Supplementary Materials

Waste Incineration Fly Ash-Based Bifunctional Catalyst for Upgrading Glucose to Levulinic Acid

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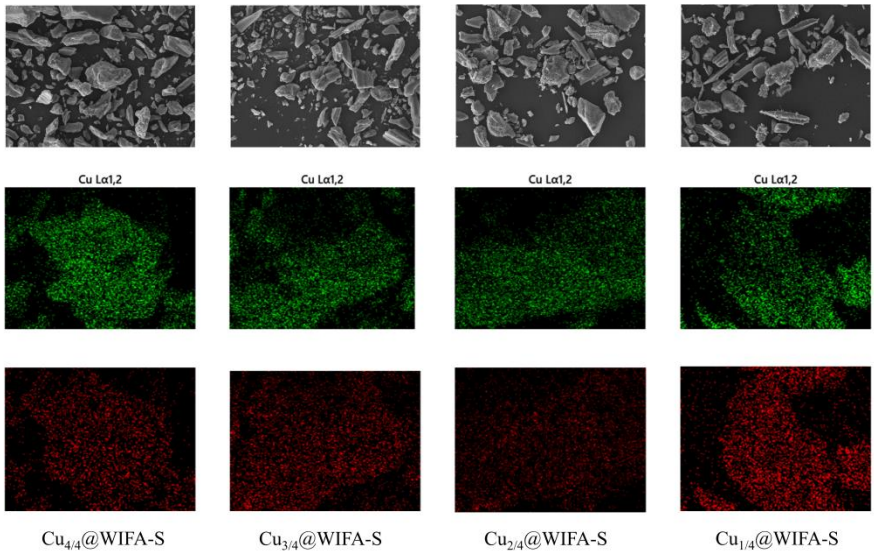


Figure S1. SEM and EDS spectra of Cu@WIFA-S catalysts in different ratios.

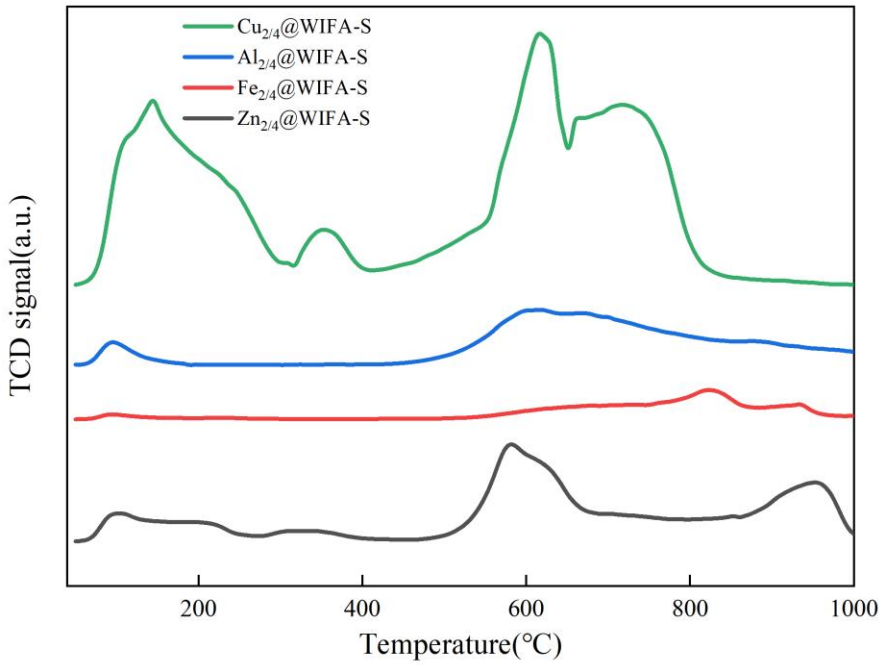


Figure S2. NH_3-TPD plots of $Zn_{2/4}$@WIFA-S, $Fe_{2/4}$@WIFA-S, $Al_{2/4}$@WIFA-S and $Cu_{2/4}$@WIFA-S.

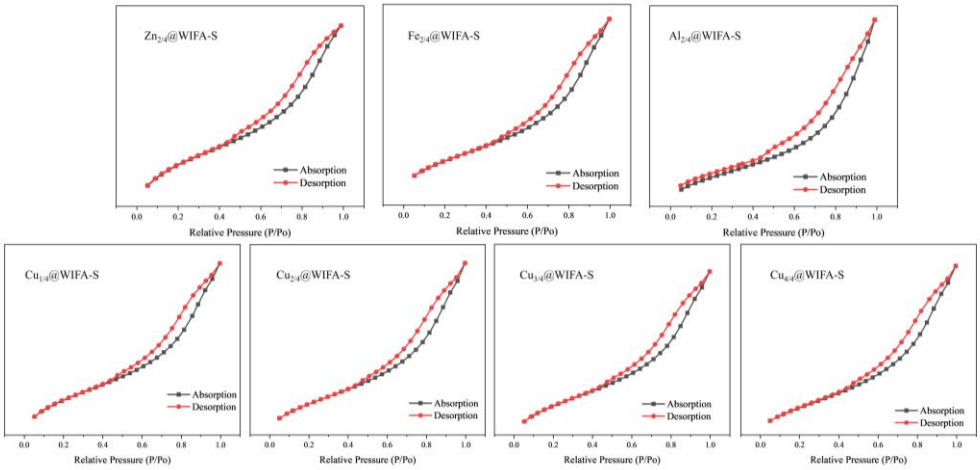


Figure S3 Adsorption isotherm plot for Metals$_{x/4}$@WIFA-S catalyst N_2.

