Waste biorefinery technologies for accelerating sustainable energy processes

Enhancing Oxygen Reduction via N-Doped Graphene Derived from PET Bottle Waste as an Efficient Carbon Support for PdNi Nanoparticles

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PET Bottle Waste as an Efficient Carbon Support for PdNi Nanoparticles

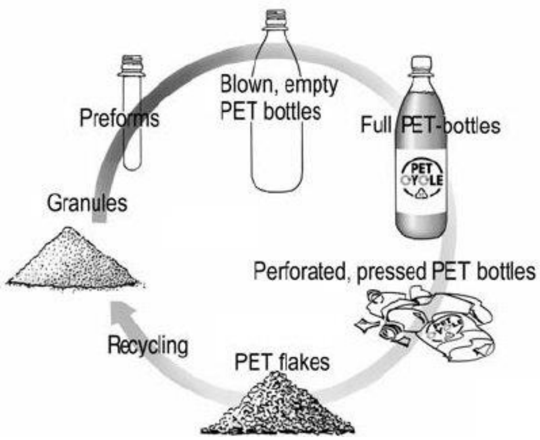
Introduction

W I R E

Why materials from PET bottles waste?

What is the problem with PET plastic waste?

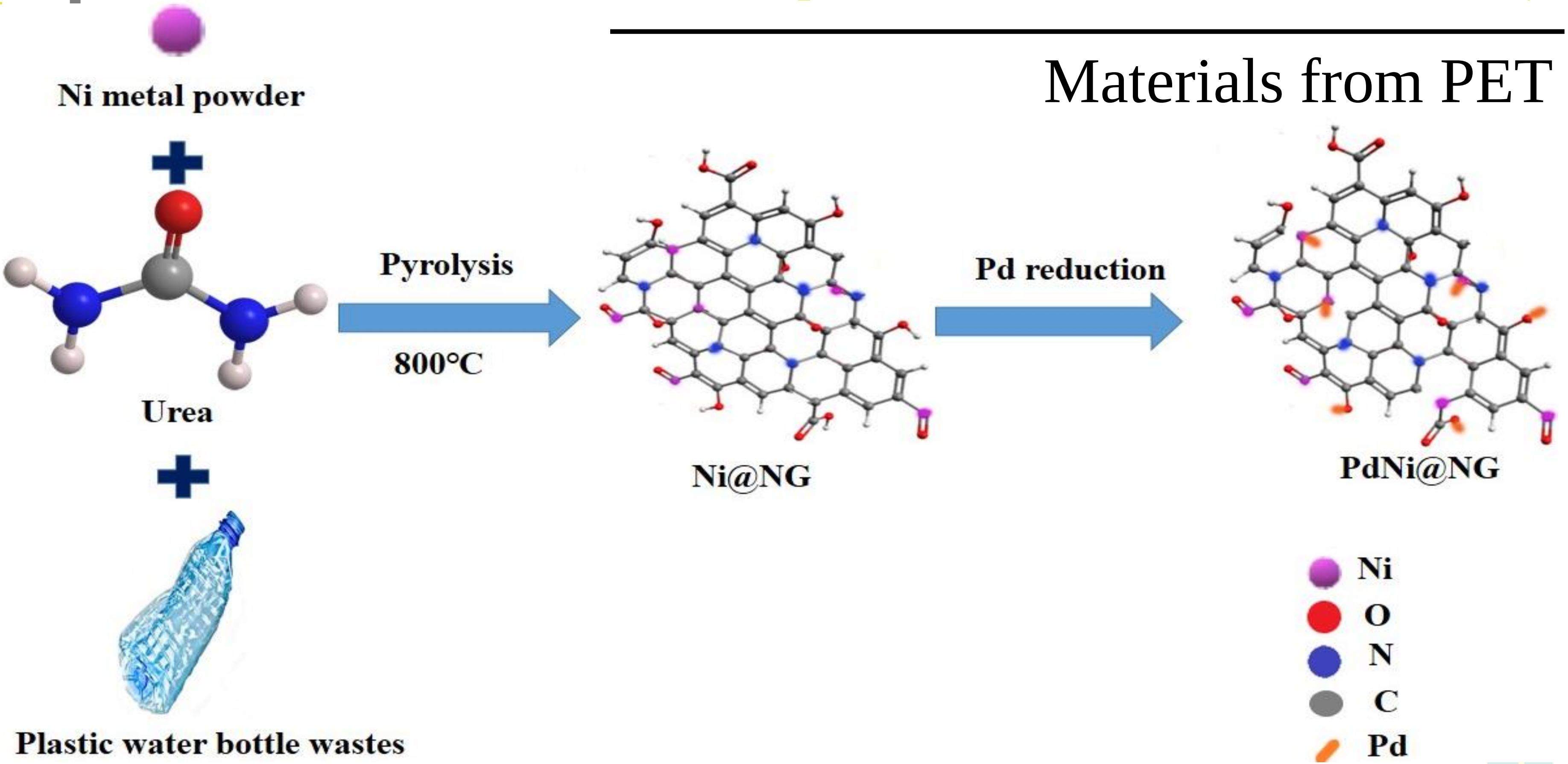
- **plastics like PET can break down into tiny pieces called microplastics**
- are pervasive in our oceans, bays, lakes, and even drinking water



