

TGA-FTIR Study of the Pyrolysis and Combustion of Montmorillonite-Tobacco Mixtures

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Montmorillonite, a kind of nano-mineral, is potentially useful for a cigarette additive because of its catalytic capability and non-toxicity. In this research, we used thermogravimetric analysis combined with Fourier transform infrared spectroscopy spectrometry (TGA-FTIR) to study the effect of montmorillonite content to the pyrolysis and combustion behavior of tobacco on the basis of the mass loss of montmorillonite-tobacco mixtures and the FTIR spectra of the evolved gas. The results showed that the addition of montmorillonite would decrease the total amount of the most evolved gas in both argon or air especially for alkanes, CO₂, carbonyl compounds, alcohols, and phenols and ethers, and make the release temperature of various gas products (like alkanes, CO, etc.) shift to a higher one. Montmorillonite had little effect on the temperature region of pyrolysis, but significantly influenced the combustion of the mixtures making the oxidizing reaction occur at a lower temperature, which demonstrated the catalytic capability of montmorillonite for the combustion of tobacco. The relevant results will provide the basis for montmorillonite as a cigarette additive to reduce the hazards during cigarette smoking, and broaden the utilization of montmorillonite resources.

Keywords: Montmorillonite, Tobacco, TGA-FTIR, Pyrolysis, Combustion.

1. INTRODUCTION

Cigarette smoking produces numerous substances which are harmful to public health, e.g., tar, nicotine, polycyclic aromatic hydrocarbons (PAHs), aromatic amines, N-nitrosamine, etc. Several researches have verified that cigarette smoking is closely related with cardiovascular, respiratory and urinary diseases containing coronary heart disease, chronic obstructive pulmonary emphysema, lung cancer, bladder cancer, etc.¹⁻³ Therefore, how to reduce the poisonous and hazardous component during cigarette smoking is a significant issue concerned by public and health organizations. The ingredient of tobacco is complex, and its thermochemical process is more complicated besides the addition of various additives. The number of major components currently identified from the mainstream smoke has exceeded 3500 through standardized machine-smoking procedures^{1,4,5} that pose a problem for a detailed study of this process. For the convenience

of research, this thermochemical process divided into two routines: pyrolysis and combustion. The resultants of pyrolysis include alcohols, aldehydes, ketones, aromatic compounds etc., and carbon monoxide and carbon dioxides for oxidation.^{6,7}

In order to reduce the harm to human and the influence to environment some researchers set their sights on porous materials like synthetic zeolite,^{8,9} SBA-15,¹⁰ MCM-41,¹¹ activated carbon,¹² and noble-metal modified catalysts such as palladium/C.¹³ These additives show high potential for the removal of hazardous components in smoke gas by adsorption and/or catalytic degradation, but the inhalation safety of these materials have not been sufficiently assessed,¹⁴ especially some metals, like palladium, have been confirmed harmful to humans.^{15,16}

Montmorillonite is widespread, inexpensive, environmental-friendly, nontoxic, humidity-insensitive, one of the natural nano-minerals, and has potential for additive of cigarette. Owing to their pore structure¹⁷ and surface acidity,¹⁸ montmorillonite and its modified

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products present excellent adsorptive and catalytic capacities,^{19,20} which is widely used in the removal of various gaseous pollutants, such as formaldehyde,²¹ benzene,²² ammonia, sulfur dioxide,²³ hydrogen sulfide,²⁴ nitrogen oxides,²⁵ polychlorinated biphenyls (PCBs).²⁶ Furthermore, a few studies discussed the effect of montmorillonite as a catalyst for the pyrolysis behavior of biomass, like cellulose.²⁷ However, to our knowledge, no research has considered montmorillonite as an additive for the thermochemical process of cigarette.

Thermogravimetric analysis combined with Fourier transform infrared spectroscopy spectrometry (TGA-FTIR) is a hyphenated analytical technique. The volatiles released from the samples on thermobalance are transferred to a gas cell inside the infrared spectrometer, and FTIR spectra as function of temperature (time) are recorded for the analysis of the composition and quantity of the evolved gas. This technique is extensively applied in the research of pyrolysis, combustion and desorption,²⁸ and it is fit for investigating the thermochemical behavior of many biomass, such as cellulose, hemicellulose, lignin, wheat straw, pine, coal, and tobacco.^{4,29–34} Baker studied the pyrolysis of 13 saccharide tobacco ingredients with different heating rates to obtain the formation rate of low molecular weight products, especially of formaldehyde, which can be measured by FTIR but are hardly detected by mass spectrometry.³⁵ Gómez-Siurana suggested the possible pyrolysis routines of tobacco and tobacco-glycerol mixture by analyzing the composition of the evolved gas at different temperature.³⁶

In this research, we used TGA-FTIR to inspect the thermochemical behavior of tobacco-montmorillonite mixture, considering

- (1) the effect of montmorillonite amount to the composition and quantity of evolved gas in different temperature range, and
- (2) the differences between pyrolysis and combustion of montmorillonite-tobacco mixtures with different montmorillonite content.

The relevant results will provide the basis for montmorillonite as a cigarette additive to reduce the hazards during cigarette smoking, and broaden the utilization of montmorillonite resources.

2. MATERIALS AND METHODS

2.1. Materials

Montmorillonite came from Chifeng, Inner-Mongolia. The distance between its (001) lattice planes is 1.53 nm, which suggested the interlayer cation is Ca²⁺. The major elements derived from X-ray fluorescence spectroscopy (XRF) is as follows: SiO₂ 72.25%, Al₂O₃ 13.70%, Fe₂O₃ 1.42%, MgO 2.06%, CaO 1.76%, Na₂O 0.64%, K₂O 1.70%, MnO 0.04%, P₂O₅ 0.05%, TiO₂ 0.14%, and the loss of ignition is 6.16%. The N, C, H, S content of this montmorillonite are 0.026%, 0.170%, 1.978%, and 0.004% respectively. The tobacco came from Mengzi,

Table I. The positions and assignments of the major FTIR absorbance.

