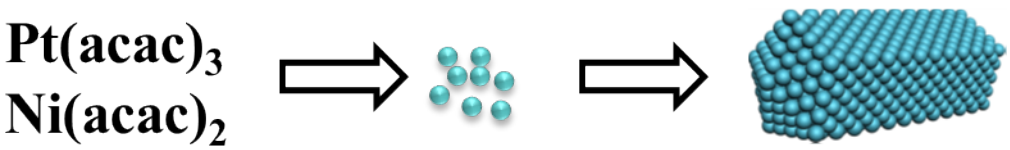
Electronic Supplementary Information

Material Characterizations

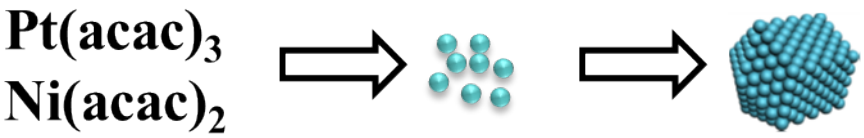
Transmission electron microscopy (TEM) and high-resolution TEM were performed on a TECNAI G2 20 S-Twin operated at 200kV and TECNAI G2 F30 operated at 300 kV. X-ray diffraction (XRD) patterns were collected with a Rigaku UltimaⅢ diffractometer system using a graphite-monochromatized Cu-Kα radiation at 40kV and 40mA.

Experimental Section

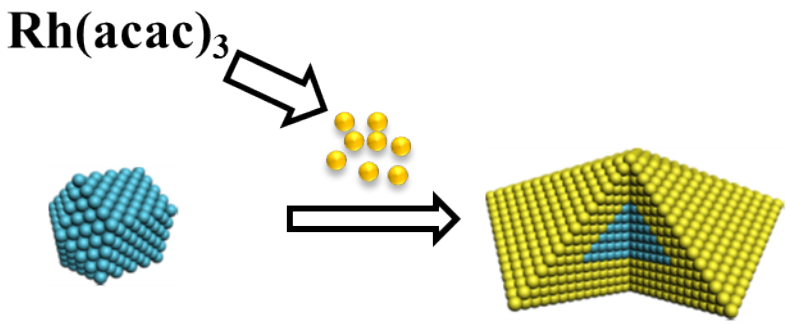
Preparation of thin Pt_3Ni nanorod (Figure 3a): A slurry of $Pt(acac)_2$ (0.06 mmol), $Ni(acac)_2$ (0.02 mmol), ethylene glycol (1.86 mmol) and octadecylamine (15 mmol) was prepared in a 15 mL two-neck round bottom flask with a magnetic stirring. After being evacuated for 120 min with stirring at 80 ^oC, the resulting solution was charged by CO gas, then heated up to 150 ^oC, and kept at that temperature for 120 min under CO gas. Finally, dark brown precipitates could be obtained by cooling down the solution to room temperature and then by centrifugation with added methanol / toluene (v / v = 15 mL / 15 mL).



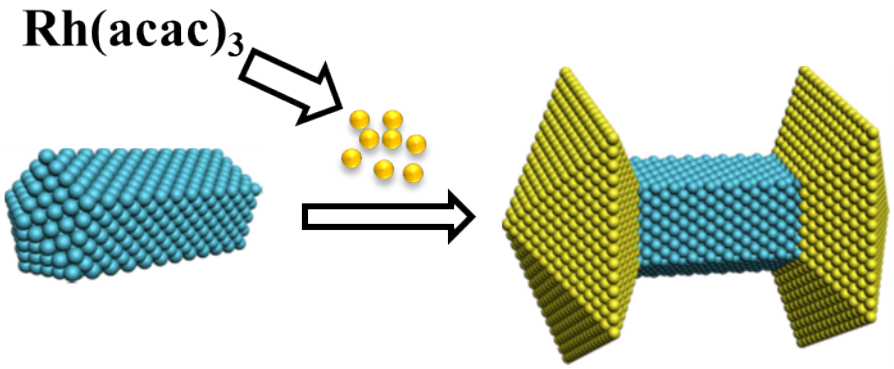
Preparation of short Pt_3Ni nanorod (Figure 2a): The method is similar to the preparation of thin Pt_3Ni nanorod, except for the evacuation time of 30 min and reaction temperature of 200 ^oC.



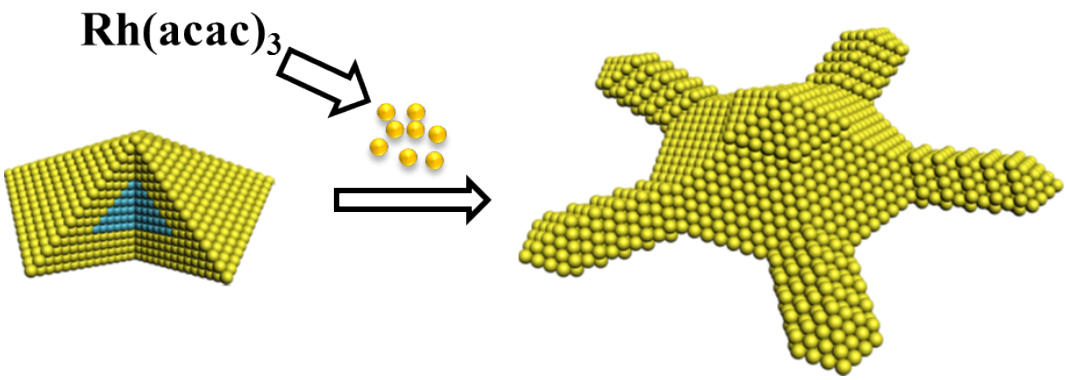
Preparation of Pt_3Ni@Rh pentagon (Figure 2b, S1a, S4): Short Pt_3Ni nanorods (~ 1 mg) were dispersed in a mixture of $Rh(acac)_3$ (0.05 mmol), ethylene glycol (1.86 mmol), stearic acid (0.15 mmol), and octadecylamine (15 mmol) in a 100 mL Schlenk tube equipped with a bubbler with a magnetic stirring at 100 ^oC. After being evacuated for 10 min with stirring at 100 ^oC, the solution was heated up to 130 ^oC and kept at the same temperature for 10 h under Ar gas condition. The resulting solution was further heated at 180 ^oC for 10 h. Finally, dark brown precipitates could be obtained by cooling down the solution to room temperature and then by centrifugation with added methanol / toluene (v / v = 15 / 15 mL).



Preparation of Rh-Pt_3Ni-Rh barbell (Figure 3b): Thin Pt_3Ni nanorods (~ 2 mg) were dispersed in a mixture of $Rh(acac)_3$ (0.05 mmol), ethylene glycol (1.86 mmol), and octadecylamine (15 mmol) in a 15 mL two-neck round bottom flask with a bubbler by magnetic stirring at 100 ^oC. After being evacuated for 10 min with stirring at 100 ^oC, the solution was heated up to 130 ^oC and kept at the same temperature for 20 h under Ar gas condition. Finally, dark brown precipitates could be obtained by cooling down the solution to room temperature and then by centrifugation with added methanol / toluene (v / v = 15 / 15 mL).



Preparation of Pt_3Ni@Rh nanostar (Figure 2c): Pt_3Ni@Rh pentagons (~ 2 mg) were dispersed in a mixture of $Rh(acac)_3$ (0.05 mmol), 1,2-hexadecanediol (0.93 mmol), and octadecylamine (10 mmol) in a two-neck round bottom flask (15 mL) with a magnetic stirring at 80 ^oC. After being evacuated for 10 min with stirring at 80 ^oC, the resulting solution was heated up to 130 ^oC and kept at the same temperature for 14 h under Ar gas condition**.** Finally, dark brown precipitates could be obtained by cooling down the solution to room temperature and then by centrifugation with added methanol / toluene (v / v = 15 / 15 mL).



Preparation of nanopaddlewheel (Figure 3c): The method is similar to the preparation of Pt_3Ni@Rh-Rh star, except that Rh-Pt_3Ni-Rh barbell (2 mg) was used as seed.

