Supporting information for

Efficient lignin conversion over Ni/(Fe/Zn/Co/Mo/Cu)-WO_3/Al_2O_3 for selectively yielding alkyl phenols

*Xinyu Lu, Xiaoli Gu**

Jiangsu Co-Innovation Center of Efficient Processing and Utilization of Forest Resources, Jiangsu Provincial Key Lab for the Chemistry and Utilization of Agro-forest biomass, College of Chemical Engineering, Nanjing Forestry University, Nanjing 210037, China.

**Corresponding authors: guxiaoli@njfu.edu.cn*

Figures

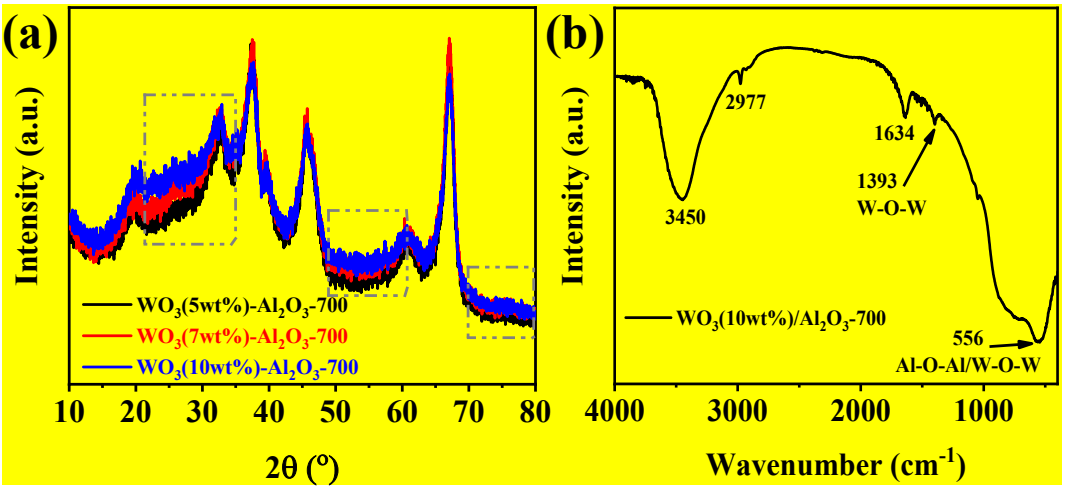

Fig. S1. (a) XRD patterns and (b) FTIR spectrum of tungsten modified supports.