Wavenumber (cm ⁻¹)	Origin	Assignment
3566	O–H stretching	Water
3076	Aromatic C–H in-plane bend	Aromatics and heterocycles
3016	C–H stretch in CH ₄	Methane
2968	Methyl C–H stretch	Alkanes or alkyl substituents
2835	Methylene C–H stretch	Alkanes or alkyl substituents
2361	Asymmetrical stretching in O=C=O	CO ₂
2195	Stretching vibration in CO	CO
1749	Carbonyl groups	Aldehydes, ketones
1047, 1191	C–O stretch	Alcohols, phenols, ethers

Yunnan, and its contents of main elements are 2.835% for N, 43.095% for C, 4.918% for H, and 0.183% for S.

2.2. Sample Preparation

Tobacco was grinded into powders in an agate mortar, then dried for 2 hours at 40 °C and designated as Tob. Montmorillonite powder was preserved for 12 hours at 40 °C and was designated as MMt. A certain amount of Tob and MMt were weighed according to the result of a calculation, and then the two powders were mixed in an agate mortar, grinded for 10 minutes, and place into an oven for 12 h at 40 °C. According to the mass percent, the mixtures of montmorillonite and tobacco were denominated as 5% MMt, 10% MMt, 15% MMt, 20% MMt, 25% MMt, and 30% MMt respectively.

2.3. Characterization Method

About 8 mg sample was weighed, and then added into an Al₂O₃ crucible with the lid. This crucible was put on the sample holder of a thermogravimetric analyzer (STA 449 F3 Jupiter, Netzsch, Germany) which hyphenated with a FTIR spectrometer (Vertex 70, Bruker, Germany). The tests were conducted in a purge gas of argon (for pyrolysis) or air (for combustion) with the flow velocity of 60 ml/min, and the range of temperature was from 40 to 800 °C with the ramp rate of 35 °C/min. The FTIR spectra were collected with a deuterated L-alanine doped triglycine sulphate (DLATGS) detector. The FTIR detection parameters are as follows: 4500–650 cm⁻¹ for scan range, 4 cm⁻¹ for resolution, and 4 for number of scans. The relative quantities of the main constituents in the evolved gas were calculated by the integral of the absorbance in the corresponding wavenumber ranges of representative functional groups (see Table I).

3. RESULTS AND DISCUSSION

3.1. Thermal Analysis of Montmorillonite (MMt) and Tobacco (Tob)

The pyrolysis of MMt in argon has three obvious mass loss regions (Fig. 1). The mass loss in 40–160 °C and

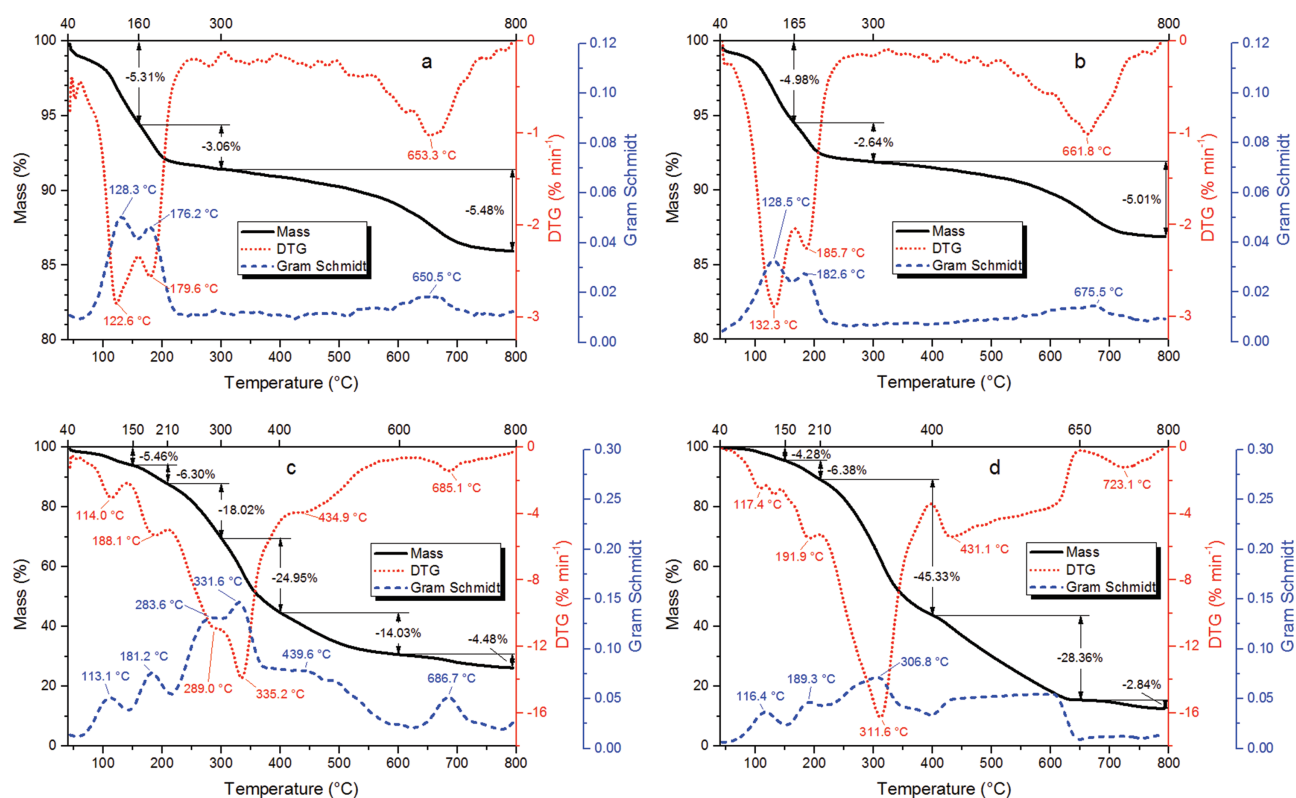


Figure 1. TG, DTG and Gram-Schmidt curves of Inner-Mongolia montmorillonite and Mengzi tobacco measured with different purge gases. (a) Montmorillonite, argon; (b) montmorillonite, air; (c) tobacco, argon; (d) tobacco, air.

