The 8th International conference on Clean Coal Technologies

Study on the reactivity and structure characteristics of rich-alkali biomass chars and coal co-hydrogasification

East China University of Science and Technology

Wang Xingjun, Kui Yao, Jingang Zhang, Huaili Zhu, Xueli Chen, etc.

May 8 - 12, 2017

Cagliari， Italy

CONTENTS

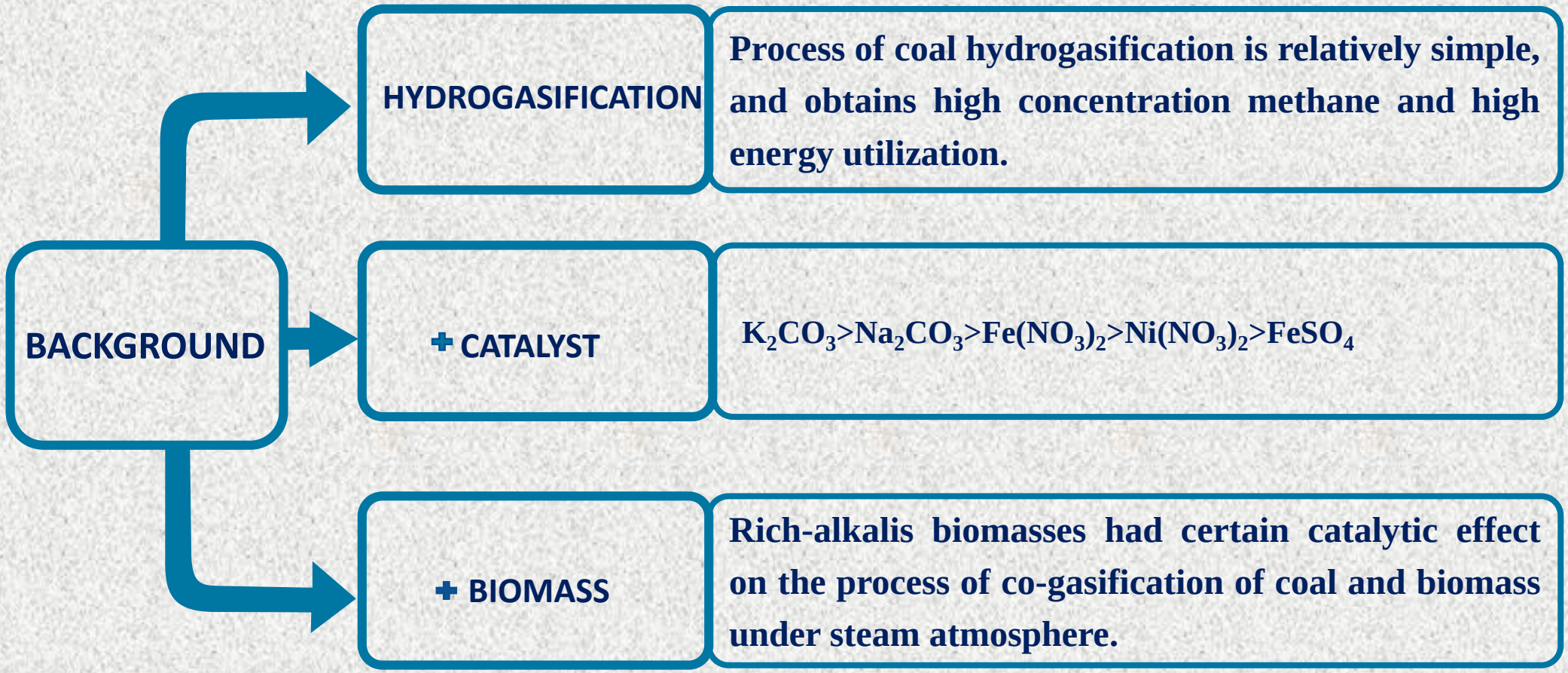
1 BACKGROUND

2 EXPERIMENT

3 DISCUSSION

4 CONCLUSIONS

Biomass chars and coal co-hydrogasification



Coal and three rich-alkalis biomass chars co-hydrogasification are studied

CONTENTS

1 BACKGROUND

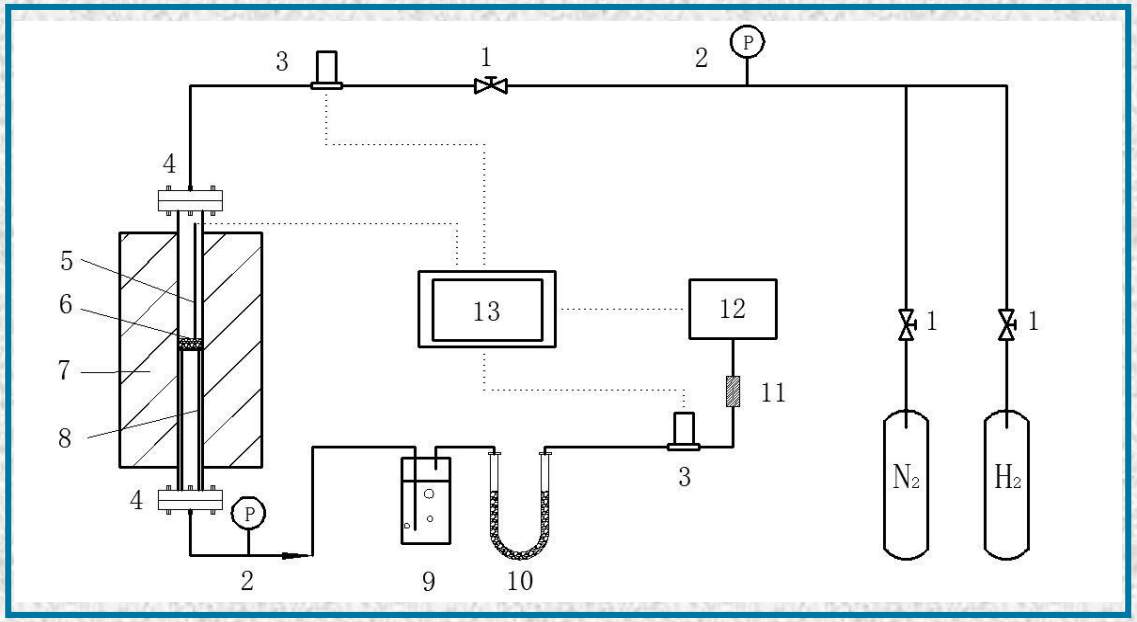
2 EXPERIMENT

3 DISCUSSION

4 CONCLUSIONS

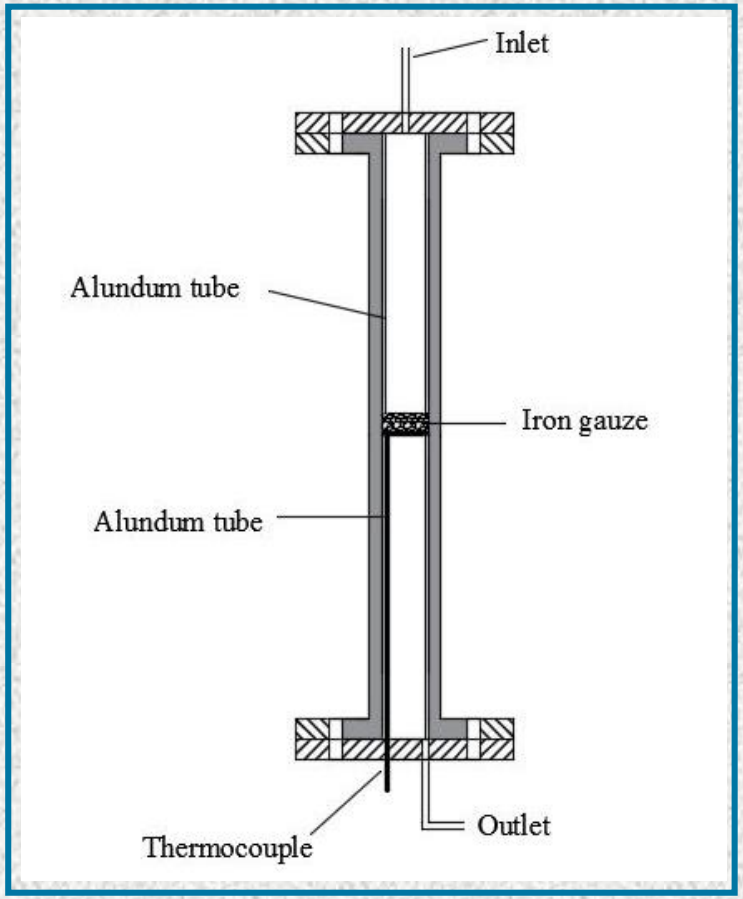
Schematic diagram of reactor system

BACKGROUND
EXPERIMENT
DISCUSSION
CONCLUSIONS



Schematic diagram of the pressurized fixed bed reactor

1: mass flow controller; 2: pressure gage; 3: flow meter; 4: flange; 5: thermocouple; 6: metal mesh; 7: electric furnace; 8: corundum tube; 9: liquid/gas separator; 10: gas drying bottle; 11: non-return value; 12: gas analyzer 13: computer