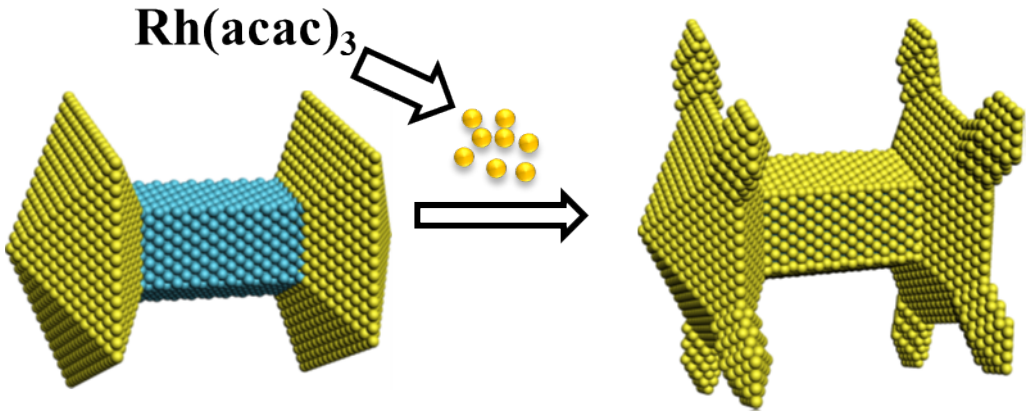


Fig. S1. (a) HRTEM of a Pt_3Ni@Rh pentagon. The blue lines denote twinning boundaries. FFT images of (b) area in the blue rectangle and (c) area in the red pentagon

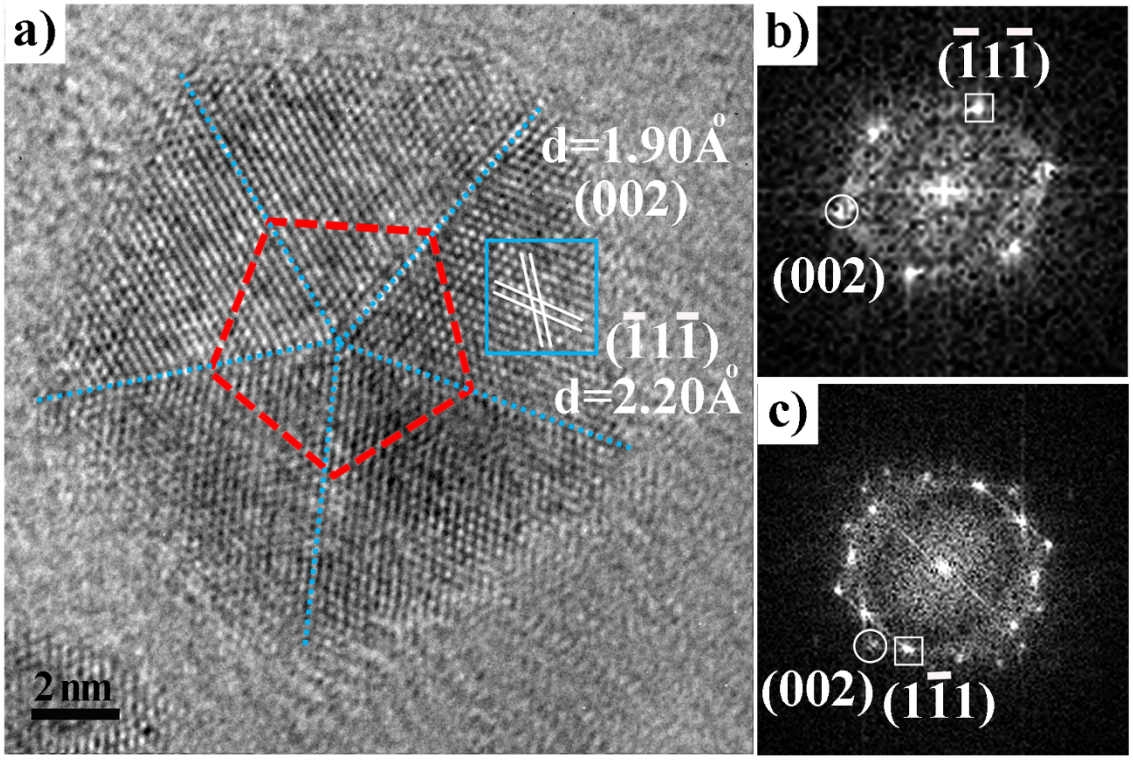


Fig. S2. a) TEM image of Pt_3Ni@Rh nanopentagons; b, c, d) The shapes of Pt_3Ni@Rh nanostars at the reaction time of 3 h, 5 h and 14 h.

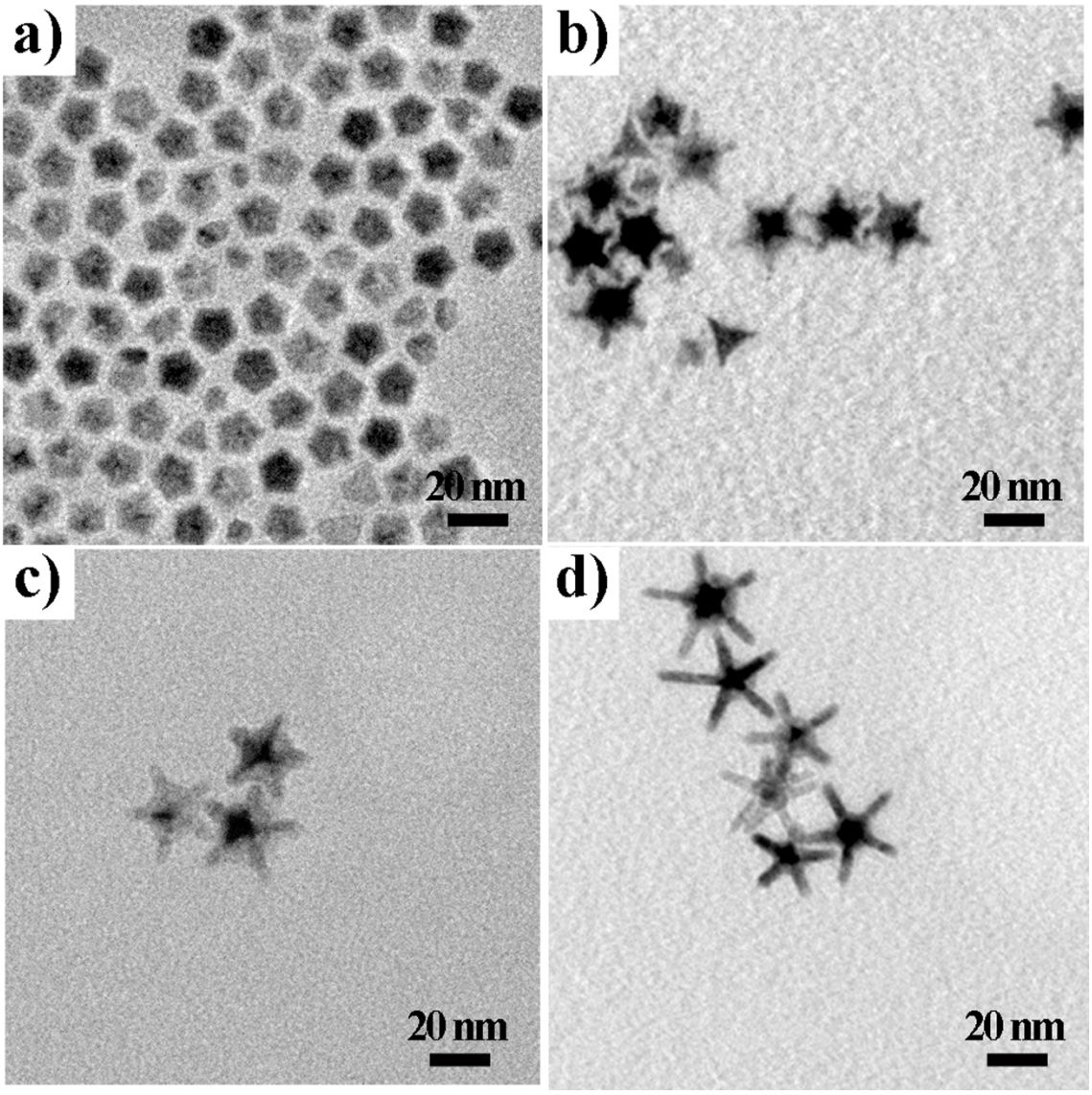


Fig. S3. TEM images of Pt_3Ni@Rh nanostars prepared by using mass ratios of (a) 10/1 [Pt_3Ni@Rh pentagon/Rh(acac)$_3$] and of (b) 15/1 [Pt_3Ni@Rh pentagon/Rh(acac)$_3$].