160–300 °C, where the temperature of maximum speed on mass losses are located at 122.6 °C and 179.6 °C, are caused by the evaporation of surface-adsorbed water and interlayer water. The subsequent mass loss between 300 °C and 800 °C where the peak of derivative thermogravimetry (DTG) at 653.3 °C is attributed to the dehydroxylation of montmorillonite and the pyrolysis or combustion of organic matters. Similarly, the combustion of montmorillonite in air atmosphere at programmed temperature has three loss intervals as well, and the temperature regions, the DTG peaks, and the reasons of mass losses are all identical with that in argon atmosphere. The cause for these mass losses are also confirmed by the FTIR spectra (Figs. 2(a and b)) collected at the temperatures of the corresponding DTG peaks. Remarkably, according to the little carbon content (0.17 wt.%) and the significant IR absorbance at 2361 cm^{-1} , the mass losses of montmorillonite between 300 °C and 800 °C in both argon and air are partially assigned to the pyrolysis or combustion of organic matters, rather than the decomposition of carbonates (above 840 °C for CaCO_3).

Combining the analyses of thermogravimetry and FTIR spectra, the pyrolysis of tobacco sample has six steps of mass losses:

- (1) the evaporation of water in 40–150 °C,
- (2) the evaporation of low molecular weight alcohols (e.g., glycerol) in 150–210 °C,

- (3) two overlapping processes in 210–400 °C, where the DTG peaks at 289.0 °C and 335.2 °C caused by the pyrolysis of hemicellulose and cellulose respectively,
- (4) the pyrolysis of lignin in 400–600 °C (the DTG peak at 434.9 °C), and
- (5) the dehydrogenation and aromatization of coke and decomposition of inorganics above 600 °C.

However, in the combustion of tobacco in air, only five stages were distinguished in the thermogravimetric curve. Two previous stages are similar with that in pyrolysis, which result from the evaporation of water (40–150 °C) and low molecular weight alcohols (150–210 °C). A significant mass loss during 210–400 °C is attributed to the little difference between the combustion of hemicellulose and cellulose, which lead to a high overlap between these two peaks. The mass loss between 400 °C and 650 °C is caused by the combustion of lignin. Lignin is a kind of aromatic polymers with complex constituents, so its combustion process widely occurs among this temperature range that making the DTG curve to form a flat-topped peak in this region. The main differences between the pyrolysis and combustion of the tobacco sample also depend on the thermal behavior of lignin in these two conditions. The mass loss of combustion in air is about two times of that during pyrolysis in argon, which is 14.03%. Moreover, the last mass loss located above 650 °C owes to the oxidation of coke.

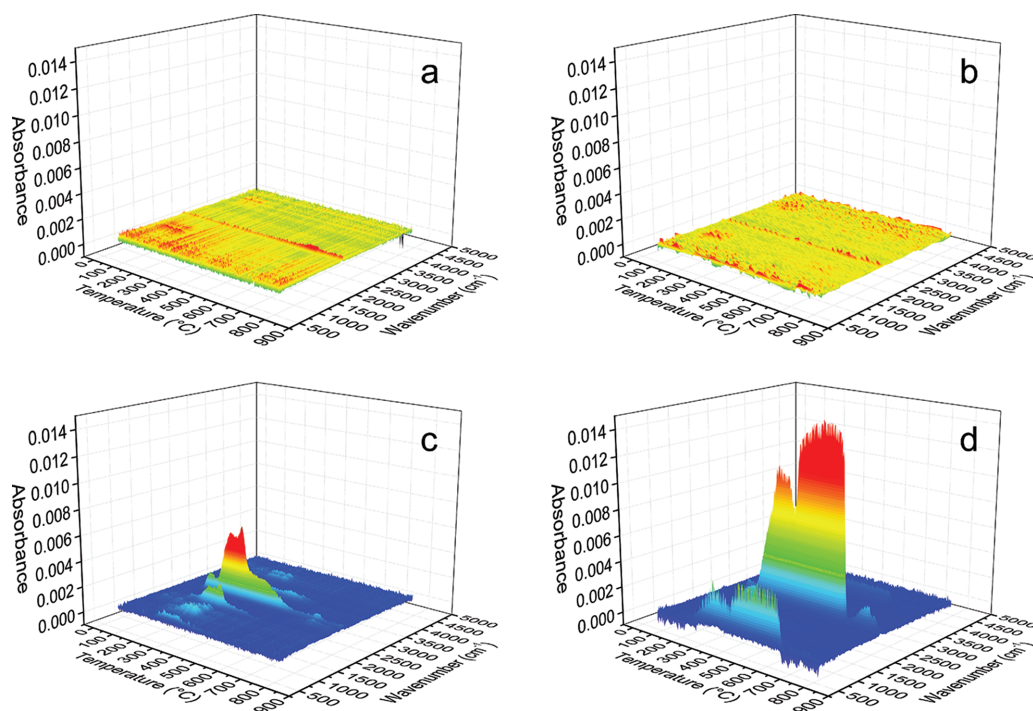


Figure 2. 3D FTIR spectra of the evolved gases for montmorillonite and tobacco with different purge gases. (a) Montmorillonite, argon; (b) montmorillonite, air; (c) tobacco, argon; (d) tobacco, air.

3.2. Evolved Gas Analysis (EGA) of Montmorillonite and Tobacco

The 3D FTIR spectra of the evolved gases of montmorillonite and tobacco are shown in Figure 2. The z-axis represents the normalized absorbance that obtained from the absorbance of evolved gas dividing by the mass of sample. Comparing with tobacco, the absorbance of gas released from montmorillonite is little in both argon (Fig. 2(a)) and air atmosphere (Fig. 2(b)), so its effects to the FTIR absorbance of the montmorillonite-tobacco mixture were neglected in this study. The FTIR spectra indicate that only a small amount of water and carbon dioxide exist in the evolved gases with either argon or air for purge gas. This is clearly verified by the spectra at selected temperatures (Fig. 3).

The FTIR spectra of the evolved gases of tobacco in inert and oxidative atmosphere have remarkable differences. Although the constituents are CO_2 , H_2O , aldehyde (ketone), and alkyl compounds in both argon and air, the released temperature and the quantity of evolved gas are different. For instance, the value of CO_2 absorbance in air are two times than that in argon, and the overall amounts in two situations have huge discrepancy.