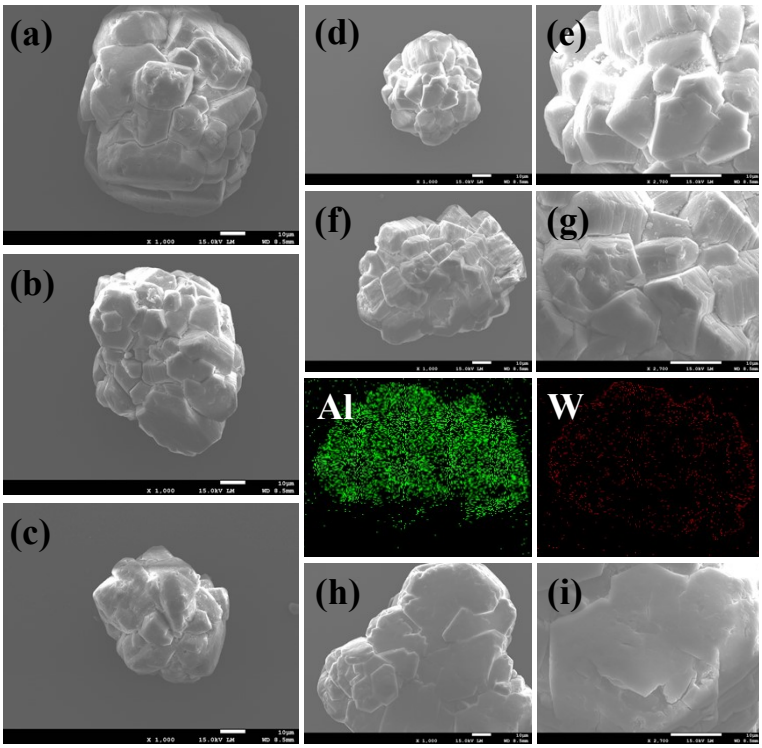

Fig. S2. SEM images of parent Al_2O_3 after calcination at (a) 500 °C, (b) 700 °C and (c) 900 °C. SEM images of WO_3(10wt%)/Al_2O_3 under low magnification (d: at 500 °C; f: at 700 °C; h: at 900 °C) and high magnification (e: at 500 °C; g: at 700 °C; i: at 900 °C), and EDS analysis (alumina and tungsten elements) of WO_3(10wt%)/Al_2O_3 prepared at 700 °C.

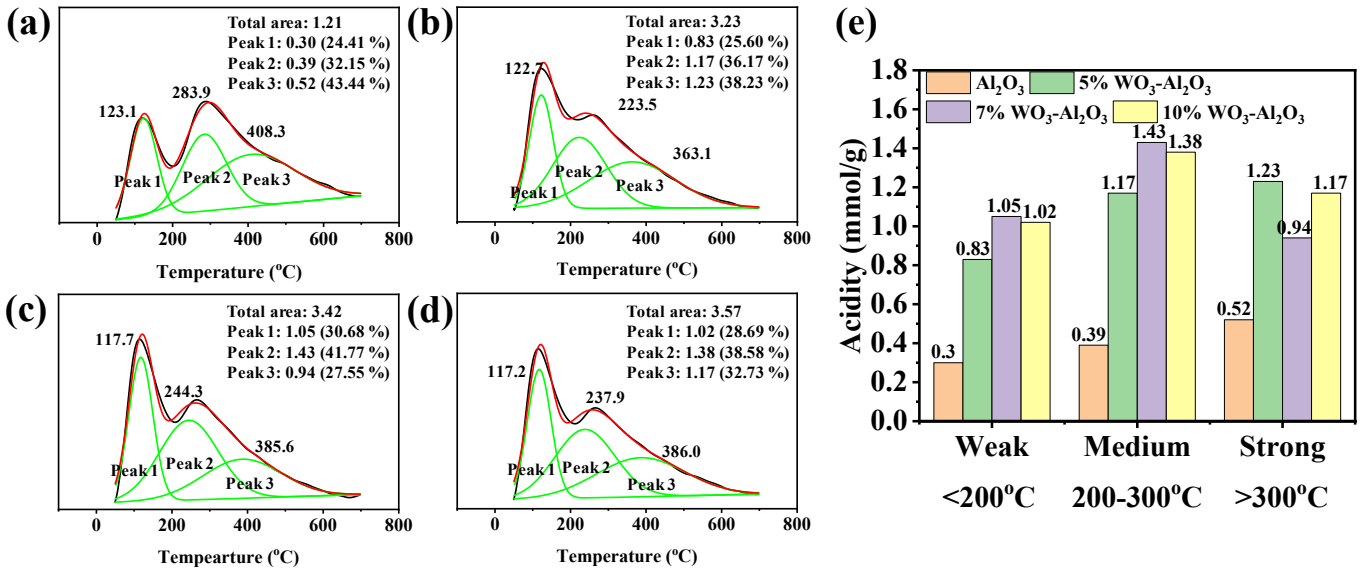

Fig. S3. (a-d) Peak fitting results of NH_3-TPD (a: Al_2O_3-700; b: WO_3(5wt%)/Al_2O_3-700; c: WO_3(7wt%)/Al_2O_3-700; d: WO_3(10wt%)/Al_2O_3-700), and (e) their acidity contributions.