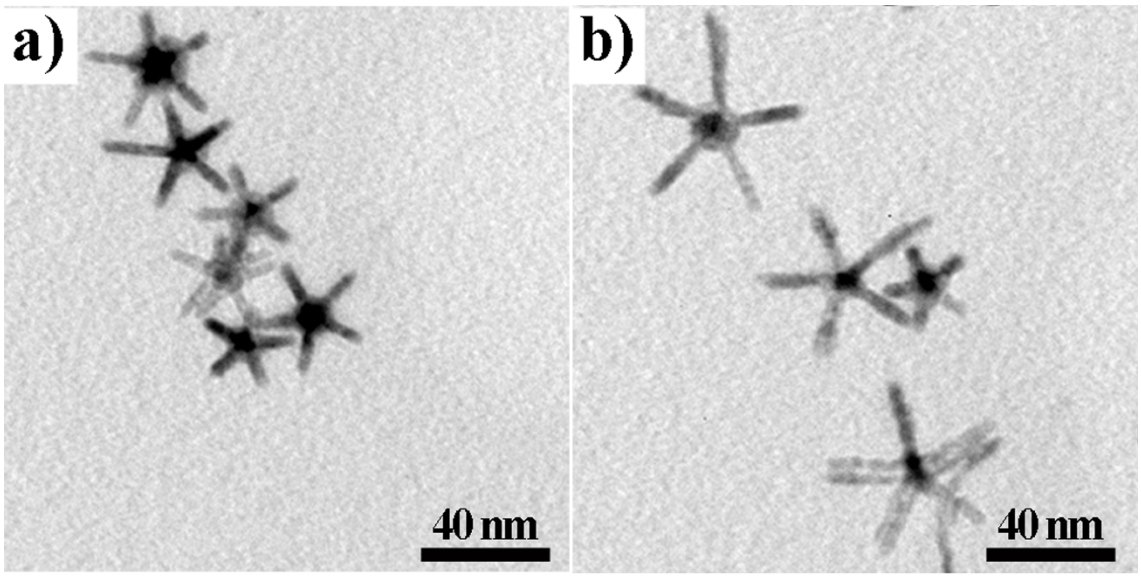


Fig. S4. Additional HRTEM images of (a) Pt_3Ni@Rh pentagon and (b) Pt_3Ni@Rh nanostar (b). A small pentagon is visible at the center of Pt_3Ni@Rh nanostar.

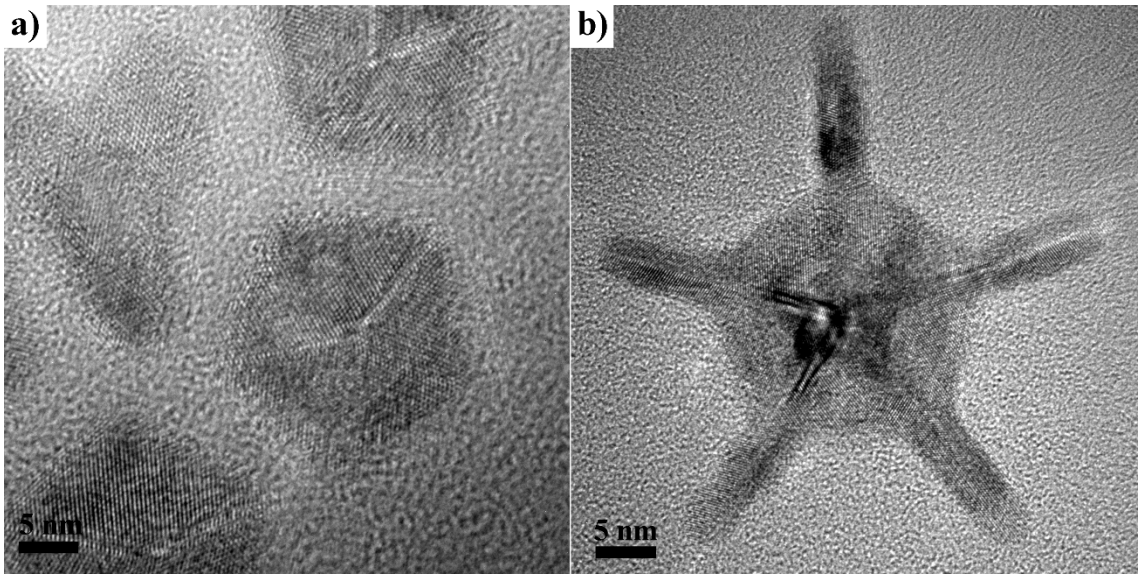


Fig. S5. HRTEM images of (a) a nanopaddlewheel standing vertically and (b) a nanopaddlewheel lying down horizontally.

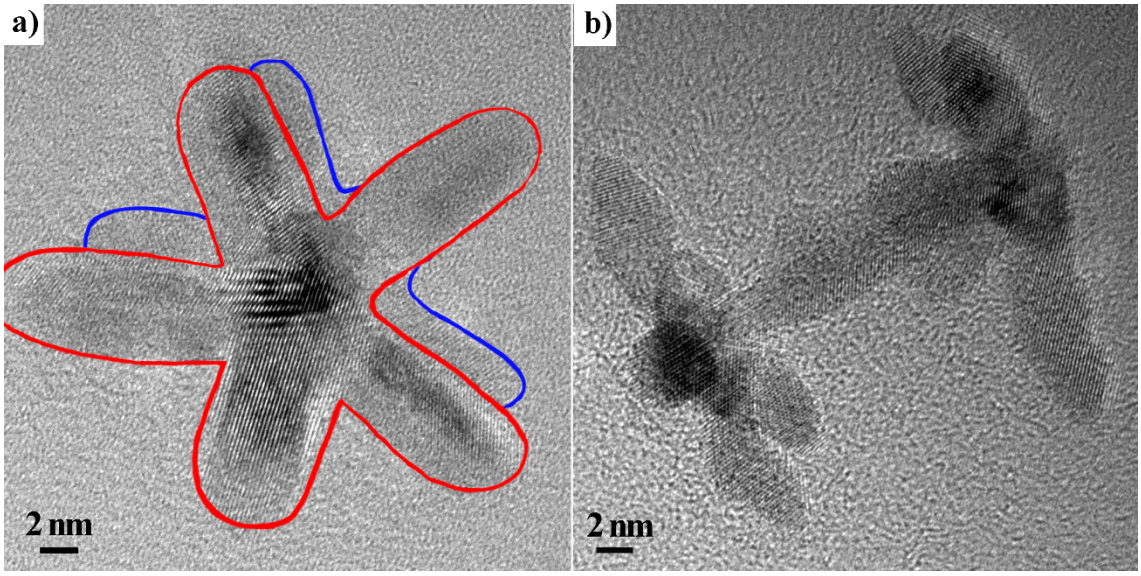


Fig. S6. Additional TEM image for nanopaddlewheels. Most of them are standing up.

