Supplementary Information (SI) for Journal of Materials Chemistry A.

Supporting Information

Sintering-resistant and active-species-adjustable Ni catalysts supported on P-doped biochar via nanopore-confined activation for efficient levulinic acid hydrogenation

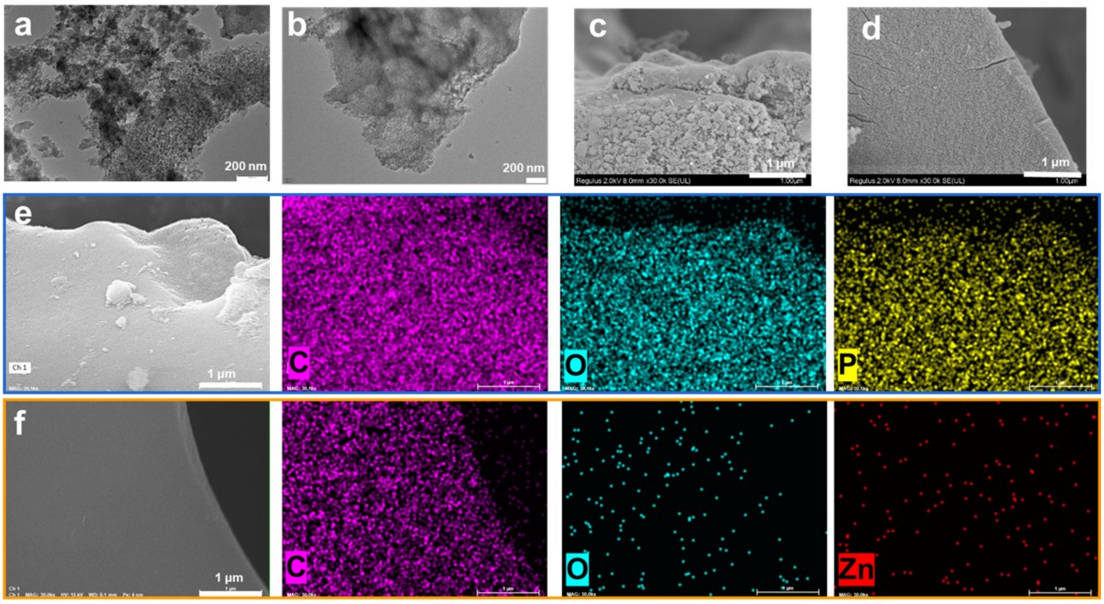

Figure S1. TEM images of (a) PAC and (b) ZAC, SEM images of (c) PAC and (d) ZAC, EDS mappings of (e) PAC and (f) ZAC

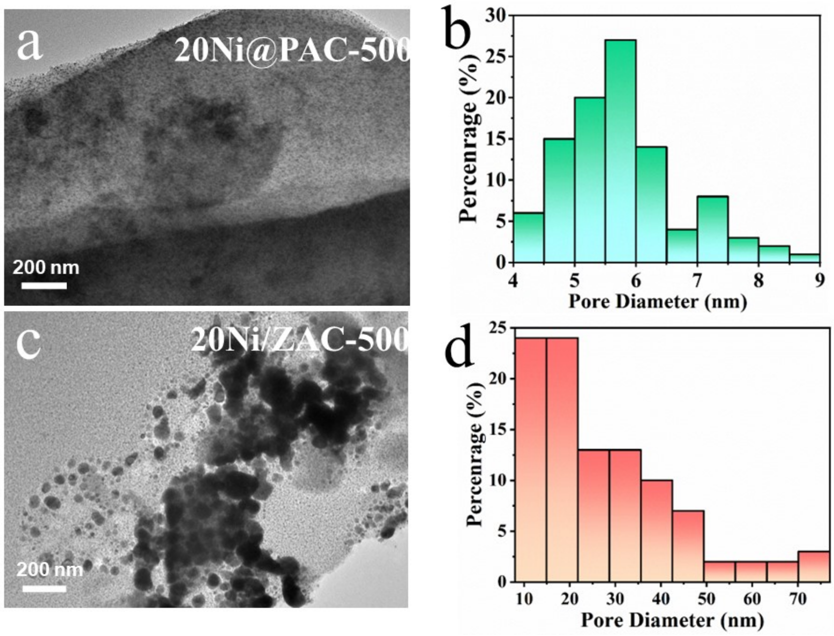

Figure S2 (a) TEM image and (b) particle size statistics of 20Ni@PAC-500; (c) TEM image and (d) particle size statistics of 20Ni/ZAC-500.