Schematic diagram of fixed-bed packing

Sample preparation

Proximate and ultimate analyses of samples

Sample	Proximate Analysis w_d%			Ultimate Analysis w_d%				
	V	FC	Ash	C	H	N	S	O*
SF	33.29	58.65	8.06	74.2	4.21	0.97	0.63	11.93
WS	72.07	17.91	10.02	38.76	5.91	0.83	5.33	39.15
SG	48.85	11.6	37.93	23.74	3.21	0.98	1.26	32.88
SD	71.42	13.11	15.47	40.21	7.01	0.72	0.32	36.27
WSC	7.91	69.45	22.64	61.32	1.21	0.31	1.11	13.41
SGC	3.09	25.07	71.84	18.15	0.87	0.72	0.7	7.72
SDC	7.54	62.32	30.14	62.95	1.14	0.26	0.25	5.26

Images of various biomass and biomass ashes

Ash composition of coal and biomass chars

Constituent %	Al_2O_3	CaO	Fe_2O_3	SiO_2	MgO	Na_2O	K_2O	Cl	Undet.
SF	12.44	27.78	9.11	33.66	1.34	1.73	0.67	0.09	13.18
WSC	2.55	8.39	1.02	60.86	3.80	6.18	9.04	0.59	7.57
SGC	2.87	10.97	1.34	12.35	3.66	17.11	17.39	29.24	5.07
SDC	12.71	24.13	6.29	42.48	4.48	1.46	2.90	0.17	5.38