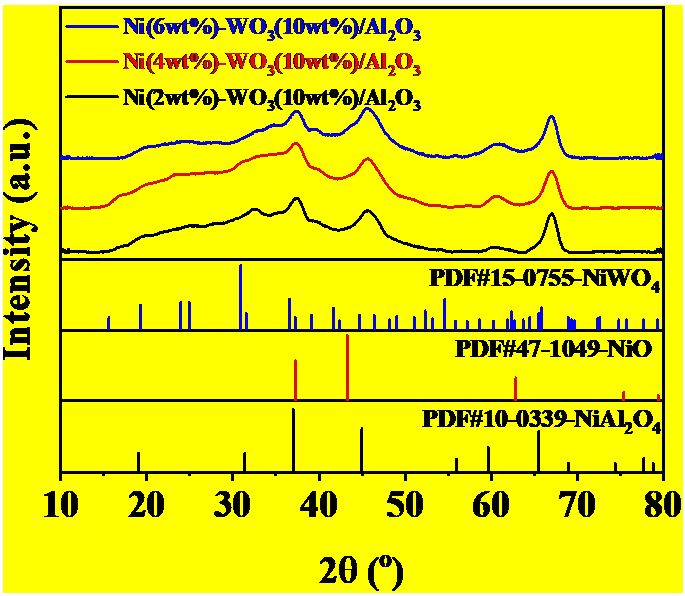

Fig. S4. XRD spectra of Ni-WO_3(10wt%)/Al_2O_3 with different Ni loading.

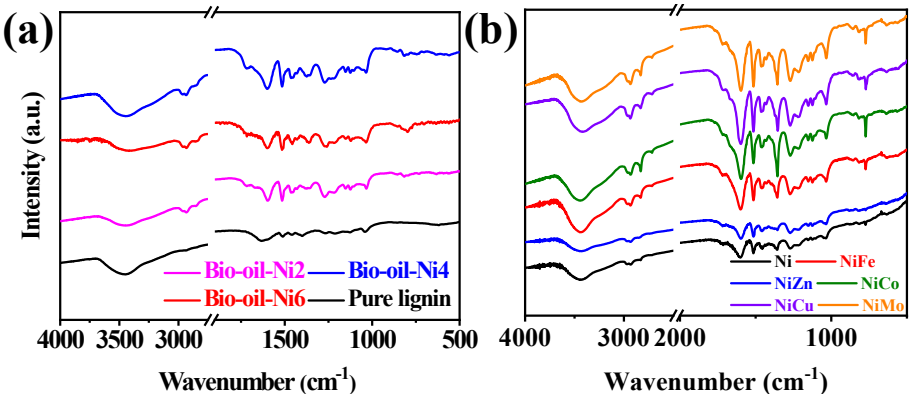

Fig. S5. FTIR spectra of lignin-derived bio-oils obtained from lignin depolymerization at (a) Ni(4~6wt%)-WO_3(10wt%)/Al_2O_3-700, and (b) $Ni_{3wt\%}$-$X_{3wt\%}$/WO_3(10wt%)/Al_2O_3-700 (X = Fe/Zn/Co/Mo/Cu).