Using **waste PET as an electrocatalyst support for electrochemical energy conversion devices can lower its environmental impact**, including greenhouse gas emissions, energy demand, water consumption, acid rain, and eutrophication potential.

Experimental

Materials from PET



Schematic illustration of the preparation of PdNi@NG nanocomposites.

Experimental

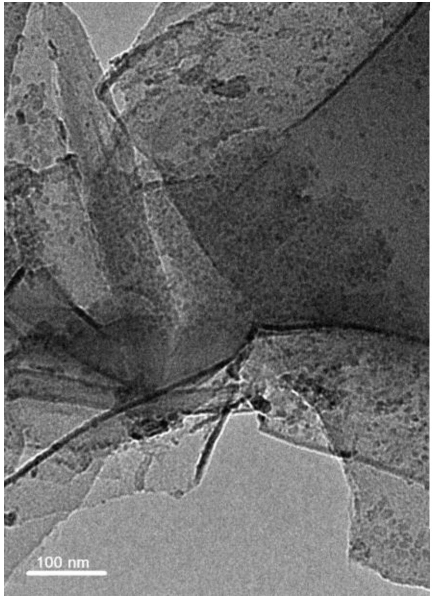
Materials from PET

The composition of the prepared catalysts as determined by ICP-OES.

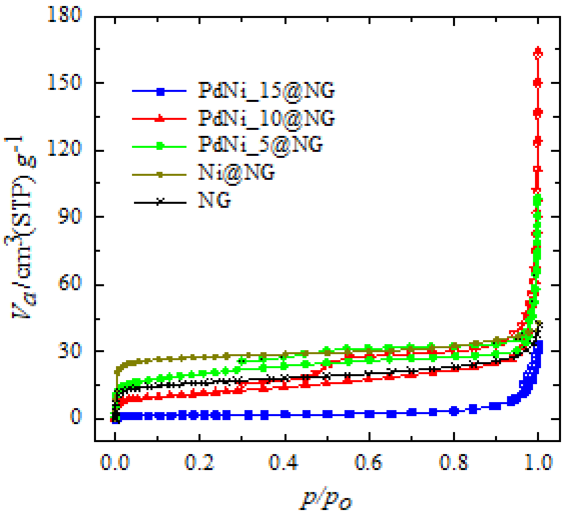
Catalyst	Loading	
	Pd, µg cm^{-2}	Ni, mg cm^{-2}
Ni@NG	-	0.70
PdNi_5@NG	0.70	0.43
PdNi_10@NG	0.94	0.41
PdNi_15@NG	2.05	0.44

Results

Characterization



TEM image of PdNi_15@NG.