Experimental setup and analysis method

BACKGROUND
EXPERIMENT
DISCUSSION
CONCLUSIONS

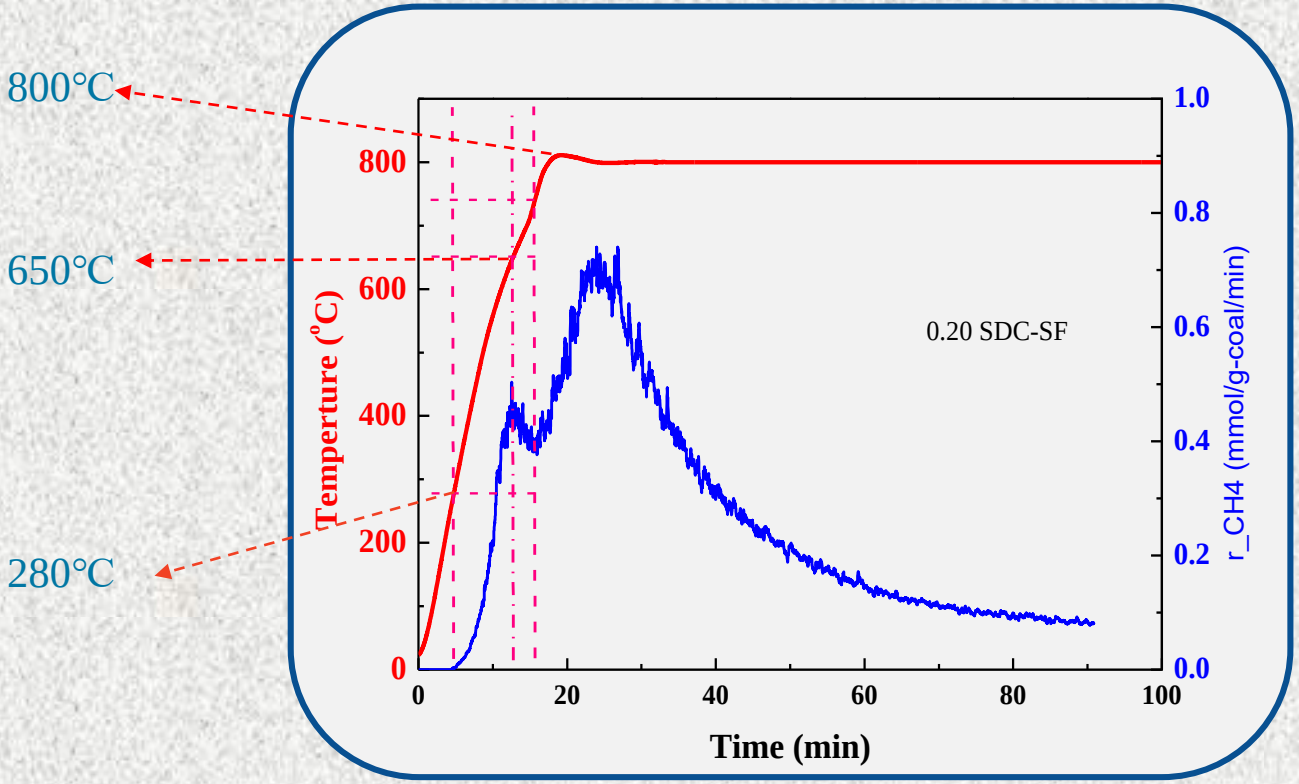
$$r_{CH_4} = 1/n_0 \cdot dn_{CH_4}(t)/dt \quad (1)$$

- $n_{CH_4}(t) = \int_0^t Q_t \cdot (V_{CH_4})/22.4 \cdot dt$
- $n_0 = m_{SF} \times W_C/M_C$

$$m_{Gas} = n_{CH_4} * 16 + n_{CO_2} * 44 + n_{CO} * 28 + n_{C_nH_m} * 30 \quad (2)$$

$$m_{Liquid} = m_{SF} + m_{Bio-C} - m_{Gas} - m_{Solid} \quad (3)$$

Char structure analysis



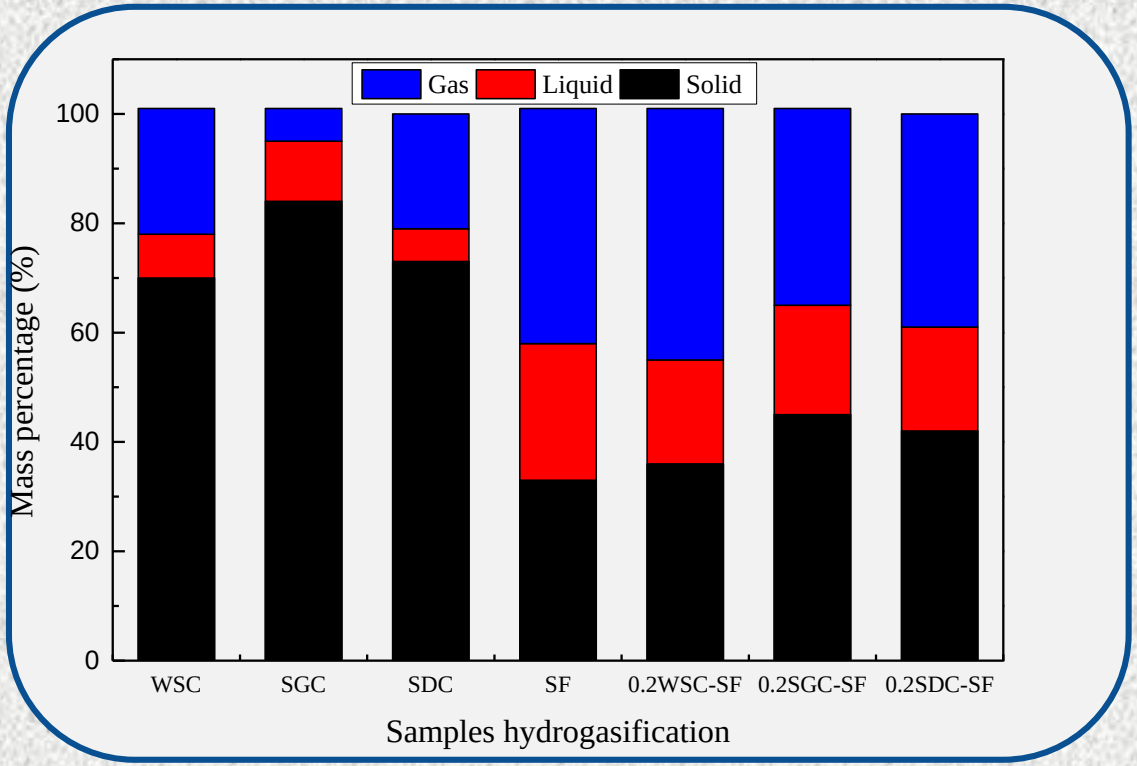
Curves of temperature and methane releasing rate versus time