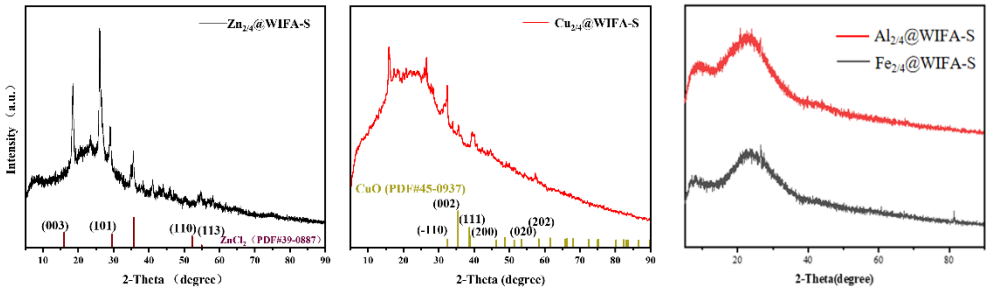


Figure S4 XRD patterns of Zn2/4@WIFA-S, Fe2/4@WIFA-S, Al2/4@WIFA-S and Cu2/4@WIFA-S catalysts.

Figure S4 shows the XRD spectra of Zn2/4@WIFA-S, Fe2/4@WIFA-S, Al2/4@WIFA-S and Cu2/4@WIFA-S catalysts. As can be seen, these four catalysts showed diffraction peaks located at 24 ° corresponding to the (002) crystallographic plane. This suggests that the amorphous carbon structure of WIFA-S was not changed after metal loading. The characteristic peaks of Cu2/4@WIFA-S catalysts at 32.4 ° correspond to the (110) crystal plane of CuO. The results suggest that Cu was successfully loaded onto the Cu2/4@WIFA-S catalyst during wet impregnation. The XRD spectra of the Fe2/4@WIFA-S catalyst and Al2/4@WIFA-S catalyst show the diffraction peaks of

graphitic carbon only. This might be attributed to the possibility that Al and Fe were uniformly dispersed on the surface of WIFA-S catalysts without an ordered crystal structure, which would be consistent with the results of EDS. The XRD spectra of the $Zn_{2/4}$@WIFA-S catalysts showed that the characteristic peaks appearing at 35.5 ° corresponded to the (101) crystalline form of $ZnCl_2$. The diffraction peaks at 28.9 ° and 55.6 ° were considered to be ZnS species, which suggests that Zn in the $Zn_{2/4}$@WIFA-S catalysts may have grafted onto -SO_3H of the WIFA-S catalysts.

Table S1 Standard curve equations for glucose and related products.

target products	公式	R^2
glucose	y=1457582x+20771	0.9998
fructose	y=1453968x-176366	0.9991
HMF	y=1585883x+141988	0.9995
LA	y=1038699x+2533	0.9992
FA	y=505411x-48735	0.9993

Text S1 Kinetic study

It is shown that the glucose dehydration reaction can be assumed to be a pseudo-primary reaction dependent on the concentration of the reactants. If the glucose dehydration reaction is assumed to follow pseudo-primary kinetics, the plot of $Ln(C_0/C)$ as a function of reaction time will be linear with a slope equal to the negative value of the reaction rate constant, K. The reaction kinetics of the glucose dehydration reaction are shown in the following table. To further illustrate the reaction process, a simplified kinetic model for the macroscopic reaction of glucose hydrolysis is proposed. As shown in Figure S5, the reaction process consists of two reactions: (1) glucose conversion and synthesis to HMF, and (2) HMF rehydration to produce LA.

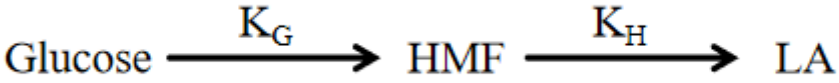


Figure S5 Kinetic modelling of reactions

$$\frac{dC_G}{dt} = -(k_G C_G + k_H C_G)$$

$$C_G = C_{G0} e^{-kt}$$

$$\frac{dC_{HMF}}{dt} = k_2 C_G = k_2 (C_{G0} e^{-kt})$$

In the above equations, C_G is the concentration of glucose raw material (g/L) and the initial concentration is recorded as C_{G0}; C_{HMF} is the concentration of HMF (g/L); k_G and k_H are the rate constants of glucose dehydration and HMF rehydration (min-1), respectively; k is the rate constant of glucose degradation; and t is the reaction time (min).

The Arrhenius formula reveals the relationship between reaction rate and temperature in the exponential form and the logarithmic form shown in their respective equations:.

$$K_F = A_F e^{-\frac{E_a}{RT}}$$

$$lnk_F = -\frac{E_a}{RT} + lnA_F$$

where AF denotes the prefinger factor (min^{-1}); R denotes the degree of the molar gas constant (8.314 kJ/(K-mol)); Ea denotes the activation energy of the reaction (kJ/mol); kF is the reaction rate constant