In order to identify the changes of evolved gas constitution with the rising of temperature, the FTIR spectra at specific temperatures were extracted in Figure 3 according to the positions of the maximum mass loss peaks. The assignments of the main FTIR absorbance peaks were listed in Table I. Changes of evolved gas for montmorillonite (Fig. 3) is equivalently small, and we have discussed

in the section of thermal analysis (refer to 3.1), so we will not go into detail. The FTIR spectra of Mengzi tobacco below 200 °C in pyrolysis and combustion are similar. The absorbance peak occurred at 120 °C is located in 3640–3550 cm^{-1} , which is attributed to the stretching vibration of hydroxyl in water. At 190 °C, the emergence of the vibration of methyl (2968 cm^{-1}) and methylene (2835 cm^{-1}) besides hydroxyl suggests the release of alcohols. Meanwhile, the peak at 1749 cm^{-1} suggests the carbonyls of aldehydes and ketones. With the rising of temperature to about 300 °C, the evolved amount of hydroxyls, alkyl compounds, and aldehydes (and/or ketones) increase steadily, especially for CO_2 . At higher temperature (450 °C), the products of pyrolysis and combustion for tobacco had made a difference. In argon, the main contents of evolved gas are aldehydes (and/or ketones), alkyl compounds and CO_2 , comparing with the high CO_2 production and still obvious absorbance of water in air. At ~700 °C, the products of pyrolysis are little CO_2 and CO, and the main product of combustion is CO_2 .

3.3. The Pyrolysis of Montmorillonite-Tobacco Mixtures

The TG and DTG curves of the mixtures with different montmorillonite content are shown in Figures 4(a) and (b). According to the ranges of mass losses determined by DTG curves, the amounts of mass losses in different ranges are calculated and listed in Table II. With the increasing of montmorillonite content, the gross mass losses of the mixtures decreased as well as that in each

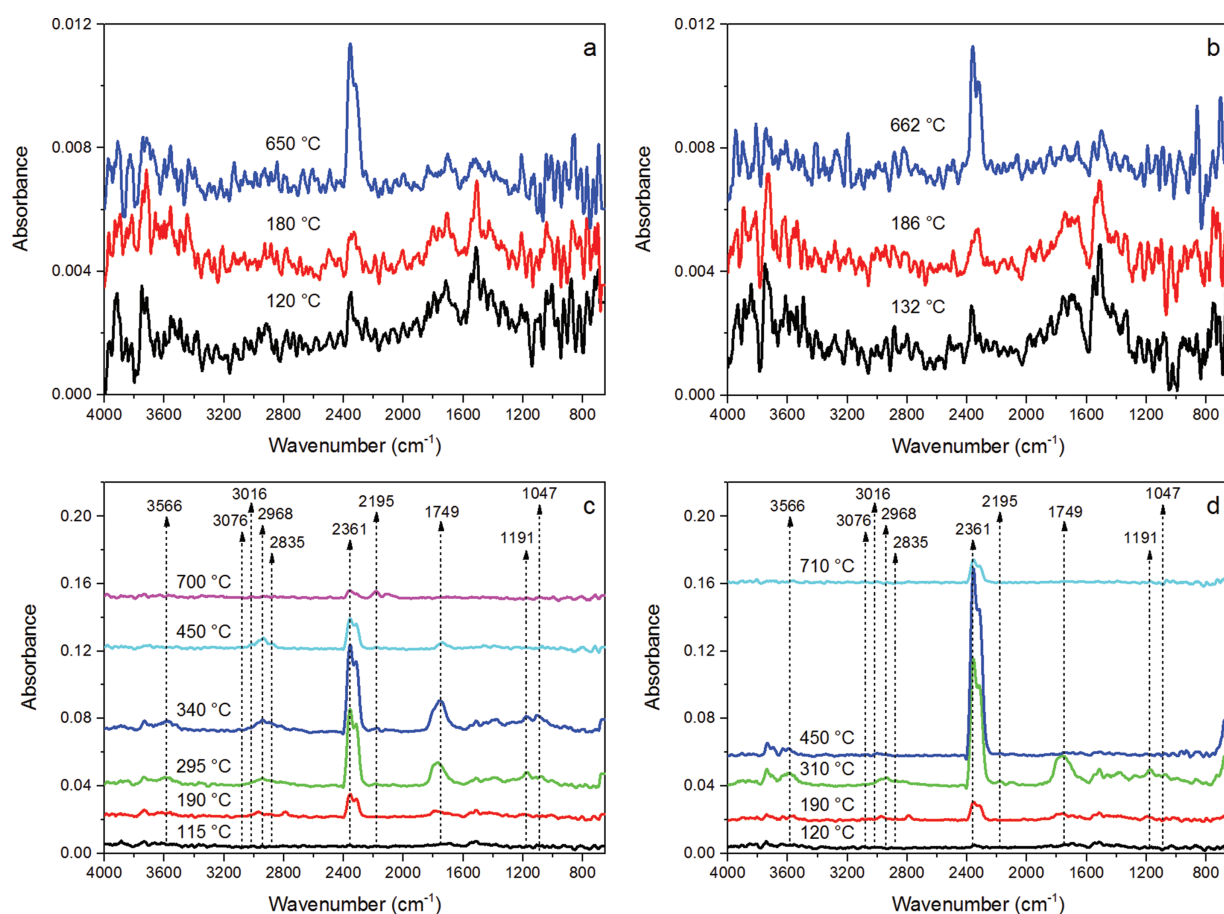


Figure 3. FTIR spectra of the evolved gases at selected temperature of montmorillonite and tobacco with different purge gases. (a) Montmorillonite, argon; (b) montmorillonite, air; (c) tobacco, argon; (d) tobacco, air.

temperature regions above 150 °C. Moreover, the mass-loss regions of the mixtures are similar with that of primitive tobacco, which demonstrated the little effect to the pyrolysis of mixtures in argon with the addition of montmorillonite.

From the normalized Gram-Schmidt curves (Fig. 4(c)), i.e., the value of Gram-Schmidt divided by the sample mass for the thermal analysis, the addition of montmorillonite can sharply reduce the gross amounts of the evolved gases in the pyrolysis of tobacco. Especially for the 5 wt.% montmorillonite addition, the decrease achieves the maximum.

In order to obtain the influence of montmorillonite contents to the constituents and quantity of the evolved gas, we chose some representative functional groups of the major constituents (Table I) and analyzed the absorbance variations on the basis of the FTIR spectra of the pyrolysis products of the tobacco and montmorillonite-tobacco mixtures (Fig. 5).

Water: The release temperature of water in tobacco was from 100 °C to 400 °C, in which the maximum evolved range was 250–400 °C. With the increasing montmorillonite content, the release amount of water decreased, and

the evolved temperature shifted to a higher temperature (Fig. 5(a)).