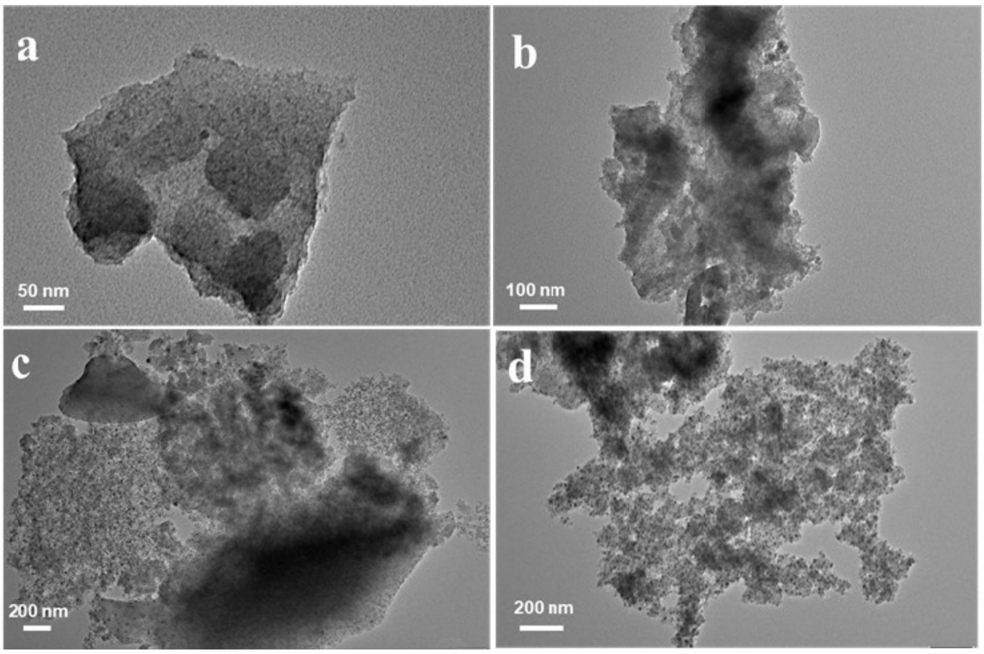

Figure S3 TEM image of (a) 5Ni@PAC-600, (b) 10Ni@PAC-600 , (c) 15Ni@PAC-600 and (d) 25Ni@PAC-600.

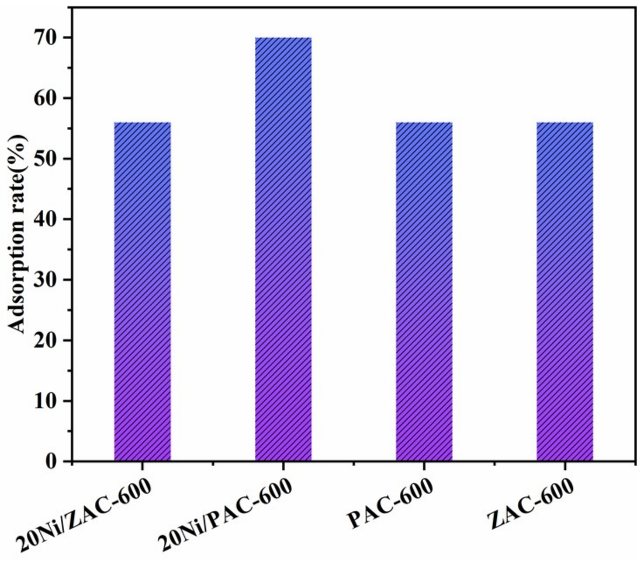

Figure S4. LA adsorption by 20Ni@PAC-600, 20Ni/ZAC-600 and biochars. Adsorption conditions: 10 mL of deionized water, 200 mg of LA, 100 mg of catalyst or biochar, 3 MPa of N_2 pressure, 120 °C, 2 h.

Table S1 Elemental analysis of biochars

	C [%]	H [%]	O [%]	N [%]	S [%]
PAC	64.85	3.20	17.87	0.65	0.16
ZAC	89.40	3.16	5.45	0.89	0.31

Table S2 The distribution of P functional groups from XPS

Distributions of phosphorus species						
	P_2O_5(%)	C-O-P(%)	$C-PO_3/C_2-PO_2$(%)	C_3-P=O(%)	Ni-P	
	135.1 eV	134.3 eV	133.5 eV	132.7 eV	130.7 eV	129.9 eV
PAC	6.8	41	44.8	7.4	\	\
20Ni@PAC-300	2.7	39.6	48.5	9.3	\	\
20Ni@PAC-400	5.8	23.3	66.8	4.1	\	\
20Ni@PAC-500	15.6	23.4	28.7	16.4	5	10.7
20Ni@PAC-600	38.5	7.7	17.4	5.2	12.1	19.1

Table S3 Comparison of hydrogenation of levulinic acid (ester) catalyzed by nickel phosphide

Entry	Catalyst	Reactant[a]	Condition	GVL yield	Ref
1	Ni_2P	LA	100 °C，4 MPa, 2h, water	22%	[1]
	$(PrPO_4)_{1.9}/Ni_2P$	LA	100 °C，4 MPa, 2h, water	95%	
2	Ni_2P	LA	120 °C，2 MPa, 2h, water	11.3%	[2]
	$(YPO_4)_{0.2}/Co_{1.0}Ni_{1.0}P$	LA	120 °C，0.5 MPa, 2h, water	98.1%	
3	NiP	LA	180 °C，3 MPa, 4h, solvent-free	26.9%	[3]
4	Ni2P	EL	250 °C，5 MPa, 6h, ethanol	41.7%	[4]
5	0.3PNi/SBA-15	ML	90 °C，2 MPa, 6h, water	98.3%	[5]
6	Ni-0.27P/Al_2O_3	EL	140 °C，2.5 MPa, 4h, n-hexane	95.4%	[6]
	Ni-0.38P/Al_2O_3	EL	140 °C，2.5 MPa, 4 h, n-hexane	97.6%	
7	Ni-P/Al_2O_3	EL	140 °C，2.5 MPa, 4 h, n-hexane	97.7%	[7]
8	Ni@PAC-600	LA	120 °C，3 MPa, 2h, water	99.9%	**This work**
			120 °C，0.5 MPa, 2h, water	76%	

[a] LA, ML and EL stand for levulinic acid, methyl levulinic acid and ethyl levulinic acid, respectively

References

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[7] Y. Li, K. Lyu, D. Liu, et al. Metal-modified Ni phosphides: Highly efficient catalysts for the hydrogenation of ethyl levulinate[J]. Catal. Today, 2024, 442, 114938.