1.Methane of biomass char and SF hydrogasification was released from 280 °C

2.Methane release rate reached the first peak value at 650 °C

3.The second peak value of CH_4 releasing rate appeared when exceeds 800 °C.

Char structure analysis



Product contents of coal/biomass char/blends hydrogasification

Gas contents of SF hydrogasification were 1.87, 7.17 and 2.05 times those of WSC, SGC and SDC hydrogasification, respectively.

Liquid content of additional biomass chars and SF co-hydrogasification was lower than that of SF hydrogasification.

Solid content of biomass char hydrogasification were more than two times that of SF hydrogasification

CONTENTS

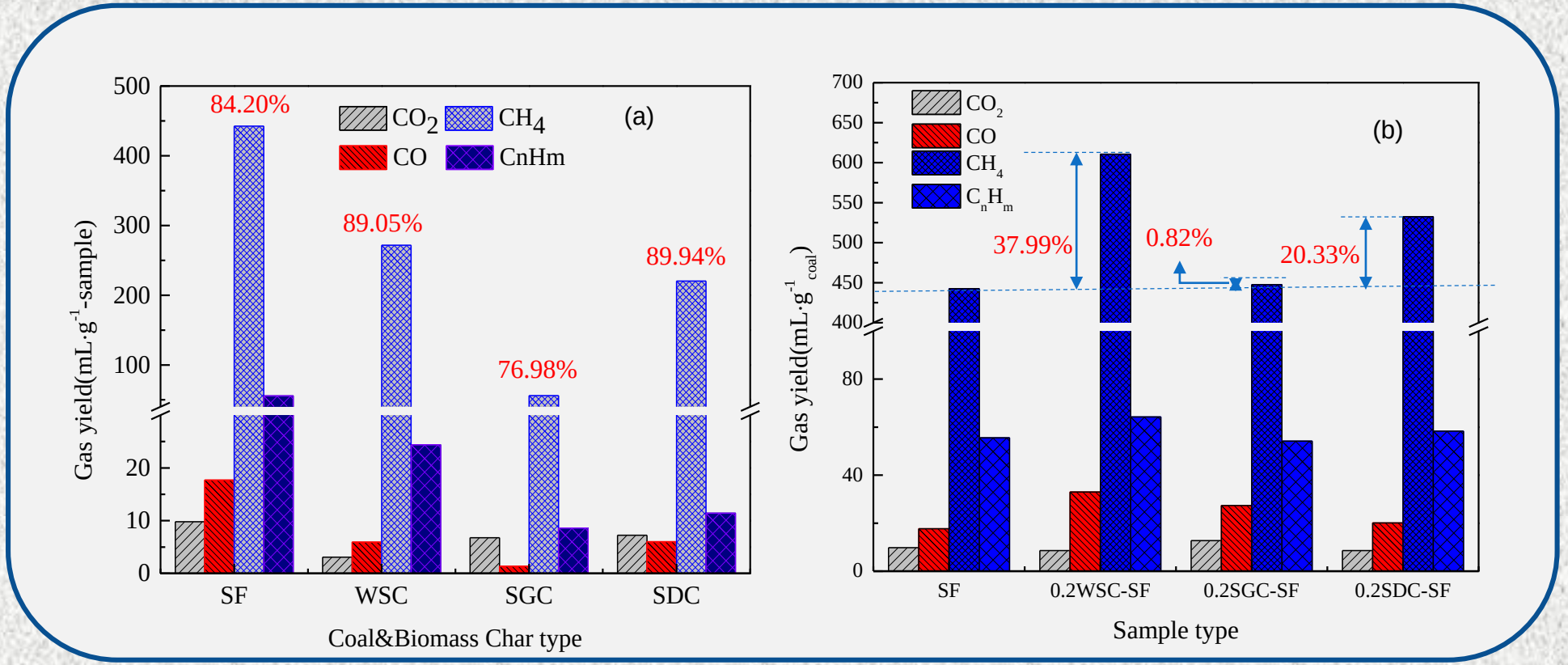
1 BACKGROUND

2 EXPERIMENT

3 DISCUSSION

4 CONCLUSIONS

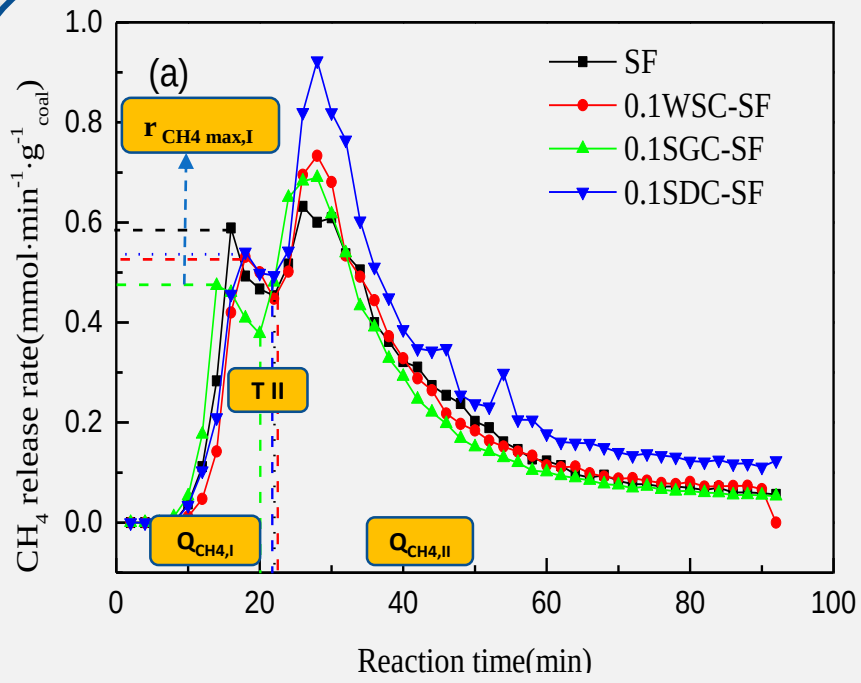
Hydrogasification product



Gaseous product yield of SF and biomass chars hydrogasification

