-Toan Nguyen, Oleksii Omelianovych, Liudmila L. Larina, Ho-Suk Choi*, "NiCoPt/Graphene-dot Nanosponge as a Highly Stable Electrocatalyst for Efficient Hydrogen Evolution Reaction in Acidic Electrolyte." Journal of Alloys and Compounds doi:10.1016/j.jallcom.2020.156651

Value of the Data

- This data provides the scientific community in the electrocatalysis field a simple method to synthesize $Ni_{48}Co_{48}Pt_4$/Graphene-dot ($Ni_{48}Co_{48}Pt_4$/G-dot) as an efficient electrocatalyst in the application of hydrogen evolution reaction.
- SEM and TEM images are taken to see the particle morphology and size of $Ni_{48}Co_{48}Pt_4$/Graphene-dot, from which the scientists could predict the electrocatalytic performance of catalysts.
- XRD pattern suggests that $Ni_{48}Co_{48}Pt_4$/G-dot possesses a carbon amount on the surface of nanoparticles, which can explain for the improvement of the stability of catalyst in the water-splitting process.
- Advanced XPS technique with the etching process of the sample before XPS measuring is examined to understand the electronic structure of electrocatalyst to explain for scientists how the activity of the catalyst can be enhanced.
- Electrochemical tests on $Ni_{48}Co_{48}Pt_4$/Graphene-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy are performed to see the improvement of hydrogen evaluation reaction (HER) performance of $Ni_{48}Co_{48}Pt_4$/Graphene-dot.

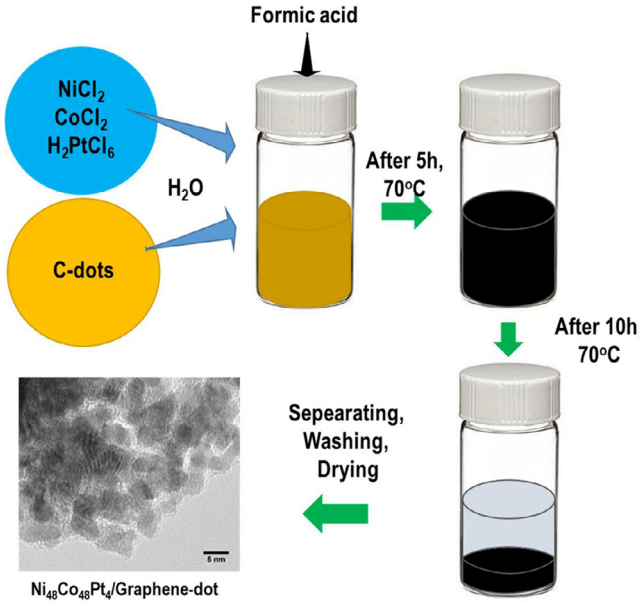

Fig. 1. Schematic representation of the synthesis of NiCoPt/G-dot nanosponge.