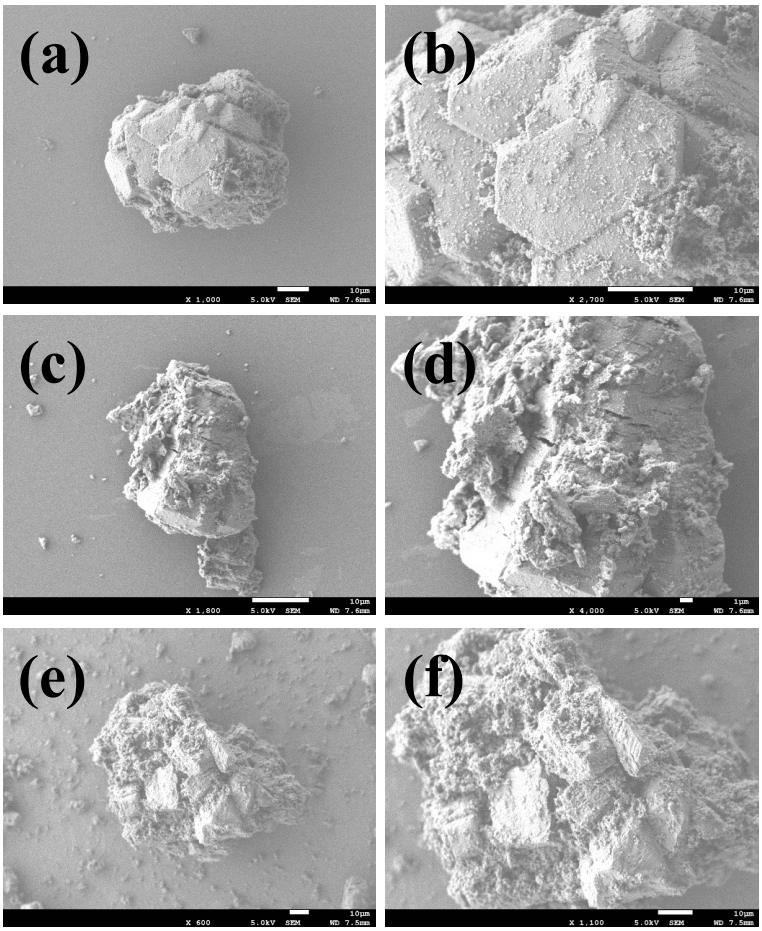

Fig. S6. SEM images of Ni(4 ~ 6 wt%)-WO_3(10 wt%)/Al_2O_3-700 under low magnification (a: 2 wt% Ni loading; c: 4 wt% Ni loading; e: 6 wt% Ni loading) and high magnification (b: 2 wt% Ni loading, d: 4 wt% Ni loading, f: 6 wt% Ni loading).