The main component of gas products is methane!

Methane release rate

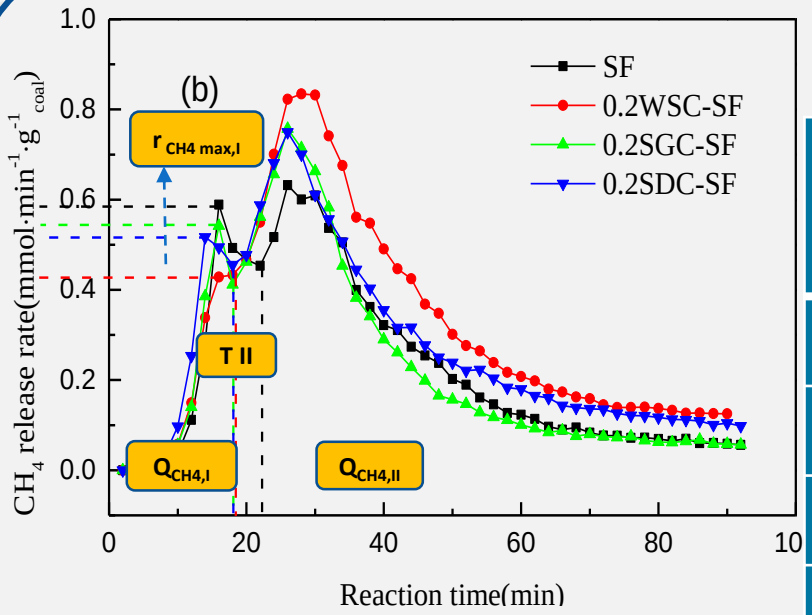


CH4 release rate of SF and biomass chars

CH4 release characters

Sample	$r_{CH4\ max,I}$ (mmol·min^{-1}·g$_{coal}^{-1}$)	$Q_{CH4,I}$ (mL·g$_{coal}^{-1}$)	T II (h:min:s)	$Q_{CH4,II}$ (mL·g$_{coal}^{-1}$)
SF	0.589	67.668	0:22:06	374.810
0.1WSC-SF	0.531	69.894	0:22:14	375.354
0.1SGC-SF	0.474	66.854	0:20:03	356.038
0.1SDC-SF	0.541	72.580	0:22:05	478.500

Methane release rate

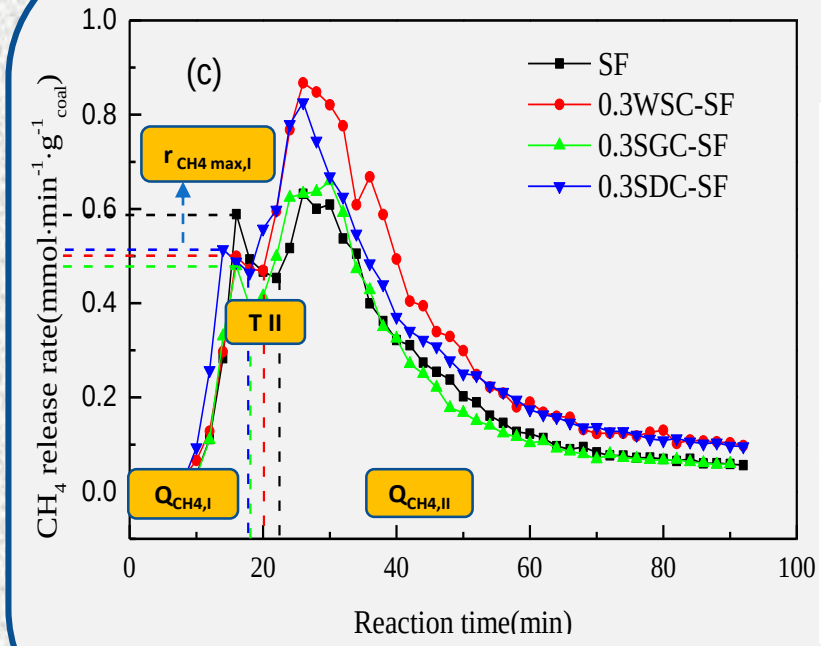


CH4 release rate of SF and biomass chars

CH4 release characters

Sample	$r_{CH4\ max,I}$ (mmol·min^{-1}·g$_{coal}^{-1}$)	$Q_{CH4,I}$ (mL·g$_{coal}^{-1}$)	T II （h:min:s）	$Q_{CH4,II}$ (mL·g$_{coal}^{-1}$)
SF	0.589	67.668	0:22:06	374.810
0.2WSC-SF	0.429	55.020	0:18:19	555.568
0.2SGC-SF	0.542	68.106	0:18:08	379.376
0.2SDC-SF	0.517	71.766	0:18:03	460.658