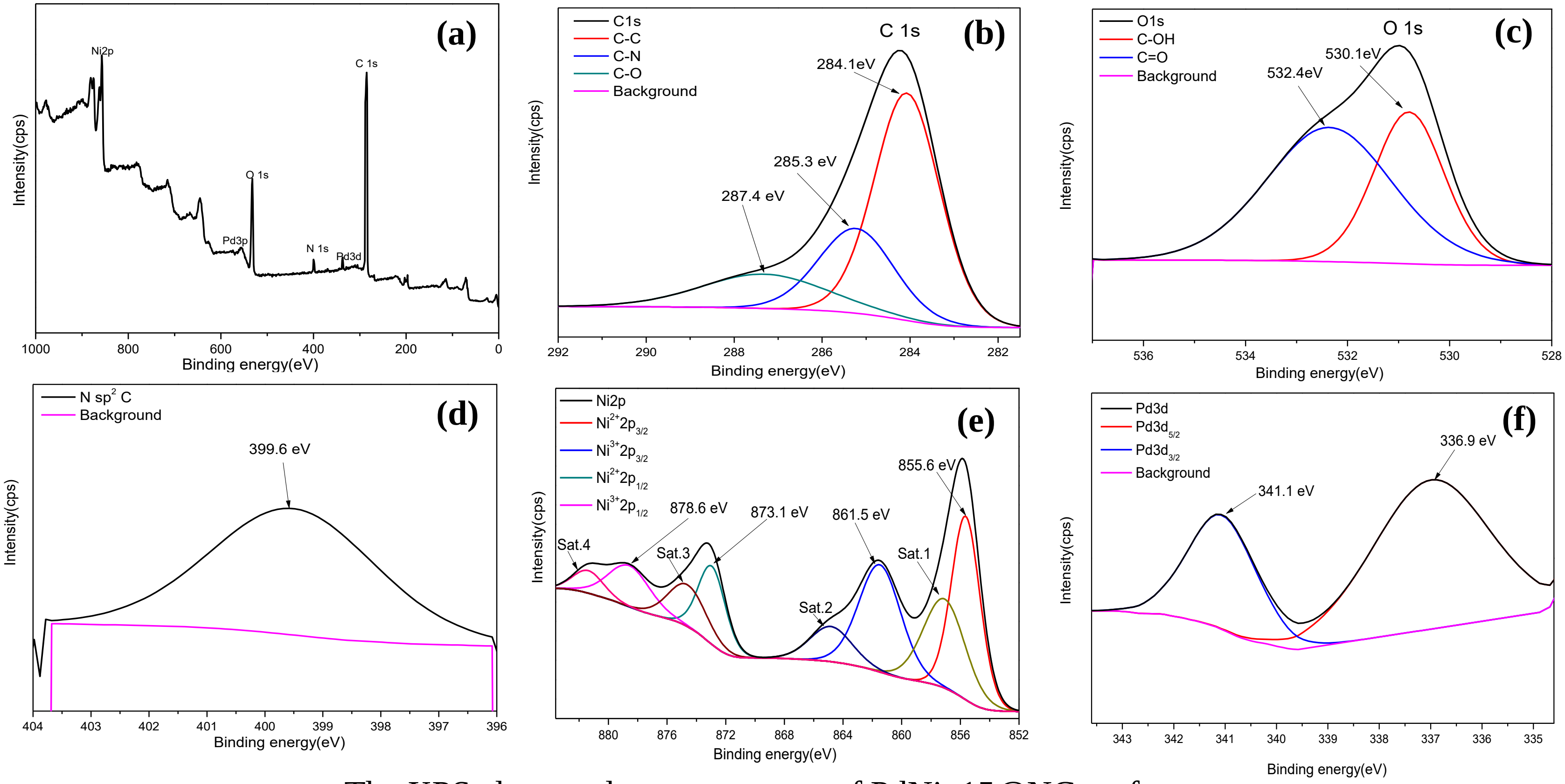
Adsorption/desorption isotherms of NG, Ni@NG, PdNi_5@NG, PdNi_10@NG, and PdNi_15@NG catalysts.

Pore structure parameters of samples.

Catalysts	$a_{S,BET}$ (m^2g^{-1})	Total pore volume (cm^3g^{-1})	Average pore diameter (nm)
NG	57.3	0.053	3.72
Ni@NG	97.3	0.062	2.56
PdNi_5@NG	70.6	0.076	4.31
PdNi_10@NG	39.5	0.089	8.99
PdNi_15@NG	6.05	0.033	21.5

Results

Characterization



The XPS elemental survey spectra of PdNi_15@NG surface.