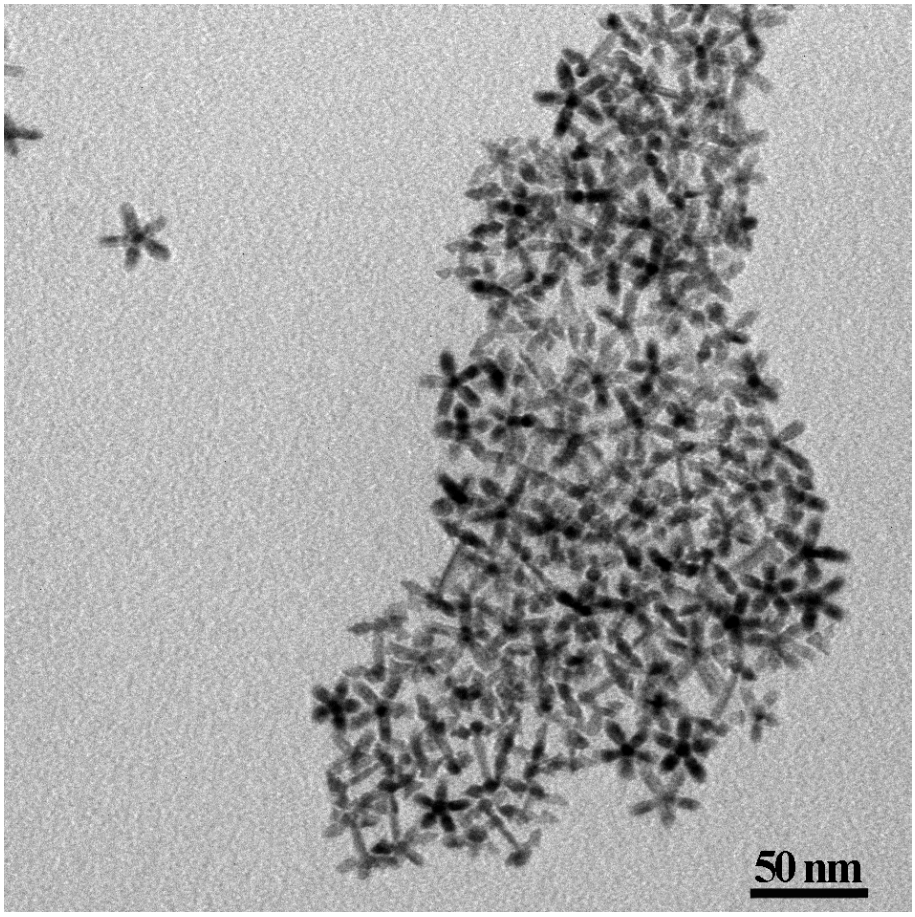


Fig. S7. X-ray diffraction patterns: a) thin Pt_3Ni nanorod; b) Pt_3Ni@Rh nanopentagon; c) Pt_3Ni@Rh nanostar; d) Rh nanoparticles (JCPDS card no 001-1214).

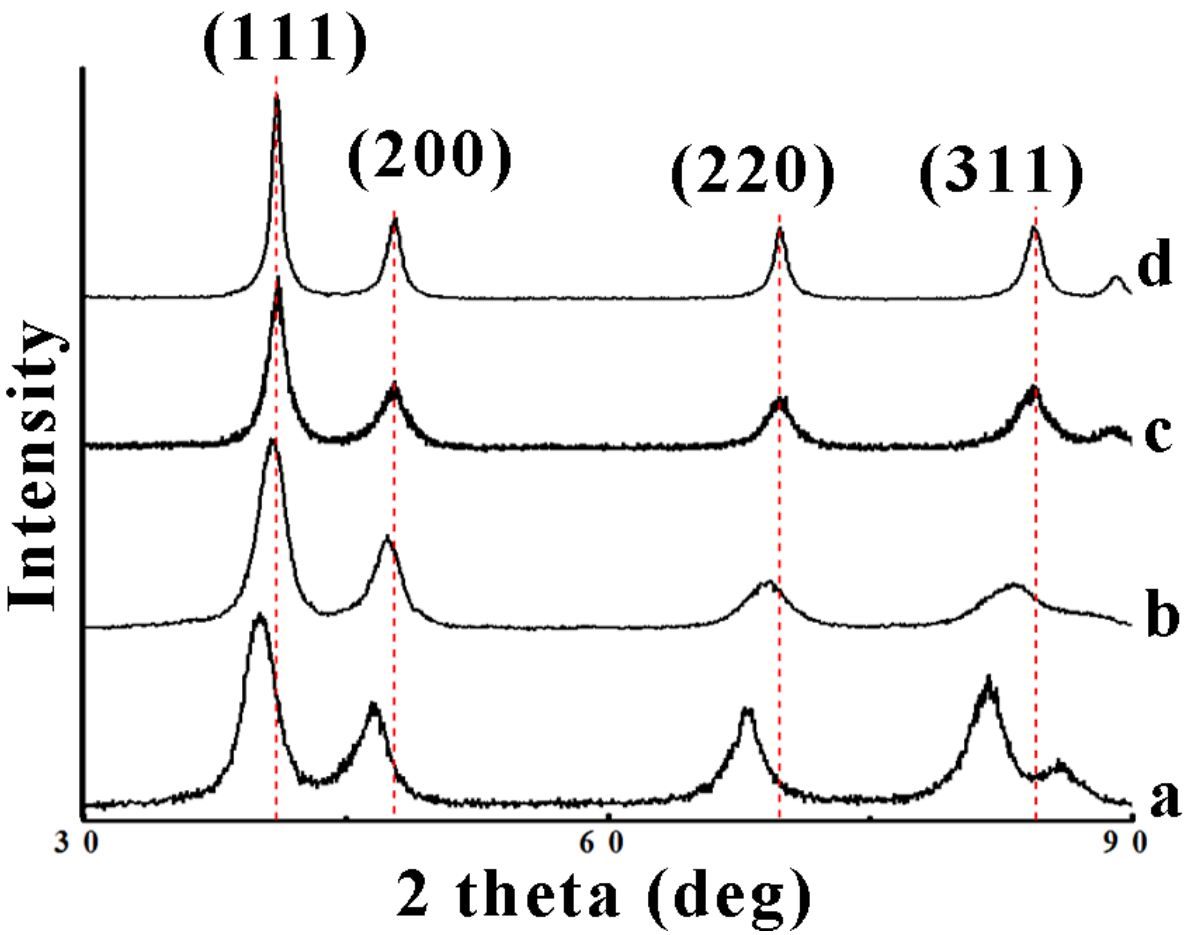


Fig. S8. TEM image of a) Ir nanocrystallites grown on a Pt_3Ni nanorod at 220 °C. TEM images of Pd nanocrystallites grown on a Pt_3Ni nanorod at (b) 90 °C and (c) 200 °C. In the case of Pd phase formed at 200 °C, independently grown Pd nanocrystals are observed.