Methane release rate

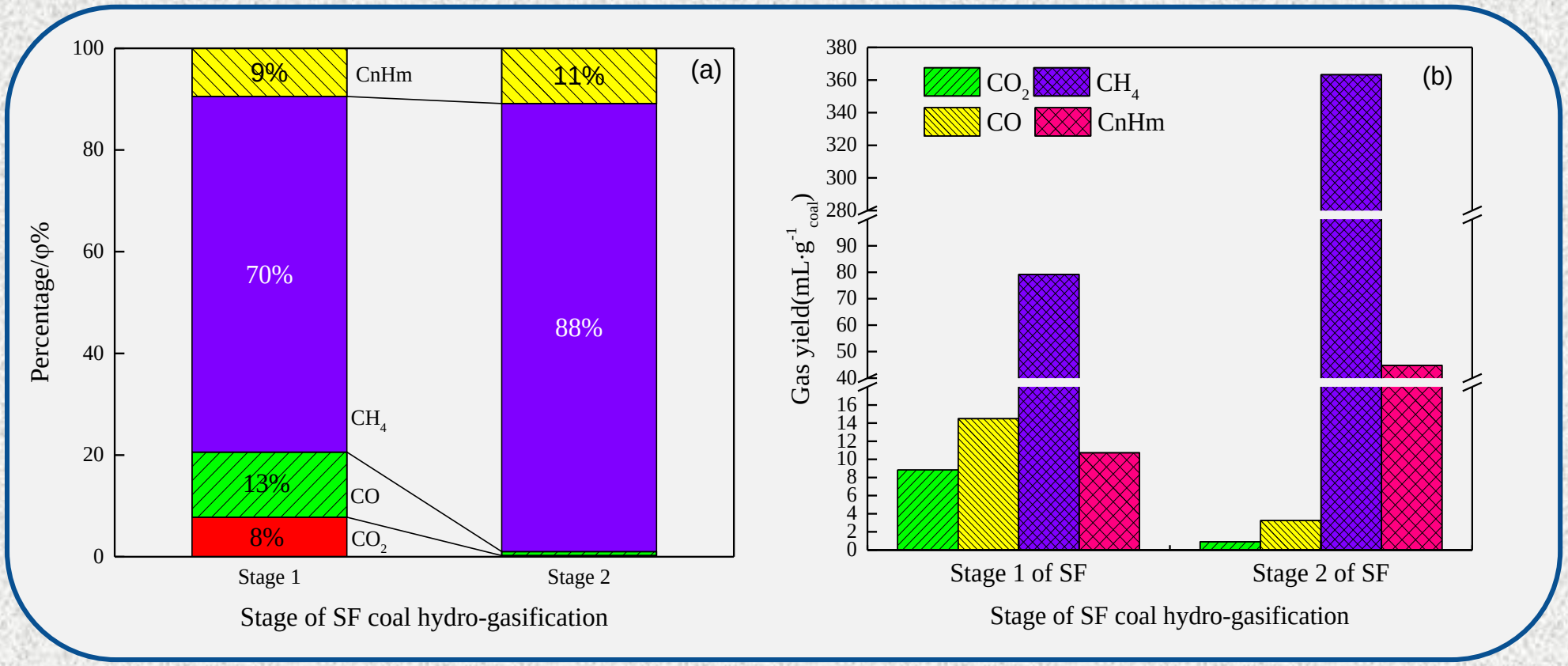


CH4 release rate of SF and biomass chars

CH4 release characters

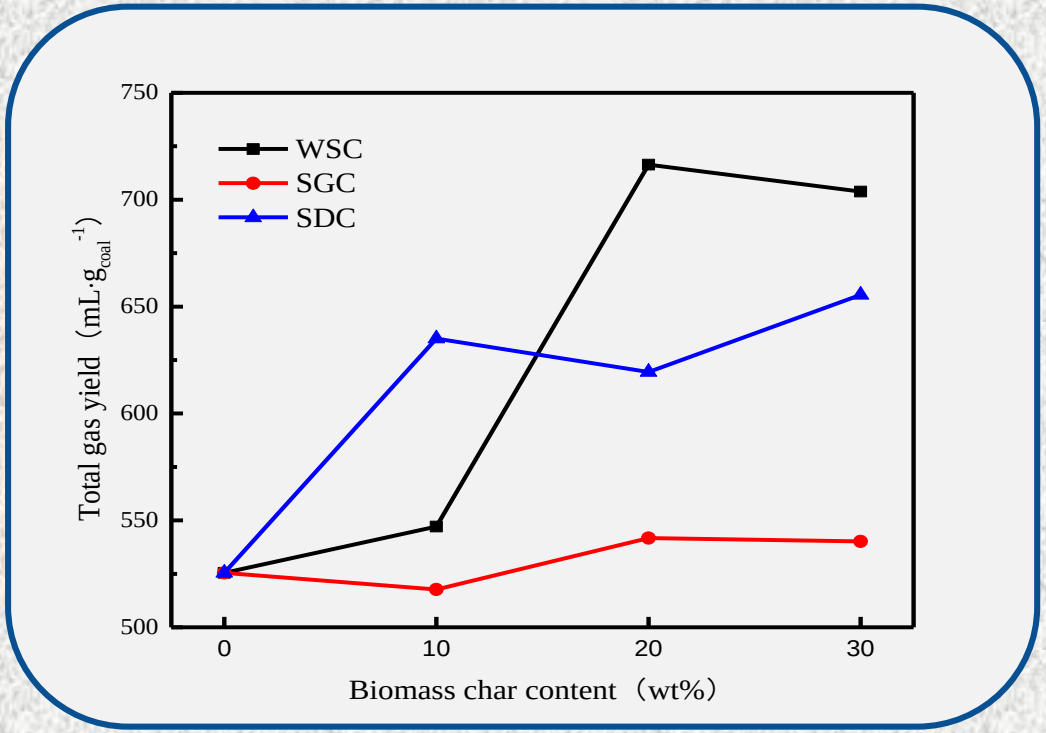
Sample	$r_{CH4\ max,I}$ (mmol·min^{-1}·g$_{coal}^{-1}$)	$Q_{CH4,I}$ (mL·g$_{coal}^{-1}$)	T II （h:min:s）	$Q_{CH4,II}$ (mL·g$_{coal}^{-1}$)
SF	0.589	67.668	0:22:06	374.810
0.3WSC-SF	0.499	52.760	0:20:24	540.538
0.3SGC-SF	0.479	60.462	0:18:23	382.438
0.3SDC-SF	0.515	59.278	0:18:05	505.006