Experimental

Materials from PET

1. Catalyst

NG;
Ni@NG;
PdNi@NG

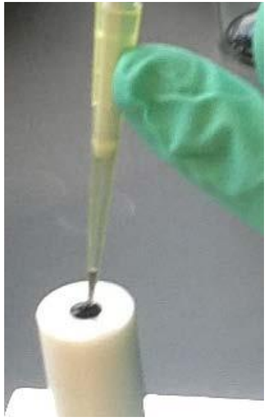
2. Catalyst ink

- 5 mg catalyst
- 100 µL of 2 wt.% solution of PVDF in NMP

Sonicated for 30 min

3 µL

3. Drying

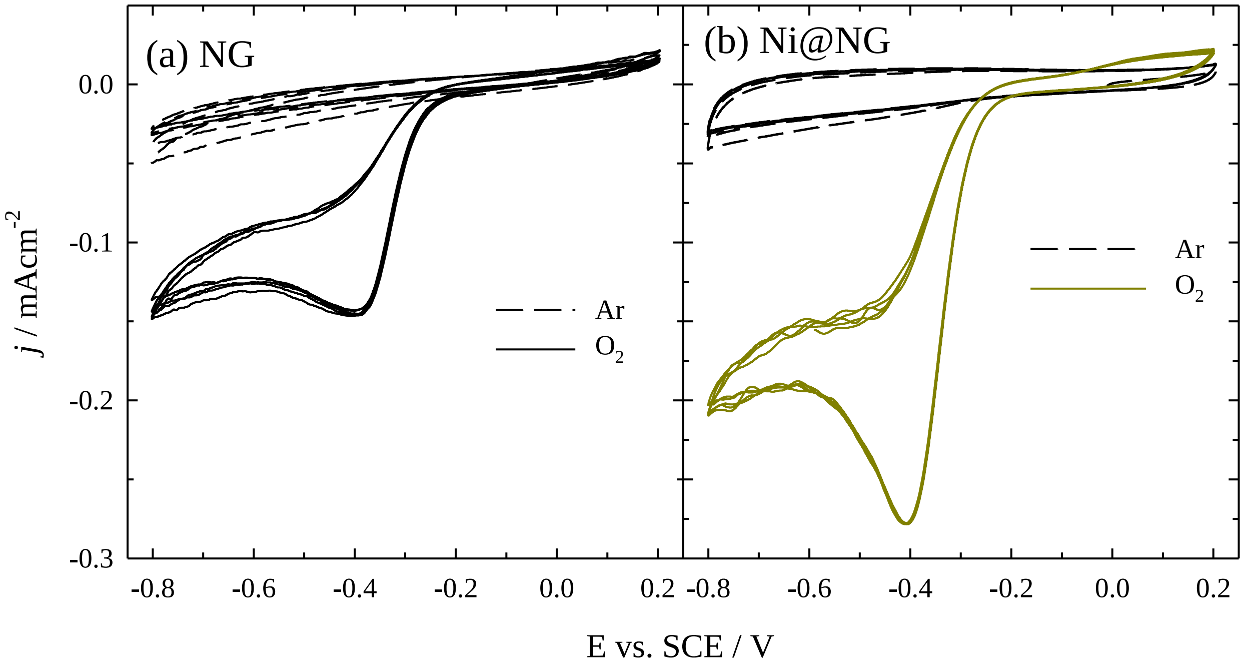


55 ºC in the oven for 4 h

PVDF – polyvinylidene fluoride; NMP – N–methyl–2– pyrrolydone

Results