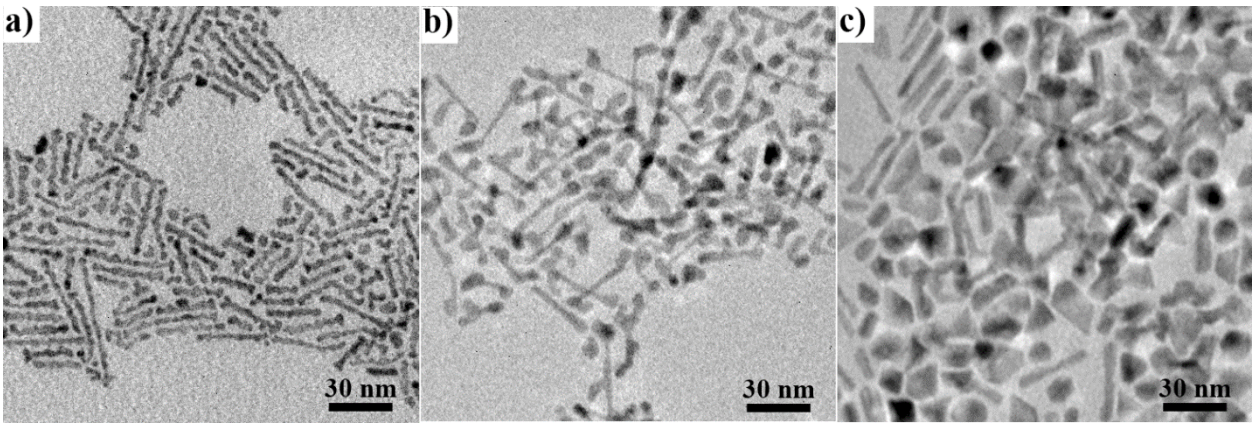
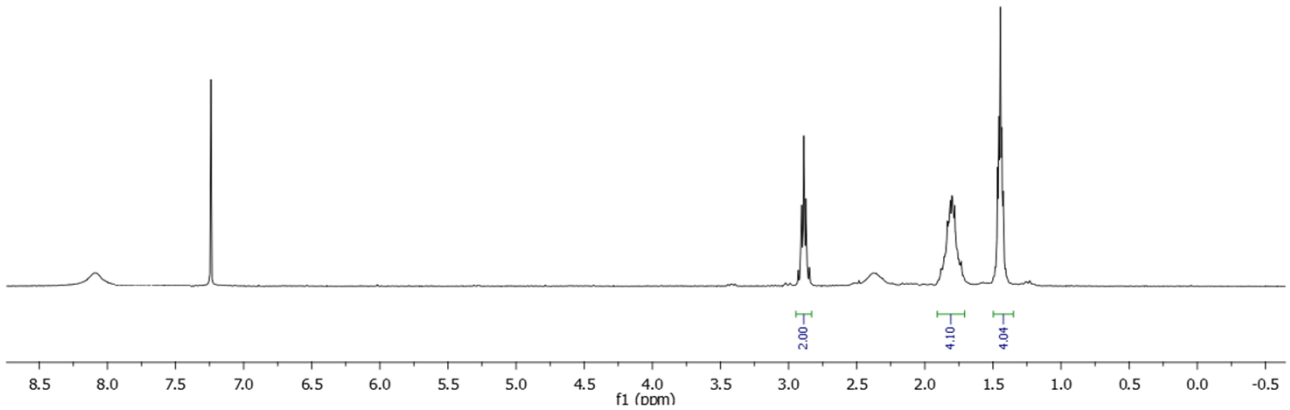
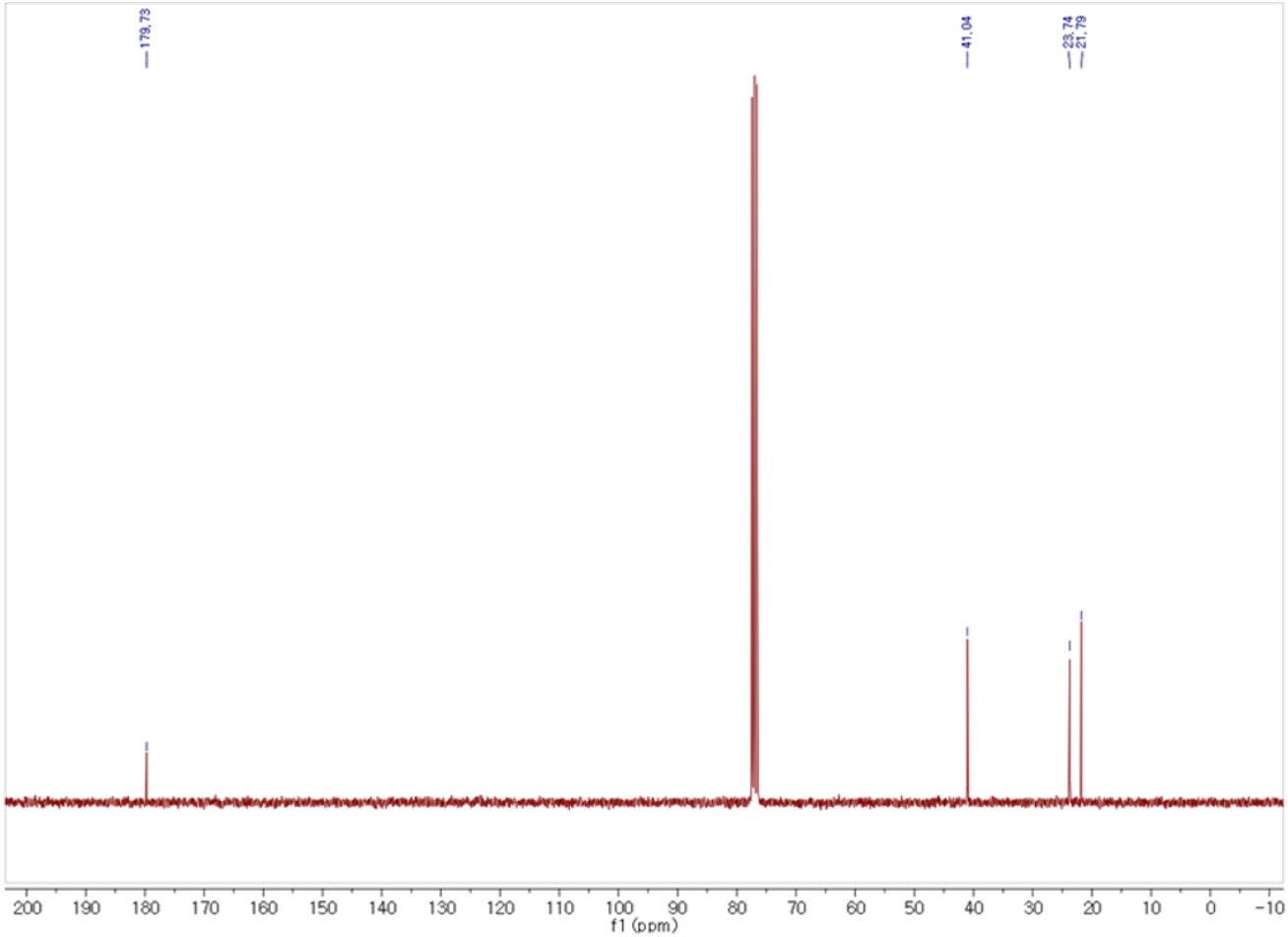


Fig. S9. NMR spectra of compound 5[1]

^{1}H NMR ($CDCl_3$)



^{13}C NMR ($CDCl_3$)



1. Reference: Y. M. Hijji, E. Benjamin, *Heterocycles* **2006**, *68*, 2259.

Fig. S10. TEM of a) Pt_3Ni@Rh pentagon, b) Pt_3Ni@Rh-Rh nanostar, c) nanopaddlewheel nanostructures supported on carbon black after catalytic application for reduction of a phenyl ring of phthalimide. No discernable structural deformations are observed after the catalysis.

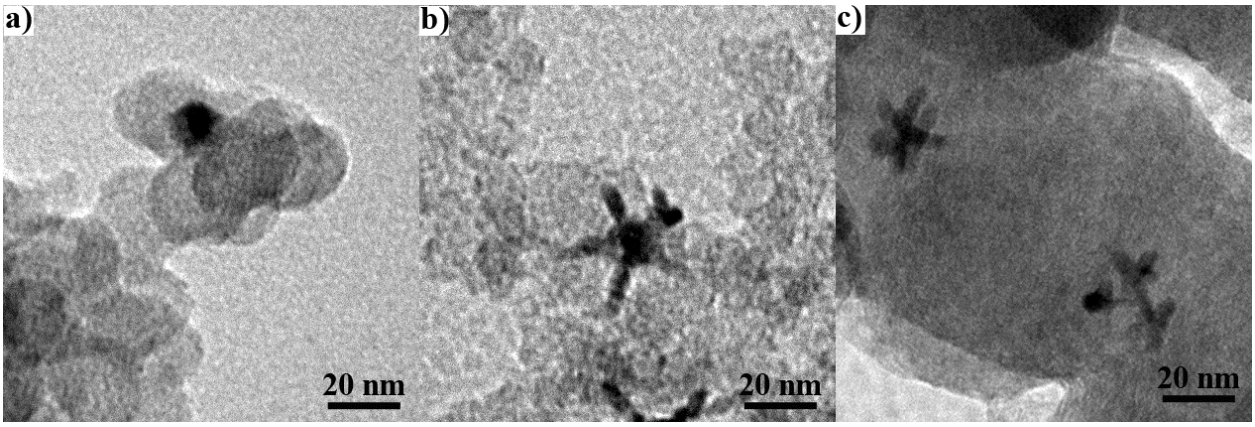
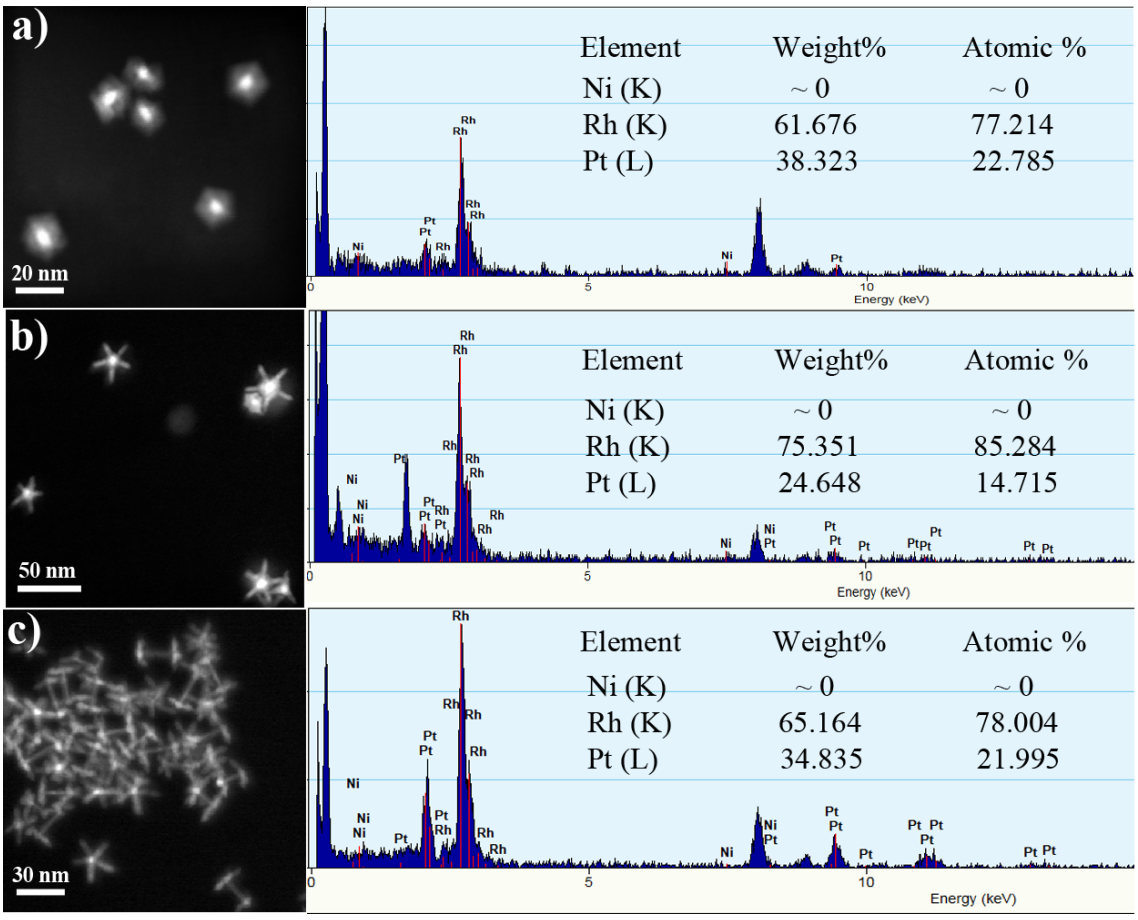