Methane release rate



Gaseous product yield of Stage 1 and 2

Addition of biomass



WSC	→	Alkalis
SGC	→	Cl
SDC	→	Ca

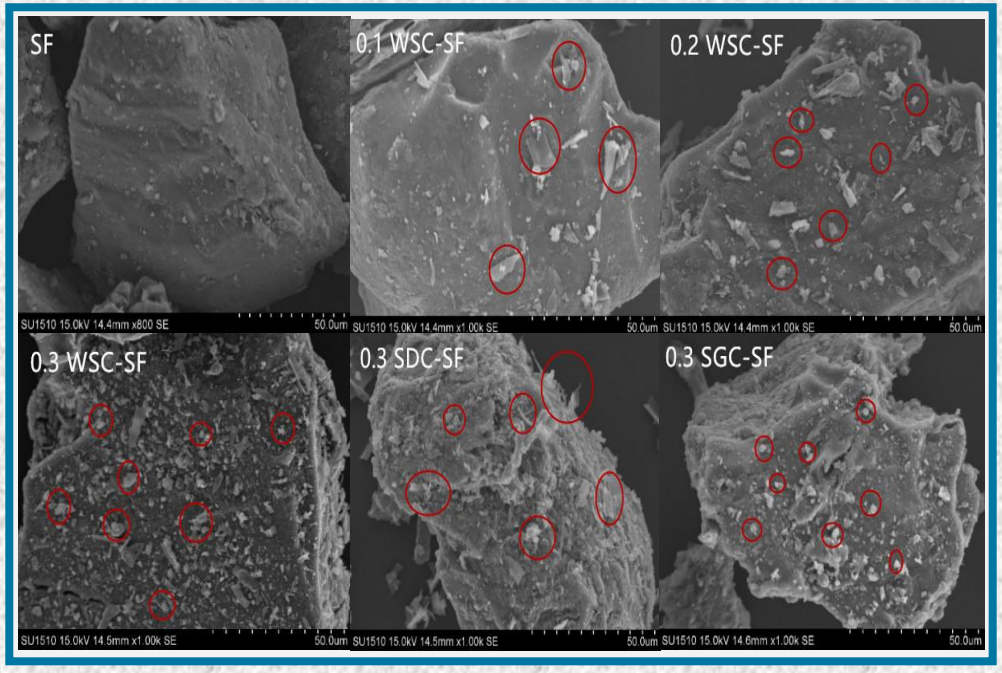
Gas products increased with increasing WSC

Chlorine has a effect SGC promotion

Calcium limited promotion of SDC

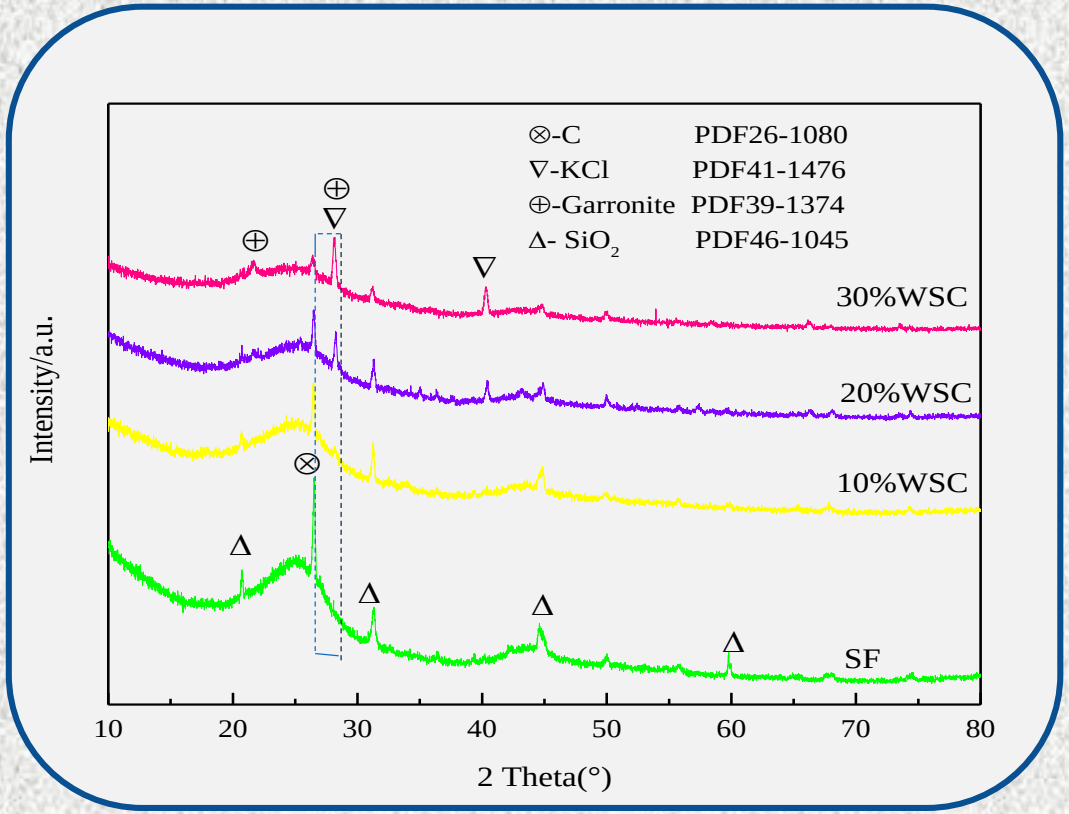
Gaseous product yield of SF and biomass chars co-hydrogasification