Oxygen reduction

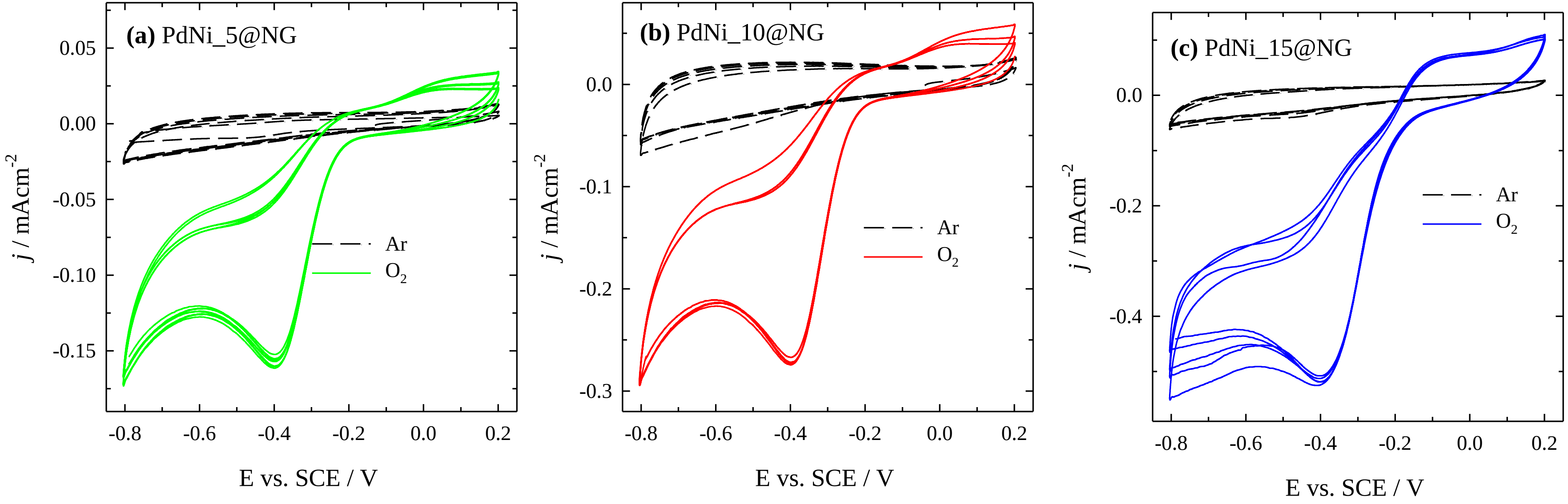


CVs of NG (a) and Ni@NG (b) recorded in 0.1 M KOH at 50 mV s^{-1}.

Current densities are ~2 times higher at Ni@NG than at the NG support

Results

Oxygen reduction



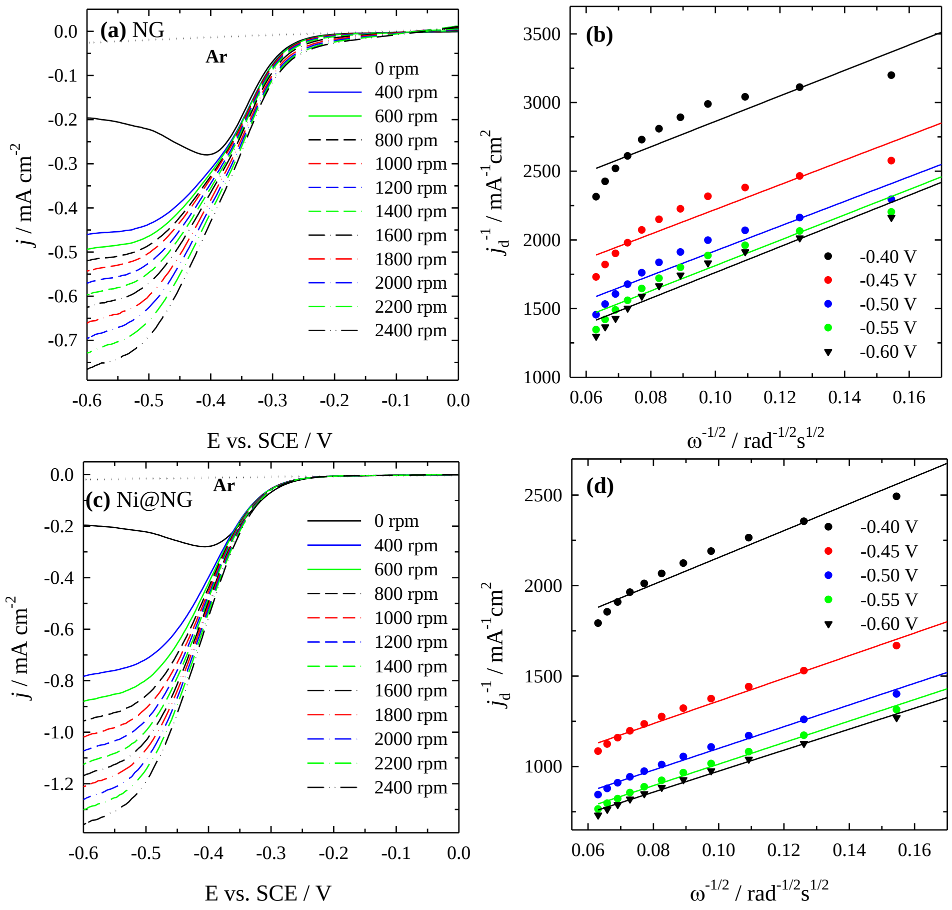
CVs of PdNi_5@NG (a), PdNi_10@NG (b), and PdNi_15@NG (c) in 0.1 M KOH at 50 mV s^{-1}.