Fig. S11. Energy dispersive X-ray spectra and corresponding HAADF STEM images of a) Pt_3Ni@Rh pentagon, b) Pt_3Ni@Rh-Rh starfish, c) nanopaddlewheel. The Ni content could not be quantified due to the marginal amount under the detection limt.



Calculation of surface area/volume of Pt_3Ni@Rh pentagon.

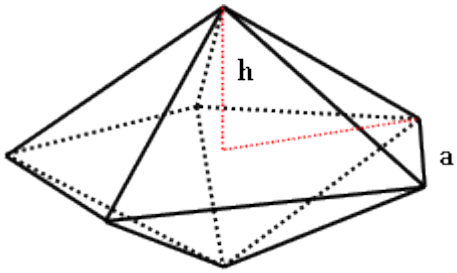


Fig. S12. Model of Pt_3Ni@Rh pentagon.

In geometry, a pentagon (decahedron or pentagonal dipyramid) is a polyhedron with ten faces, 15 edges and 7 vertices, symmetry group (D_{5h}).

The regular pentagonal dipyramid has a base that is a regular pentagon and lateral faces that are equilateral triangles. Its height h, from the midpoint of the pentagonal face to the apex, (as a function of ***a***, where ***a*** is the side length), can be computed as:

$$h = \sqrt{\frac{5-\sqrt{5}}{10}}a$$

Surface area of pentagon, S, can be computed as the area of ten times the area of one triangle:

$$S = 10\frac{\sqrt{3}}{4}a^2 = \frac{5\sqrt{3}}{2}a^2$$

Its volume (V) when an edge length is known can be figured out with this formula:

$$V = \frac{5+\sqrt{5}}{12}a^3$$

$$m_{pentagon} = \rho_{pentagon} * V$$

Where $\rho_{pentagon}$: densities of pentagon, which can computed by formula:

$$\frac{100}{\rho_{pentagon}} = \frac{x}{\rho_{Ni}} + \frac{y}{\rho_{Rh}} + \frac{z}{\rho_{Pt}}$$

x, y, z and ρ_{Ni}, ρ_{Rh}, ρ_{Pt} are % by weight and densities of Ni, Rh, and Pt, respectively

<u>Apply for Pt_3Ni@Rh pentagon:</u> (standard deviations measured from 50 NPs)

a = 7.94 ± 0.43 nm

$$S_{Pt_3Ni@Rh\ pentagon} = \frac{5\sqrt{3}}{2}(7.94)^2 \fallingdotseq 272.99\ (nm^2)$$

$$V_{Pt_3Ni@Rh\ pentagon} = \frac{5+\sqrt{5}}{12}(7.94)^3 \fallingdotseq 301.84\ (nm^3)$$

The energy dispersive X-ray spectroscopy (EDAX) analysis of Pt_3Ni@Rh pentagon nanostructures showed the % weight of Ni, Rh and Pt: ~ 0 %, 61.676 % and 38.323 % (Figure S9a). Density of Ni, Rh and Pt: $8.90*10^{-21}$ g.nm^{-3}, $12.41*10^{-21}$ g.nm^{-3}, $21.45*10^{-21}$ g.nm^{-3}

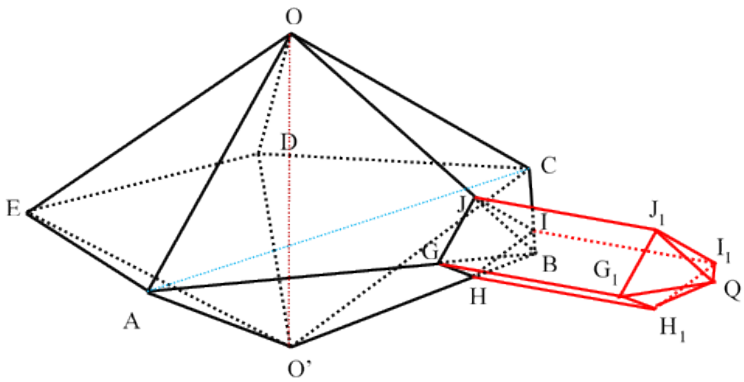
$$\rightarrow \rho_{Pt_3Ni@Rh\ pentagon} \fallingdotseq 14.80 * 10^{-21}\ g.nm^{-3}$$

$$m_{Pt_3Ni@Rh\ pentagon} = 14.80 * 10^{-21} * 301.84 \fallingdotseq 4467.23 * 10^{-21} g$$

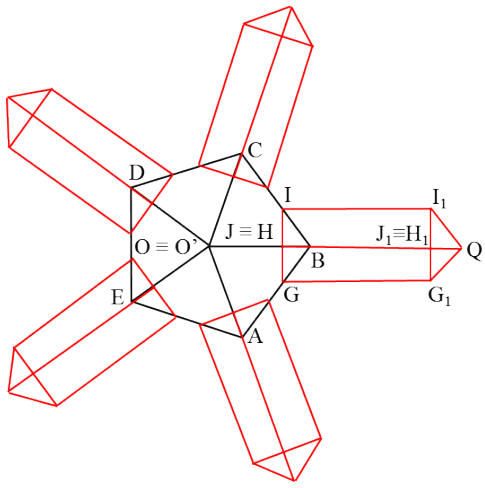
$$\frac{surface\ area}{weight} = \frac{272.99\ nm^2}{4467.23 * 10^{-21} g} \fallingdotseq 6.11 * 10^{19} (\frac{nm^2}{g}) \fallingdotseq 61.1 (\frac{m^2}{g})$$

$$\frac{surface\ area}{volume} = \frac{272.99\ nm^2}{301.84\ nm^3} \fallingdotseq 0.90\ (\frac{1}{nm})$$

Calculation of surface area/volume of Pt_3Ni@Rh-Rh star shape.



a)



b)

Fig. S13. Model of a) Pt_3Ni@Rh star shape (Only one arm is shown for clarity. But for calculation, all five arms are considered.), b) projection of starshape on ABCDE plane.

With star shape, surface area has two parts: 1) area of pentagon part with five corners cut by arms and 2) area of five arms (For simplicity, only one arm is shown in Fig. S10.).