Hydrogasification residual analysis



SEM images of residuals

morphological structure is dense, relatively smooth.



XRD spectrum of hydrogasification residuals

With the increase of biomass char addition, the diffraction peak intensity of KCl crystal strengthened.

Hydrogasification residual analysis

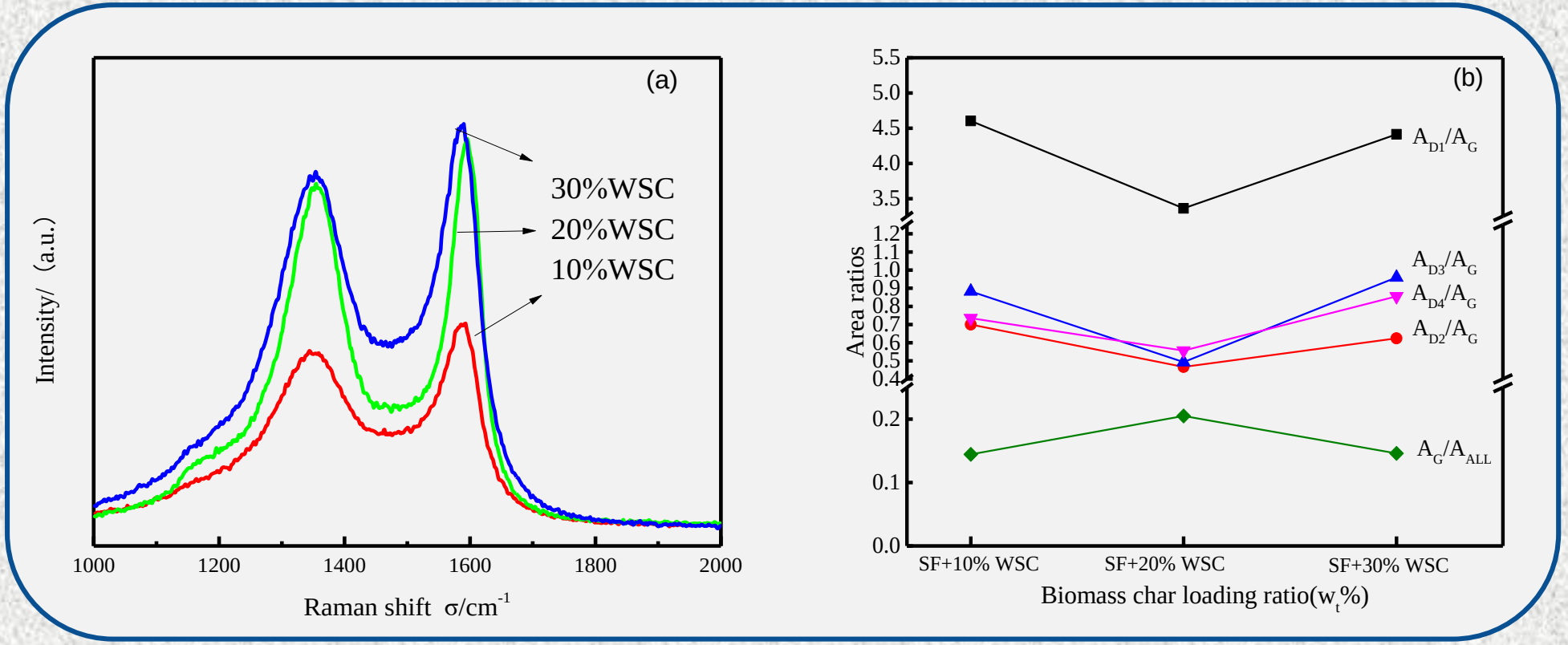


Fig. Raman spectra and fitted Raman area ratios of residues

20% biomass chars addition, an inhibition effect on order degree of carbon structure and obviously promotes the coal hydrogasification reaction

CONTENTS

1 BACKGROUND

2 EXPERIMENT

3 DISCUSSION

4 CONCLUSIONS

Conclusions

1. The hydrogasification process can be divided into Stage 1 and Stage 2.

2. The liquid production of co-hydrogasification is less than that of coal hydrogasification.

3. CO_2 and CO yields in Stage 1 is more than 95 % of the whole hydrogasification process, and CH_4 yield of Stage 2 is more than 82%.

4. The effect of biomass char on coal hydrogasification mainly occurred in stage 2

THANK YOU！