Current densities are ~2 and over 3 times higher at PdNi_15@NG than at PdNi_10@NG and PdNi_5@NG catalysts, respectively.

Results

WIRE

Oxygen reduction



Koutecky-Levich (K-L) equation:

$$\frac{1}{I} = \frac{1}{I_k} + \frac{1}{I_d} = -\frac{1}{nFAkc^{b}_{O_2}} - \frac{1}{0.62\, nFAD^{2/3}_{O_2}\nu^{-1/6}c^{b}_{O_2}\,\omega^{1/2}}$$

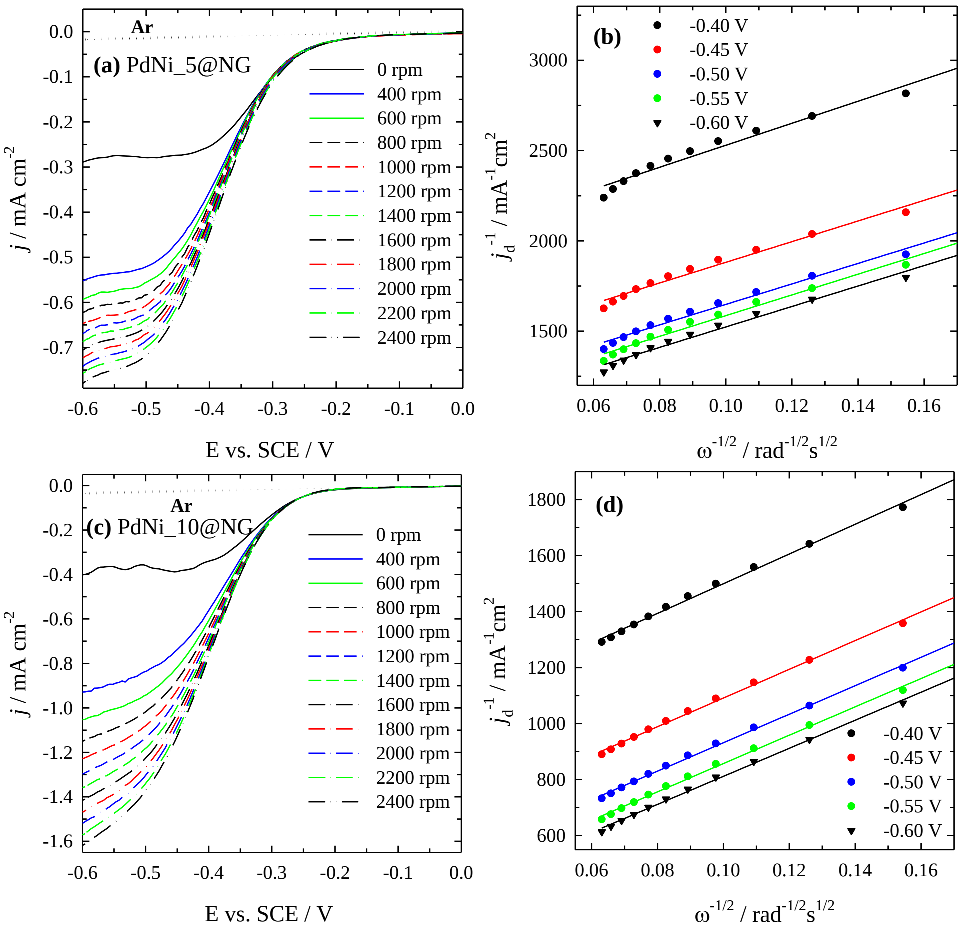
Current densities increase ~ 3.9 and 6.9 times with the increase of rotation rate from 0 to 2400 rpm on NG and Ni@NG catalysts, respectively.

LSVs of NG (a) and Ni@NG (c) recorded in 0.1 M KOH at 10 mV s^{-1} at different rotation rates. (b,d) K-L plots of the NG (b) and Ni@NG (d) collected at different potentials.