Aromatics and heterocycles: The overall evolved amount of aromatics and heterocycles in tobacco was little, which form a small peak at about 500 °C. The addition of montmorillonite had little effect to the release of these compounds (Fig. 5(b)).

Methane: The release temperature of methane in tobacco was 150–650 °C. The evolved amounts of methane in mixtures decreased with the addition of montmorillonite (Fig. 5(c)).

Alkanes or alkyl substituents: The emerging temperature of methyl and methylene in the evolved gas of tobacco was 150–650 °C, where the peaks at 250, 350 and 500 °C were for methyl groups (Fig. 5(d)) and three peaks between 250–300 °C were for methylene (Fig. 5(e)). The methyl and methylene amounts in the evolved gas decrease with the increase of montmorillonite, and the decrement in the low-temperature region (150–400 °C) is significantly more than that in high-temperature region (400–650 °C).

CO₂: A volume of CO₂ released in the pyrolysis of tobacco, and the evolved temperature was in a wide range extending from 150 °C to 750 °C with the temperature at 350 °C for the maximum evolved amount (Fig. 5(f)).

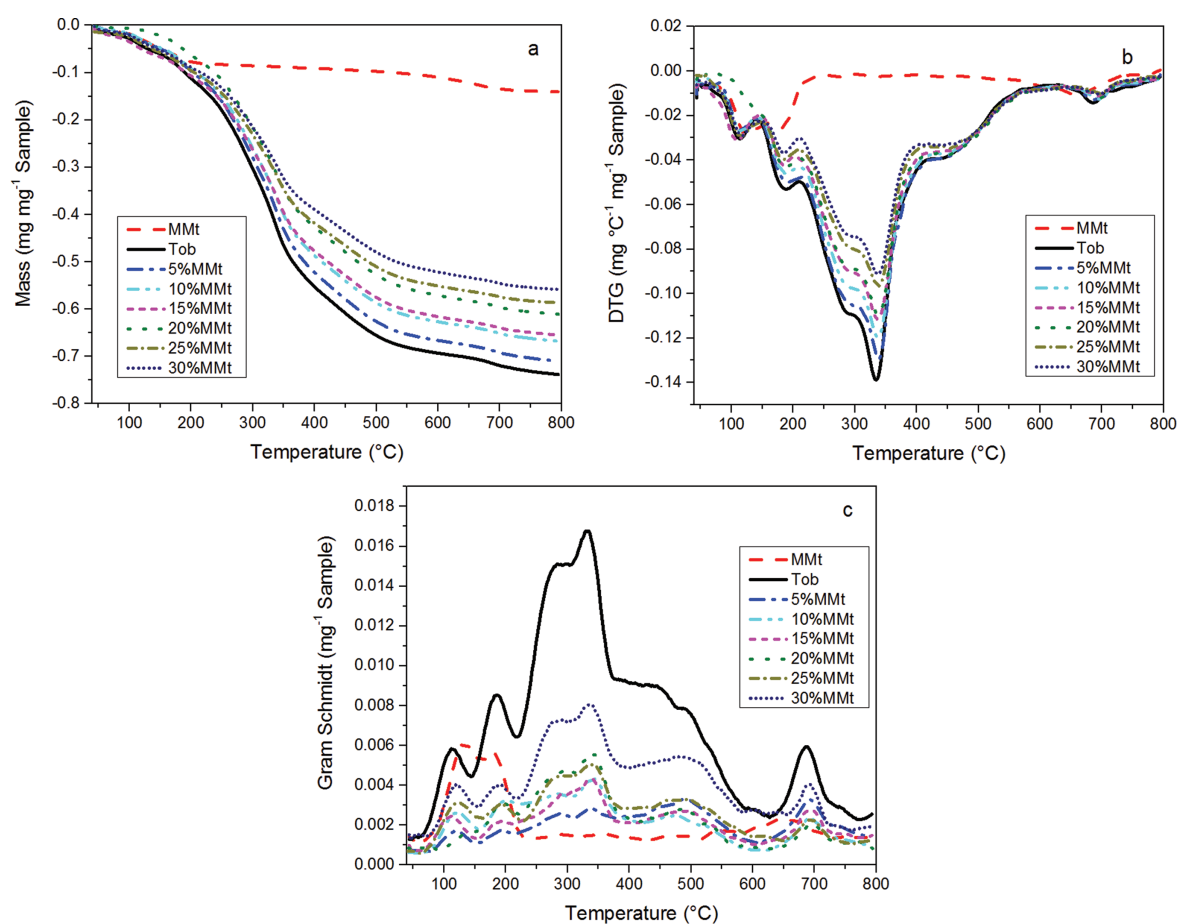


Figure 4. (a) TG, (b) DTG and (c) Gram-Schmidt curves of montmorillonite, tobacco and montmorillonite-tobacco mixtures during pyrolysis in argon.

With the increase of montmorillonite content, the release amount of CO_2 decreased, while the maximum decrease occurred in 250–450 °C.

CO: The release temperature of CO (above 600 °C) was higher than that of the other gas constituents. The amount of CO was reduced with the addition of montmorillonite (Fig. 5(g)).

Aldehydes and ketones: The carbonyl in the evolved gas of tobacco arose in 100–500 °C with two strong peaks of FTIR absorbance at 280 and 350 °C. With the increase of montmorillonite content, the production of carbonyl decrease, and the peak at 280 °C were attenuated from a single peak to a shoulder peak (Fig. 5(h)).

Alcohols, phenols and ethers: The evolved temperature of alcohol, phenol and ether was in 150–450 °C, in which 250–350 °C for the rapid-release region. The vibration intensity of C–O absorbance became weak with the addition of montmorillonite (Figs. 5(i and j)).

3.4. The Combustion of Montmorillonite-Tobacco Mixtures

During combustion in air, the addition of montmorillonite led to the decrease of the mass loss of montmorillonite-tobacco mixture (Fig. 6(a) and Table III). The DTG curves of the samples suggested that the

Table II. Mass losses of montmorillonite, tobacco and montmorillonite-tobacco mixtures in different temperature ranges during pyrolysis in argon.