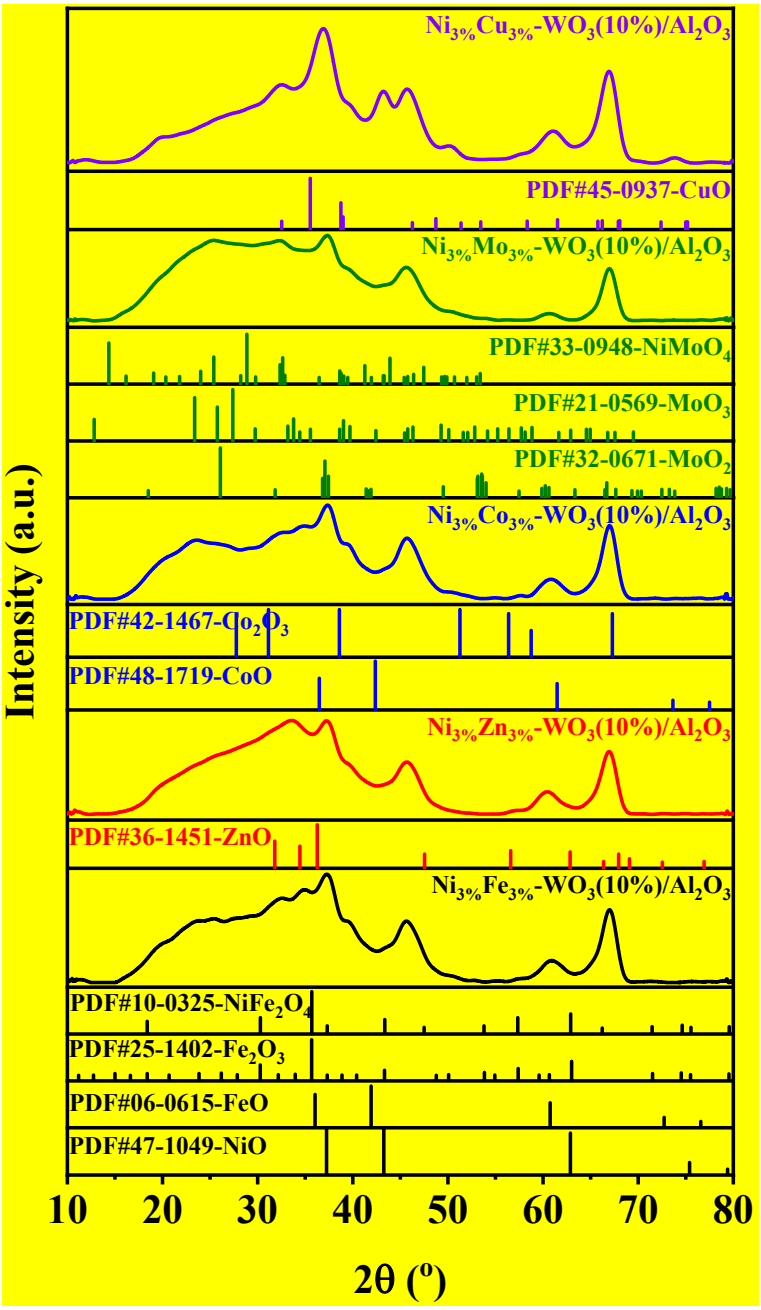

Fig. S7. XRD spectra of $Ni_{3wt\%}$-$X_{3wt\%}$/WO_3(10wt%)/Al_2O_3-700 (X = Fe/Zn/Co/Mo/Cu).