Results

W I R E

Oxygen reduction



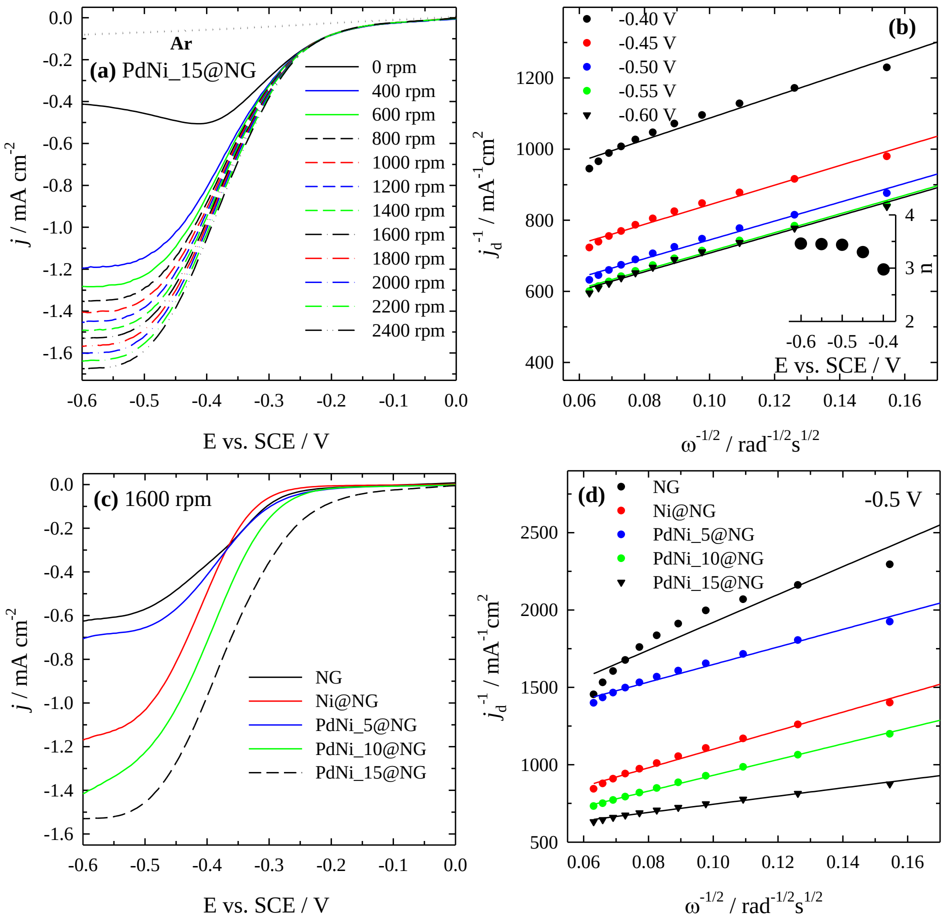
Current densities increase ~2.7 and 4.0 times with the increase of rotation rate from 0 to 2400 rpm on PdNi_5@NG and PdNi_10@NG catalysts, respectively.

LSVs of PdNi_5@NG (a) and PdNi_10@NG (c) recorded in 0.1 M KOH at 10 mV s^{-1} at different rpms. (b,d) K-L plots of PdNi_5@NG (b) and PdNi_10@NG (d) collected at different potentials.

Results

W I R E

Oxygen reduction



(a) LSVs of PdNi_15@NG recorded in 0.1 M KOH at 10 mV s^{-1} at different rpms. (b) K-L plots of PdNi_15@NG collected at different potentials. (c) Comparison of cathodic currents of different catalyst compositions at 1600 rpm. (d) K-L plots of the different catalysts collected at -0.5 V.

The current densities are ~ 1.1-2.5 times higher on PdNi_15@NG.

Table 3. ORR performance of different catalysts.

	E_{onset} (V)	$E_{1/2}$ (V)	j_d (mA cm^{-2})
GN	-0.274	-0.371	-0.63
Ni@GN	-0.293	-0.410	-1.16
PdNi_5@NG	-0.258	-0.376	-0.71
PdNi_10@NG	-0.249	-0.396	-1.41
PdNi_15@NG	-0.161	-0.366	-1.53

Conclusions

- The studies showed that the prepared PdNi@NG catalysts have good electrochemical stability in alkaline solution.
- The PdNi_15@NG catalyst exhibited the best electrocatalytic activity for the oxygen reduction reaction.
- The prepared PdNi@NG catalysts are promising electrode materials for alkaline fuel cells.
- N-doped graphene from PET bottle wastes was demonstrated to be an effective electrocatalyst support.