Sample No.	Sample no.	Sample mass (mg)	40–150 °C (%)	150–210 °C (%)	210–300 °C (%)	300–400 °C (%)	400–600 °C (%)	600–800 °C (%)	Total
1	Tob	8.6850	−5.53	−6.33	−17.96	−24.87	−14.05	−4.49	−73.23
2	MMt	8.1010	−4.69	−3.09	−0.62	−0.49	−1.85	−3.09	−13.83
3	5% MMt	9.1260	−4.71	−5.81	−17.31	−24.22	−14.35	−4.38	−70.79
4	10% MMt	8.6300	−4.63	−5.33	−15.87	−22.71	−14.02	−4.06	−66.63
5	15% MMt	8.3170	−5.89	−4.81	−14.79	−21.40	−13.83	−3.85	−64.57
6	20% MMt	8.7460	−4.57	−4.92	−14.52	−21.04	−14.41	−4.00	−63.46
7	25% MMt	8.8120	−4.65	−4.65	−12.82	−18.61	−13.28	−3.52	−57.54
8	30% MMt	8.6120	−5.11	−4.30	−11.96	−17.42	−13.24	−3.72	−55.74

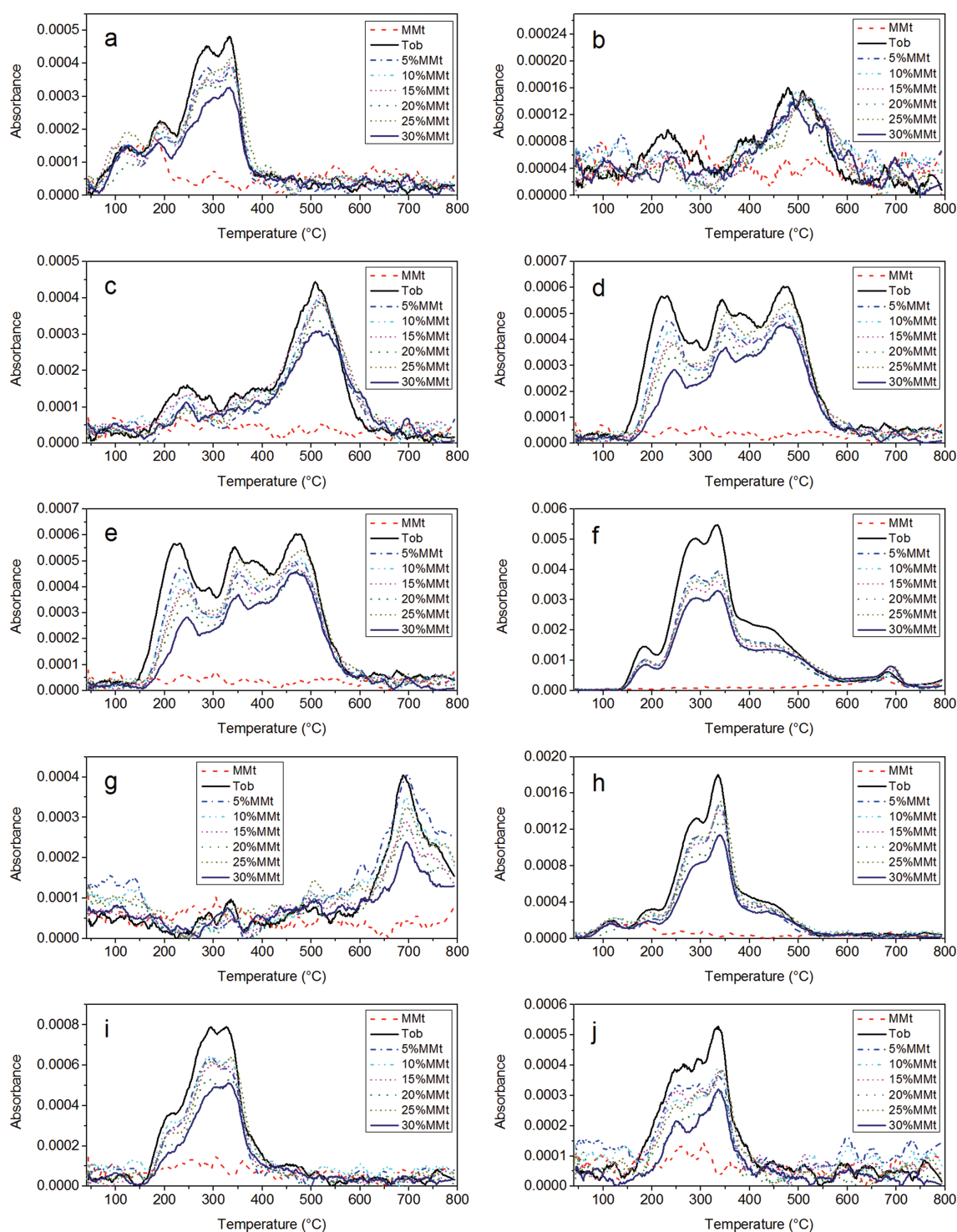


Figure 5. The content evolution of major constituents in montmorillonite, tobacco and montmorillonite-tobacco mixtures with the rising of temperature during pyrolysis in argon. (a) Water: 3566 cm^{-1} ; (b) aromatics and heterocycles: 3076 cm^{-1} ; (c) CH_4 : 3016 cm^{-1} ; (d) $-\text{CH}_3$: 2968 cm^{-1} ; (e) $-\text{CH}_2$: 2835 cm^{-1} ; (f) CO_2 : 2361 cm^{-1} ; (g) CO : 2195 cm^{-1} ; (h) $\text{C}=\text{O}$: 1749 cm^{-1} ; (i) $\text{C}-\text{O}$: 1191 cm^{-1} ; (j) $\text{C}-\text{O}$: 1047 cm^{-1} .

addition of montmorillonite had a greater impact to the combustion of the mixtures above $400\text{ }^\circ\text{C}$, resulting in the transition of oxidation process from high temperature to low temperature. It demonstrated that the addition of montmorillonite, virtually served as

a catalyst, had changed the oxidation process of tobacco.