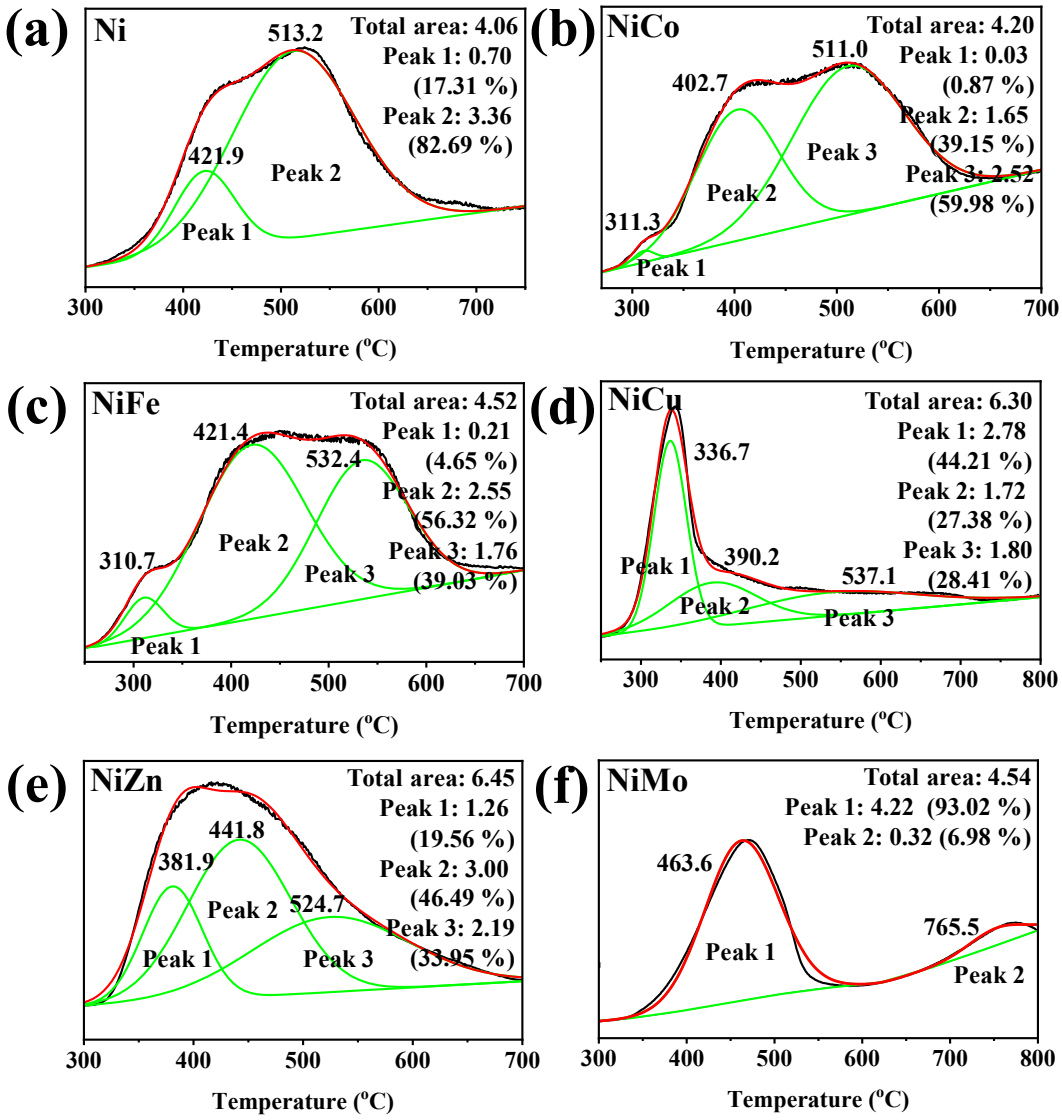

Fig. S8. Peak fitting results of H_2-TPR of single and bimetallic Ni-based catalysts.