For pentagon part: Surface area can be computed as the area of ten times the area of one truncated triangle. Area of truncated triangle can be computed by formula.

$$S_{\text{truncated triangle}} = S_{ABO} - 2*S_{GBJ} \rightarrow S_{\text{pentagon part}} = 10(S_{ABO} - 2*S_{GBJ})$$

ABO is equilateral triangles with ***a*** as the given side length: AB = AO = BO = a → $S_{ABO} = \frac{\sqrt{3}}{4}a^2$

GBJ is also equilateral triangles with $\boldsymbol{a_1}$ as the given side length, BG = JG = BJ = a_1

$$\frac{a_1}{a} = \frac{BG}{BA} = \frac{GI}{AC} \rightarrow a_1 = \frac{GI}{AC}a$$

ABCDE is pentagon → AC = 2*AB*sin (0.3π) = 2*a*sin (0.3π)

$$\rightarrow a_1 = \frac{GI * sin(0.3\pi)}{2} \qquad \rightarrow S_{GBJ} = \frac{\sqrt{3}}{4}a_1^2 = \frac{\sqrt{3}}{4}\left(\frac{GI * sin(0.3\pi)}{2}\right)^2$$

For arm part: arm is right prism $GHIJG_1H_1I_1J_1$ with tetrahedronal base have side length a_1 = GJ, the height l = GG_1 and pyramid $QG_1H_1I_1J_1$ (Fig. S9).

lateral surface area of arm part = lateral surface area of $GHIJG_1H_1I_1J_1$+ lateral surface area of $QG_1H_1I_1J_1$

$$S_{arm} = S_{GHIJG_1H_1I_1J_1} + S_{QG_1H_1I_1J_1}$$

$$S_{GHIJG_1H_1I_1J_1} = GG_1(GJ + JI + IH + GH) = 4GG_1 * GJ = 4GG_1 * a_1$$

$$S_{QG_1H_1I_1J_1} = S_{QG_1H_1} + S_{QG_1J_1} + S_{QH_1I_1} + S_{QI_1J_1} = 4\,S_{QG_1H_1}$$

$$\rightarrow S_{star} = S_{pentagon\,part} + 5 * S_{arm} = 10(S_{ABO} - 2 * S_{GBJ}) + 5(4GG_1 * a_1 + 4\,S_{QG_1H_1})$$

Other hand: $S_{GBJ} = S_{QG_1H_1}$

$$\rightarrow S_{star} = 10S_{ABO} + 20GG_1 * a_1 = S_{pentagon} + 20GG_1 * a_1 = \frac{5\sqrt{3}}{2}a^2 + 10GG_1 * GI * sin(0.3\pi)$$

Same method for volume: $V_{star} = V_{pentagon} + 5 * V_{arm} = V_{pentagon} + 5 * V_{GHIJG_1H_1I_1J_1}$

$$V_{pentagon} = \frac{5+\sqrt{5}}{12}a^3 = \frac{5+\sqrt{5}}{12}AB^3$$

$$V_{GHIJG_1H_1I_1J_1} = GG_1 * S_{GHIJ} = GG_1 * \left(\frac{1}{2} * GI * JH\right)$$

$$\frac{JH}{OO'} = \frac{BJ}{BO} = \frac{GI}{AC} \rightarrow JH = OO'\frac{GI}{AC} = \sqrt{\frac{5-\sqrt{5}}{10}}a * \frac{GI}{2a\sin(0.3\pi)} = \sqrt{\frac{5-\sqrt{5}}{10}}\frac{GI}{2\sin(0.3\pi)}$$

$$V_{GHIJG_1H_1I_1J_1} = GG_1 * \left(\frac{1}{2} * GI * \sqrt{\frac{5-\sqrt{5}}{10}}\frac{GI}{2\sin(0.3\pi)}\right) = \sqrt{\frac{5-\sqrt{5}}{10}}\frac{GI^2GG_1}{4\sin(0.3\pi)}$$

$$V_{star} = \frac{5+\sqrt{5}}{12}AB^3 + 5\sqrt{\frac{5-\sqrt{5}}{10}}\frac{GI^2GG_1}{4\sin(0.3\pi)}$$

<u>Apply for Pt_3Ni@Rh-Rh star</u>: (standard deviations measured from 50 NPs)

$\bar{AB} = a = 9.96 \pm 0.97\ nm$; $\bar{GI} = 5.16 \pm 0.26\ nm$; $\bar{GG_1} = 13.66 \pm 1.33\ nm$;

$S_{Pt_3Ni@Rh-Rh\ star} \fallingdotseq 999.80\ (nm^2)$

$V_{Pt_3Ni@Rh-Rh\ star} \fallingdotseq 891.24 (nm^3)$

The energy dispersive X-ray spectroscopy (EDAX) analysis of Pt_3Ni@Rh-Rh star nanostructures showed the % weight of Ni, Rh and Pt: ~ 0 %, 75.351 % and 24.648 % (Figure S9b). Density of Ni, Rh and Pt: $8.90*10^{-21}$ g.nm^{-3}, $12.41*10^{-21}$ g.nm^{-3}, $21.45*10^{-21}$ g.nm^{-3}

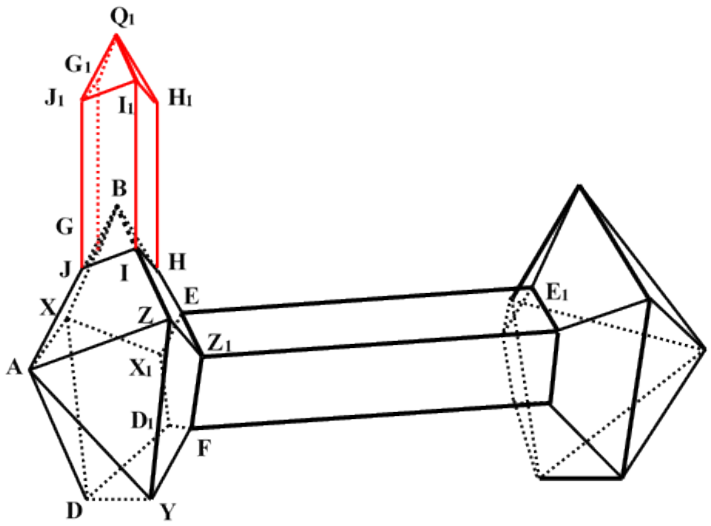
$$\rho_{Pt_3Ni@Rh\ pentagon} \fallingdotseq 13.85 * 10^{-21}\ g.nm^{-3}$$

$$m_{Pt_3Ni@Rh\ pentagon} = 13.85 * 10^{-21} * 891.24 \fallingdotseq 12342.48 * 10^{-21} g$$

$$\frac{surface\ area}{weight} = \frac{999.80\ nm^2}{12342.48 * 10^{-21} g} \fallingdotseq 8.10 * 10^{19}\left(\frac{nm^2}{g}\right) \fallingdotseq 81.0\left(\frac{m^2}{g}\right)$$

$$\frac{surface\ area}{volume} = \frac{999.80\ nm^2}{891.24\ nm^3} \fallingdotseq 1.12\ \left(\frac{1}{nm}\right)$$

Calculation of surface area/volume of paddlewheel.



a)

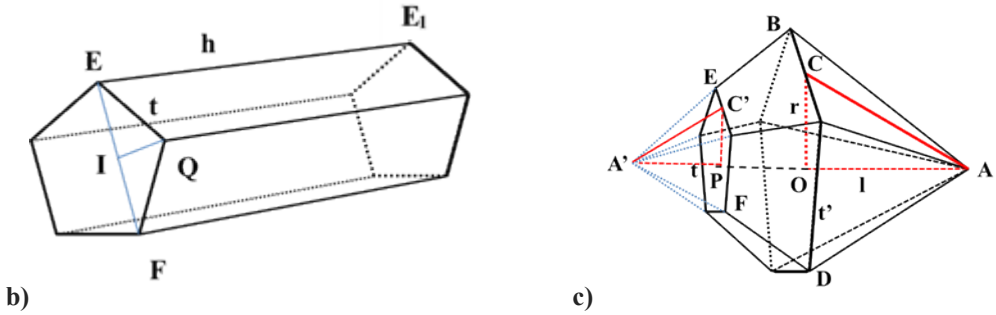


Fig. S14. Model of a) nanopaddlewheel (Only one arm is shown for clarity. But for calculation, all five arms are considered.), b) a five-fold twinned Pt_3Ni@Rh nanorod part, and c) one tip without arm.

Paddlewheel has two structural components: rod part and stars at the tips

Rod part is right prism with pentagon base have side length t and h = EE_1 is the height (Fig. S11b).

→ Interior angle of pentagon base: $\frac{(n-2)\pi}{n} = \frac{(5-2)\pi}{5} = 0.6\pi$

where n: number sided regular polygons; angle $E\hat{Q}I = 0.3\,\pi$

we can get EF from TEM image (see maximum length on the TEM image and see Fig. S11b).

→ $$t = \frac{EI}{sin E\hat{Q}I} = \frac{EF}{2sin(0.3\pi)}$$

→the surface area of rod part is lateral area of prism:

$$S_{rod\ part} = n.t.h = 5.\frac{EF}{2sin(0.3\pi)}.EE_1$$

$$V_{rod\ part} = \frac{n\ h.t^2}{4\ tan\frac{\pi}{n}} = \frac{5.EE_1}{4tan(0.2\pi)}\left(\frac{EF}{2sin0.3\pi}\right)^2$$

Star at tip has 3 parts: one part is shaped as pyramid and other are frustum and five arms (see Fig. S11).