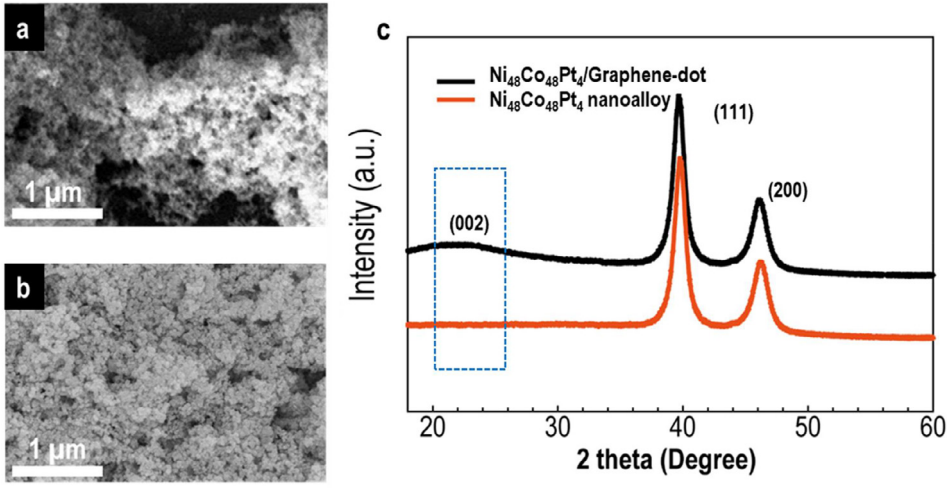

Fig. 2. (a) and (b) SEM images of $Ni_{48}Co_{48}Pt_4$/G-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy, respectively. (c) X-ray diffraction patterns of $Ni_{48}Co_{48}Pt_4$/G-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy. The broad peaks at 24.35° indicates the formation of graphene in $Ni_{48}Co_{48}Pt_4$/G-dot.

1. Data Description

The data of this article provides information on the synthesis of $Ni_{48}Co_{48}Pt_4$ alloy wrapped with graphene dots, which shows the high HER performance as well as very stable in the long-term of hydrogen production. Fig. 1 gives a synthesis process of $Ni_{48}Co_{48}Pt_4$/Graphene-dot (mentioned as $Ni_{48}Co_{48}Pt_4$/G-dot). Fig. 2 presents the morphology and structure of $Ni_{48}Co_{48}Pt_4$/G-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy. Fig. 3 shows the morphology and lattice fringes with inter-planner

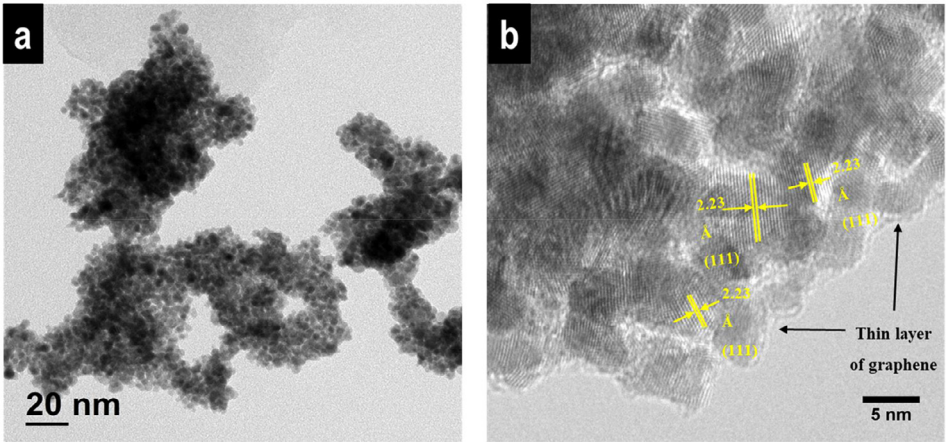

Fig. 3. (a) TEM and (b) HRTEM images of $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge.

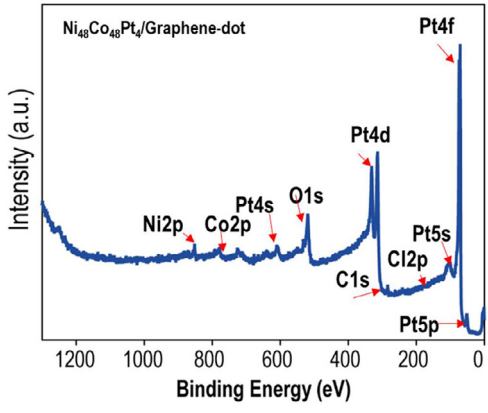

Fig. 4. The survey XPS spectrum was taken from $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge after a mild etching of the sample with the acceleration energy of 0.5 keV.

Table 1
Electrochemical performance data of $Ni_{48}Co_{48}Pt_4$/G-dot, $Ni_{48}Co_{48}Pt_4$ nanoalloy, and commercial Pt/C catalysts.

Electrocatalysts	Overpotential (mV)	Tafel slope (mV.dec^{-1})	R_{ct} (Ω)	C_{dl} (mF)	ECSA (cm^2)
$Ni_{48}Co_{48}Pt_4$ nanoalloy	52.70	37.62	47.15	1.599	45.71
$Ni_{48}Co_{48}Pt_4$/G-dot	45.54	33.90	29.05	2.013	57.51
Pt/C	41.60	30.23	19.60	2.080	59.43

distances of 2.23 Å corresponding to the (111) crystal plane. Fig. 4 supplies the survey XPS spectrum to disclose the electronic structure of $Ni_{48}Co_{48}Pt_4$/G-dot. Table 1 indicates the detailed values of electrochemical performance in the hydrogen evolution reaction (HER) application.