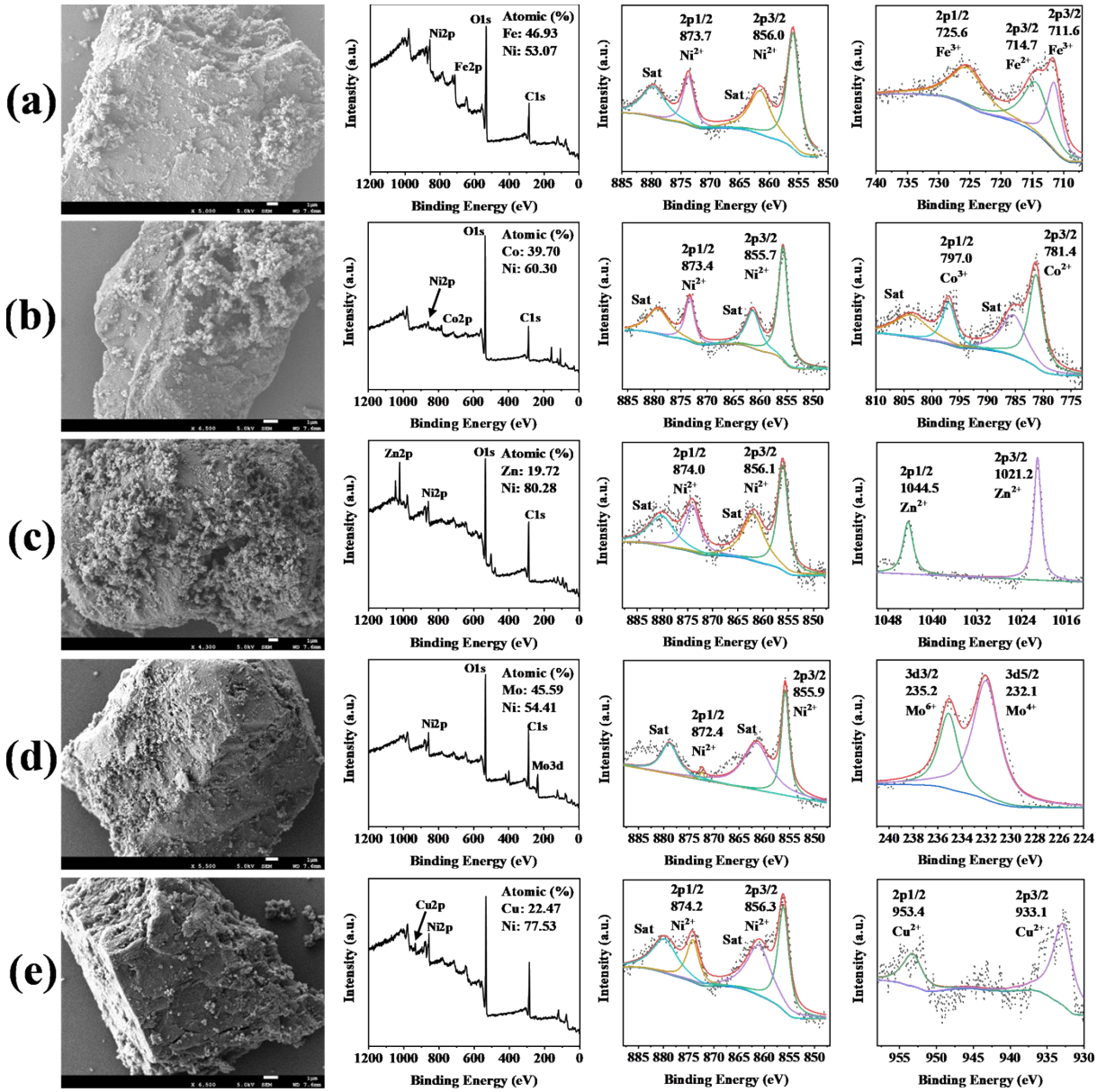

Fig. S9. SEM images and XP spectra of $Ni_{3wt\%}$-$X_{3wt\%}$/WO_3(10wt%)/Al_2O_3-700 (X = (a) Fe/(b) Zn/(c) Co/(d) Mo/(e) Cu).

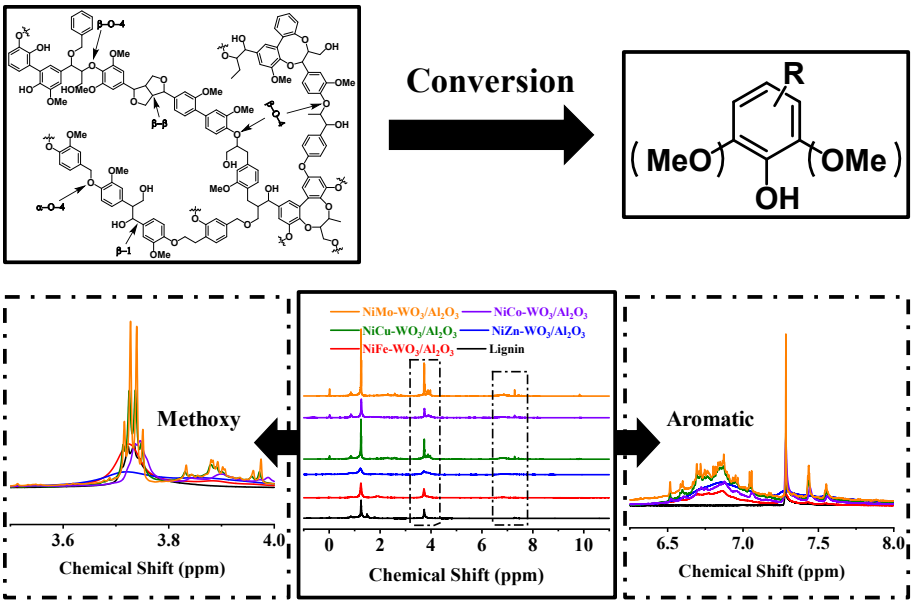

Fig. S10. ^{1}H NMR spectra of bio-oils obtained from lignin degradation at Ni(3wt%)-X(3wt%, Fe/Zn/Co/Mo/Cu)/WO_3(10wt%)/Al_2O_3-700.

Tables

Table S1. Elemental analysis of lignin.

C (wt%)	H (wt%)	N (wt%)	O[a] (wt%)	H:C[b]	O:C[b]
61.85	6.87	0.15	31.13	1.33	0.38

[a] Determined via residual mass balance.

[b] Molar ratio.

Table S2. Quantitative analysis of representative phenolic compounds in bio-oils.

Compounds (wt%)	Ni/Fe	Ni/Zn	Ni/Co	Ni/Mo	Ni/Cu
2-Methoxy-phenol	0.9	2.4	0.6	0.9	0.6
Vanillin	2.8	0.7	0.7	2.3	2.6
Homovanillyl alcohol	0.5	0.7	2.9	1.1	0.9