Same method for calculation of a star shape.

*Lateral surface area of star at tip = Lateral surface area of pentagon pyramid ABZYDX + Lateral surface area of frustum $BZYDXEZ_1FD_1X_1$ + 5*Lateral surface area of $GHIJG_1H_1I_1J_1$*

*Volume of star at tip = Volume of pentagon pyramid ABZYDX + Volume of frustum $BZYDXEZ_1FD_1X_1$ + 5*Volume of $GHIJG_1H_1I_1J_1$*

<u>For pentagon pyramid ABZYDX</u>

Pyramid is pentagonal with base side length $t_1 = \frac{BD}{2sin(0.3\pi)}$ and slant height AC

$$AC = \sqrt{l^2 + r_1^2}$$

Where l is the pyramid altitude, l = AO, r_1 is the radius of the base.

$$r_1 = \frac{t_1}{2sin\frac{\pi}{n}} = \frac{BD}{4sin\frac{\pi}{5}sin(0.3\pi)} \rightarrow AC = \sqrt{AO^2 + \frac{BD^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}$$

→lateral surface area of pyramid part:

$$S_{ABZYDX} = n.\frac{1}{2}t_1.AC = 5.\frac{BD}{4sin(0.3\pi)}\sqrt{AO^2 + \frac{BD^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}$$

$$V_{ABZYDX} = \frac{n}{12}l.t_1^2cot\frac{\pi}{n} = \frac{5}{12}AO\left(\frac{BD}{2sin(0.3\pi)}\right)^2cot\frac{\pi}{5} = \frac{5cot(0.2\pi)}{48(\sin(0.3\pi))^2}AO * BD^2$$

<u>For frustum BZYDXEZ$_1$FD$_1$X$_1$</u>

Frustum part is the portion of a pyramid that lies between two parallel planes cutting it. Bases of frustum are pentagon with side t and t_1 (t_1>t).

*Lateral surface area of frustum is lateral surface area of big pyramid (*apex is A' and base is pentagon containing the point BDC, center O) *subtraction lateral surface area of small pyramid (*apex is A' and base is pentagon containing the point EFC', center P*)*.

lateral surface area of big pyramid =

$$5.\frac{BD}{4\sin(0.3\pi)}\sqrt{A'O^2 + \frac{BD^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}} = 5.\frac{BD}{4sin(0.3\pi)}\sqrt{AO^2 + \frac{BD^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}$$

Same method for calculation of pyramid part.

→ lateral surface area of small pyramid $= n\frac{t.A'C'}{2} = 5.\frac{EF}{4sin(0.3\pi)}\sqrt{A'P^2 + \frac{EF^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}$

where A'P = A'O – OP = AO – OP

→ lateral surface area of small pyramid = $5.\frac{EF}{4sin(0.3\pi)}\sqrt{(AO - OP)^2 + \frac{EF^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}$

→lateral surface area of frustum part:

$$S_{BZYDXEZ_1FD_1X_1} = \frac{5}{4\sin(0.3\pi)}\left(BD\sqrt{AO^2 + \frac{BD^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}} - EF\sqrt{(AO - OP)^2 + \frac{EF^2}{(4\sin(0.2\pi).\sin(0.3\pi))^2}}\right)$$

$$\frac{A'P}{A'O} = \frac{A'E}{A'B} = \frac{EF}{BD} \rightarrow A'P = \frac{EF}{BD}A'O = \frac{EF}{BD}AO \rightarrow OP = AO - \frac{EF}{BD}AO$$

*Volume of frustum $BZYDXEZ_1FD_1X_1$ is volume of big pyramid (*apex is A' and base is pentagon containing the point BDC, center O) *subtraction volume of small pyramid (*apex is A' and base is pentagon containing the point EFC', center P*).*

$$V_{BZYDXEZ_1FD_1X_1} = \frac{5}{12}A'O\left(\frac{BD}{2\sin(0.3\pi)}\right)^2 cot(0.2\pi) - \frac{5}{12}A'P\left(\frac{EF}{2\sin(0.3\pi)}\right)^2 cot(0.2\pi) = \frac{5cot(0.}{48(\sin(0.3}$$

→*Lateral surface area of one tip can be computed as:*

$$S_{tip} = S_{ABZYDX} + S_{BZYDXEZ_1FD_1X_1} + 5 * S_{GHIJG_1H_1I_1J_1} = \frac{5}{4\sin(0.3\pi)}\left(2.BD\sqrt{AO^2 + \frac{}{(4\sin(}}\right.$$
$$+ 10GG_1 * GI * sin(0.3\pi)$$

Total surface area of paddlewheel:

$$S_{PW} = S_{rod\,part} + 2 * S_{tip} = 5.\frac{EF}{2\sin(0.3\pi)}.EE_1 + \frac{5}{2\sin(0.3\pi)}\left(2.BD\sqrt{AO^2 + \frac{BD^2}{(4\sin(0.2\pi).s}}\right.$$
$$+ 20GG_1 * GI * sin(0.3\pi)$$

*Volume of paddlewheel = Volume of rod part + 2*Volume of star on the tip*

$$V_{tip} = V_{ABZYDX} + V_{BZYDXEZ_1FD_1X_1} + 5 * V_{GHIJG_1H_1I_1J_1} = \frac{5\cot(0.2\pi)}{48(\sin(0.3\pi))^2}AO * BD^2 + \frac{5c}{48(}$$
$$+ 5 * \sqrt{\frac{5-\sqrt{5}}{10}}\frac{GI^2GG_1}{4\sin(0.3\pi)} = \frac{5\cot(0.2\pi)}{48(\sin(0.3\pi))^2}[2AO * BD^2 - (AO - OP)EF^2] + 5 * \sqrt{\frac{5}{}}$$

$$V_{PW} = V_{rod\,part} + 2 * V_{tip} = \frac{5.EE_1}{4tan(0.2\pi)}\left(\frac{EF}{2sin0.3\pi}\right)^2 + \frac{5\cot(0.2\pi)}{24(\sin(0.3\pi))^2}[2AO * BD^2 - (A$$

<u>Apply for nanopaddlewheel</u>: (standard deviations measured from 50 NPs)

$\bar{B}Z = a = 5.85 \pm 0.32\ nm$; $\bar{G}I = 5.42 \pm 0.24\ nm$; $\bar{G}G_1 = 11.46 \pm 1.12\ nm$;

$\bar{E}F = 3.76 \pm 0.27\ nm$; $\bar{E}E_1 = 21.44 \pm 1.97\ nm$;

→ $\bar{A}O = h = \sqrt{\frac{5-\sqrt{5}}{10}}a \fallingdotseq 3.08\ nm$

$\bar{B}D = 2a * \sin(0.3\pi) \fallingdotseq 9.47\ (nm)$

$\bar{O}P = \bar{A}O - \frac{\bar{E}F}{\bar{B}D}\bar{A}O \fallingdotseq 1.96$ (nm)

$S_{PW} \fallingdotseq 1570.37\ (nm^2)$

$V_{PW} \fallingdotseq 938.96\ (nm^3)$

The energy dispersive X-ray spectroscopy (EDAX) analysis of paddlewheel nanostructures showed that % weight of Ni, Rh and Pt are ~ 0 %, 65.164 % and 34.835 % (Figure S9c).

density of Ni, Rh and Pt: $8.90*10^{-21}$ g.nm^{-3}, $12.41*10^{-21}$ g.nm^{-3}, $21.45*10^{-21}$ g.nm^{-3}

$\rightarrow \rho_{Pt_3Ni@Rh\ pentagon} \fallingdotseq 14.55 * 10^{-21}\ g.nm^{-3}$

$$m_{Pt_3Ni@Rh\ pentagon} = 14.55 * 10^{-21} * 938.96 \fallingdotseq 13661.87 * 10^{-21} g$$

$$\frac{surface\ area}{weight} = \frac{1570.37\ nm^2}{13661.87 * 10^{-21} g} \fallingdotseq 11.49 * 10^{19} (\frac{nm^2}{g}) \fallingdotseq 114.90 (\frac{m^2}{g})$$

$$\frac{surface\ area}{volume} = \frac{1570.37\ nm^2}{938.96\ nm^3} \fallingdotseq 1.67 \left(\frac{1}{nm}\right)$$