After synthesizing $Ni_{48}Co_{48}Pt_4$/G-dot sample as described in Figure 1, the morphology and structure of obtained catalysts were investigated as seen in Fig. 2. Clearly, in the presence of C-dots in the synthesis process, the morphology of $Ni_{48}Co_{48}Pt_4$/G-dot is sponge-like in contrast to $Ni_{48}Co_{48}Pt_4$ nanoalloy (synthesized without C-dots) with nanoparticles that tend to be aggregated (Fig. 2a, b). Fig. 2c shows the XRD patterns of $Ni_{48}Co_{48}Pt_4$/G-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy samples. In detail, the pattern of $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge, a weak and broad peak

at approximately 24.35° representing the crystal plane of (002) is observed. However, no peak is found at 24.35° in the pattern of $Ni_{48}Co_{48}Pt_4$ nanoalloy. The obtained result indicates the formation of graphene layers in $Ni_{48}Co_{48}Pt_4$/G-dot, which wraps the synthesized catalyst and creates a sponge-like polycrystalline structure [2]. The morphology of $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge is confirmed again by TEM as seen in Fig. 3a. The nanoparticles wrapped by graphene layers are clearly seen in Fig. 3b. Fig. 4 shows the survey XPS spectrum of $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge, which was treated under a mild acceleration Ar^+ energy of 0.5 keV. The high-resolution of Ni2p, Co 2p, Pt4f, and C1s spectra are deconvoluted as seen in the reference [1]. As a result, the carbon amount has recorded of 25.43 at%, suggesting that the surface of the nanoparticle is enriched with carbon. On the other hand, atomic percentages of metal elements obtained from survey spectra taken from $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge are given with 86.69 % of atomic percentage for Pt while only 7.14 and 6.17% are found for Co and Ni. The top layer is enriched up to 86.69% Pt suggesting that the surface composition of an alloy is controlled by the tendency of Pt metal segregates towards the surface. This result can be used to explain why the HER performance of $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge is excellent as seen in Table 1.

The beneficial effect of graphene-dot wrapped nanosponge on the HER activity is proven by direct comparison of the HER performance of the $Ni_{48}Co_{48}Pt_4$ with and without G-dots as seen in Table 1. The overpotential value of 52.70 mV for $Ni_{48}Co_{48}Pt_4$ nanoalloy is higher than that of $Ni_{48}Co_{48}Pt_4$/G-dot (45.54 mV) to obtain a current density of 10 $mA.cm^{-2}$. The obtained data prove that the coverage of the nanoparticles with G-dots not only enhances durability but also increases its electrical conductivity and provides a favorable catalyst/electrolyte interface for electron transfer from the electrode to the protons in the electrolyte.

The beneficial impact of the G-dot is further confirmed by the EIS, Tafel plots, and the double layer capacitance analysis. The Tafel slope of $Ni_{48}Co_{48}Pt_4$/G-dot is 33.90 (mV/dec), which is smaller than the slope of 37.62 mV/dec recorded for $Ni_{48}Co_{48}Pt_4$ nanoalloy. This data suggests that the electrochemical recombination step is the rate-determining step and the reaction follows the Volmer-Tafel mechanism [3–5]. The ECSA of $Ni_{48}Co_{48}Pt_4$/G-dot is 57.51 cm^2, which is larger than that of 45.71 cm^2 of $Ni_{48}Co_{48}Pt_4$ nanoalloy. In addition, the smaller value of 29.05 Ω for R_{ct} is fitted for the $Ni_{48}Co_{48}Pt_4$/G-dot compared to the R_{ct} of 47.15 Ω recorded for $Ni_{48}Co_{48}Pt_4$ nanoalloy, suggesting a more effective charge transfer across the catalyst/electrolyte interface that promotes the electrochemical reaction.