From the Gram-Schmidt curves (Fig. 6(c)), the addition of montmorillonite reduced the total amount of evolved gas below $350\text{ }^\circ\text{C}$. The amount of released gas was at

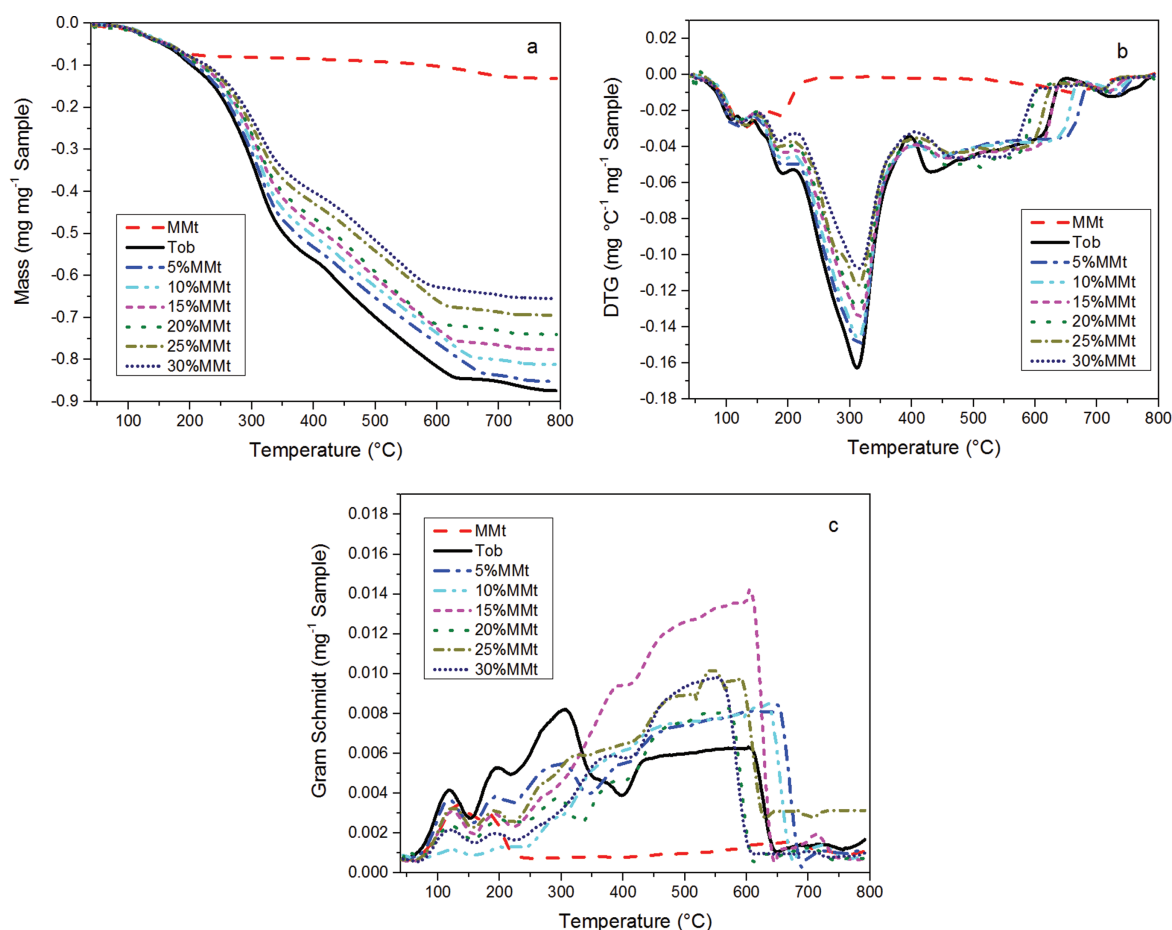


Figure 6. (a) TG, (b) DTG and (c) Gram-Schmidt curves of montmorillonite, tobacco and montmorillonite-tobacco mixtures during combustion in air.

the least while the 10 wt.% montmorillonite was added. But the addition of montmorillonite would increase the total amount of evolved gas above 350 °C, and the release amount achieved a maximum when the montmorillonite content was 15 wt.%.

Water: The release temperature range of vapor in air is wider than that in argon, extending from 100 °C to about 650 °C (Fig. 7(a)). Adding montmorillonite would reduce the amount of vapor.

Aromatics and heterocycles: The FTIR response to aromatics is little, and the influence of montmorillonite addition is little (Fig. 7(b)).

Methane: The generation of methane happened in the range of 150–650 °C, existing two release peaks at 300 and 500 °C (Fig. 7(c)). The significant decrease of evolved methane occurred until the montmorillonite content exceeded 20 wt.%.

Alkanes or alkyl substituents: Alkanes evolved from 150 to 400 °C during the combustion of tobacco. The addition of montmorillonite not only reduced the release amount of alkanes, but also elevated their evolved temperature (Figs. 7(d and e)).

CO₂: Carbon dioxide released in 150–650 °C for the combustion of tobacco in air. When a few

Table III. Mass losses of montmorillonite, tobacco and montmorillonite-tobacco mixtures in different temperature ranges during combustion in air.

No.	Sample no.	Sample mass (mg)	40–150 °C (%)	150–210 °C (%)	210–300 °C (%)	300–400 °C (%)	400–600 °C (%)	600–800 °C (%)
1	Tob	8.6850	−4.25	−6.43	−45.39	−28.38	−2.87	−87.33
2	MMt	8.1010	−4.15	−2.84	−0.98	−2.73	−1.85	−12.55
3	5% MMt	9.1260	−4.31	−5.89	−42.98	−27.96	−3.99	−85.13
4	10% MMt	8.6300	−3.47	−5.47	−41.25	−28.30	−2.21	−80.70
5	15% MMt	8.3170	−4.21	−5.41	−41.12	−29.46	−3.13	−83.32
6	20% MMt	8.7460	−3.61	−4.85	−36.91	−25.85	−1.81	−73.03
7	25% MMt	8.8120	−3.58	−4.62	−33.95	−25.06	−1.62	−68.82
8	30% MMt	8.6120	−4.02	−4.35	−31.45	−23.64	−1.78	−65.25