The comparative chronoamperometric curves recorded for $Ni_{48}Co_{48}Pt_4$ alloy and $Ni_{48}Co_{48}Pt_4$/G-dot are given in the reference [1]. The 40% loss of current density after 18 h of operation was recorded for $Ni_{48}Co_{48}Pt_4$ nanoalloy, whereas $Ni_{48}Co_{48}Pt_4$/G-dot nanosponge retains 94% of the current density after 21 h, showing an excellent catalytic activity. The result illustrates the positive impact of the G-dot in the stability of $Ni_{48}Co_{48}Pt_4$/G-dot catalyst in acidic electrolyte.

2. Experimental Design, Materials, and Methods

2.1. Materials

Nickel chloride hexahydrate ($NiCl_2$•$6H_2O$, 99.99%), cobalt chloride hexahydrate ($CoCl_2$•$6H_2O$, 99.9%), chloroplatinic acid hexahydrate (H_2PtCl_6•$6H_2O$, 99.9%), formic acid (HCOOH, 95 %, reagent grade), and ethanol (C_2H_5OH, 99.99%) were obtained from Sigma-Aldrich, USA. The Nafion D521 solution (5 wt%) was bought from Dupont (USA).

2.2. Methods

NiCoPt/Graphene-dots (referred to as NiCoPt/G-dot) were synthesized from the mixed precursor solutions and carbon dots (C-dots). C-dots were synthesized using a procedure developed

in our previous work [2,6,7]. A typical synthesis for the $Ni_{48}Co_{48}Pt_4$/G-dot nanohybrid can be described as seen in Fig. 1. $Ni_{48}Co_{48}Pt_4$ nanoalloy was synthesized with the same method to obtain NiCoPt/G-dot except using C-dots.

2.3. Experimental design

After synthesizing $Ni_{48}Co_{48}Pt_4$/G-dot and $Ni_{48}Co_{48}Pt_4$ nanoalloy samples, their physical characteristics such as crystalline structure, morphology, and surface chemical state were analyzed by using techniques such as the Powder X-ray diffraction (XRD), the scanning electron microscopy (SEM) and transmission electron microscopy (TEM), and X-ray photoelectron spectroscopy (XPS), respectively. In more detail, an X-ray diffractometer (Smart Lab, $\lambda = 1.5406$ Å, Cu Kα radiation, Rigaku corporation) was used to analyze the crystalline structure of the NiCoPt/G-dot nanosponge. Scanning electron microscopy (FE-SEM, Hitachi S-4800 with UHR lens) and high-resolution transmission electron microscopy (HRTEM, JEM-2100 F, 200 kV, JEOL LTD., Japan) were used to analyze the morphology of the synthesized NiCoPt/G-dot nanosponge. X-ray photoelectron spectroscopy (XPS) using a Thermo Fisher Theta Probe system equipped with a monochromated Al-K X-ray source with a photon energy of 1486.6 eV (K-Alpha+, Thermo Fisher Scientific) was used to analyze the surface chemical state of synthesized sample.

For measuring the electrochemical performance of the NiCoPt/G-dot catalyst, a three-electrode scheme with a rotating disc electrode was employed, using a potentiostat (IviumStat electrochemical analyzer from Ivium Technologies, Netherlands). NiCoPt/G-dot catalyst coated on glassy carbon (GC) electrode was used as the working electrode (WE). A platinum coil and a Ag/AgCl (NaCl 3 M) electrode were used as the counter and reference electrodes, respectively. The electrochemical catalytic activity of the NiCoPt/G-dot was performed in the acidic electrolyte (0.5 M H_2SO_4) by linear sweep voltammetry (LSV) at a scan rate of 10 mV/s. The electrolyte was degassed by bubbling with ultra-pure nitrogen gas for 30 min before the measurements. The electrochemical impedance spectroscopy (EIS) was examined at a voltage of -0.20 V vs a reversible hydrogen electrode (RHE) in a frequency range of 0.1 to 10^5 Hz.

Ethics Statement

The data resulted from experimental neither on animal models nor with human volunteers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Acknowledgments

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Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.106332.

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