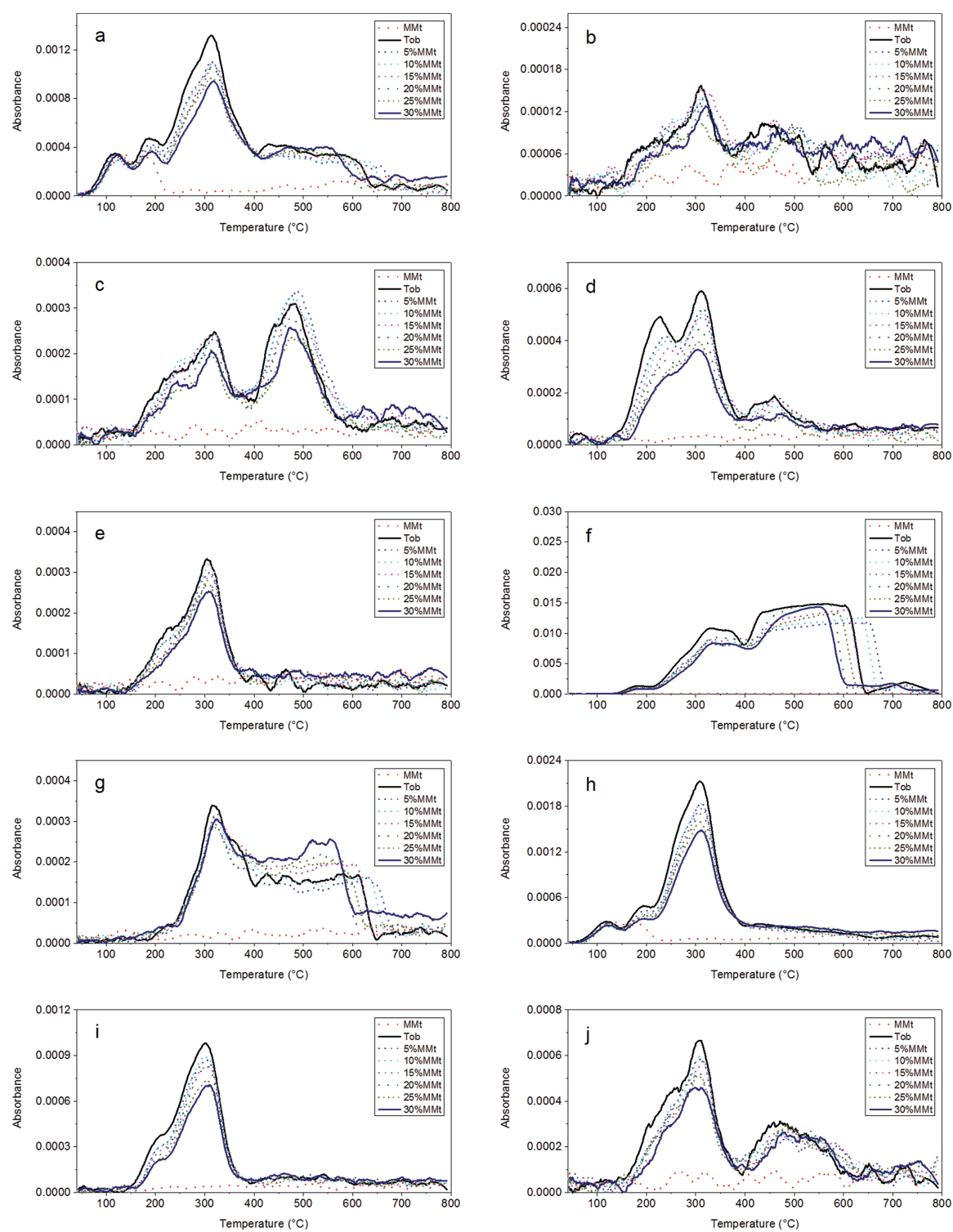


Figure 7. The content evolution of major constituents in montmorillonite, tobacco and montmorillonite-tobacco mixtures with the rising of temperature during combustion in air. (a) Water: 3566 cm^{-1} ; (b) aromatics and heterocycles: 3076 cm^{-1} ; (c) CH_4 : 3016 cm^{-1} ; (d) $-\text{CH}_3$: 2968 cm^{-1} ; (e) $-\text{CH}_2-$: 2835 cm^{-1} ; (f) CO_2 : 2361 cm^{-1} ; (g) CO : 2195 cm^{-1} ; (h) $\text{C}=\text{O}$: 1749 cm^{-1} ; (i) $\text{C}-\text{O}$: 1191 cm^{-1} ; (j) $\text{C}-\text{O}$: 1047 cm^{-1} .

montmorillonites (5–10 wt.%) were added, the production of CO_2 reduced significantly, and the producing temperature extended to a higher temperature. With a further increase of montmorillonite content, the formation of CO_2 shifted to a lower temperature, which would narrow the

emerging temperature range of CO_2 and reduce the amount of evolved gas (Fig. 7(f)).

CO : The temperature region of the evolved CO during the combustion of tobacco in air (200–650 °C) was obviously wider than that in pyrolysis (Fig. 7(g)). The quantity

of CO increased with the addition of montmorillonite and the major region of increase was above 400 °C.

Aldehydes and ketones: The carbonyl was detected in 100–400 °C, with the maximum signal at about 300 °C, during the combustion of tobacco. The addition of montmorillonite would reduce the amounts of aldehydes and ketones (Fig. 7(h)).

Alcohols, phenols and ethers: Figures 7(i) and (j) suggested the evolved temperature of these compounds were in the range of 150–650 °C (300 °C for the maximum amount). The vibration of C–O in the gas was attenuated with the increase of montmorillonite content.

4. CONCLUSION

(1) Comparing with tobacco, the addition of montmorillonite can obviously reduce the total amounts of the evolved gases during the pyrolysis of montmorillonite-tobacco mixtures. The greatest declines occurred when the montmorillonite content was 5 wt.%. But for the combustion, the gas amount evolving below 350 °C decrease (10 wt.% montmorillonite content for the minimum evolved gas) and that evolving amount above 350 °C increase (15 wt.% montmorillonite for the maximum evolved gas) with the increase of montmorillonite content. Meanwhile, the addition of montmorillonite elevated the evolved temperature of alkanes and carbon dioxide in both argon and air.

(2) With the increase of montmorillonite content, the total mass loss and the mass loss in each temperature regions above 150 °C both decrease for the pyrolysis of the montmorillonite-tobacco mixtures. The temperature ranges of mass loss for the mixtures had small differences with that for tobacco. Addition of montmorillonite had significantly changed the combustion behavior of tobacco, making the oxidation reaction occurring above 400 °C shift to a lower temperature. It indicated that montmorillonite possessed a certain catalytic capability during the combustion of the mixtures.

(3) Whether the pyrolysis in argon or the combustion in air, the evolved amounts of the monitored gases decreased with the increase of montmorillonite content of mixtures, especially for alkanes, CO₂, carbonyl compound, alcohols, phenols and ethers which were most apparent.

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