Exploring the Catalytic Potential of Oxide Glasses-(Ceramics) in the Thermal Decomposition of Fatty Acids

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INTRODUCTION

Why renewable fuels?

- to tackle the critical issue of reducing greenhouse gas emissions, renewable fuels such as renewable diesel present an attractive alternative to fossil fuels due to their lower toxicity, renewability, biodegradability, and cleaner combustion [1,2]

Why fatty acids?

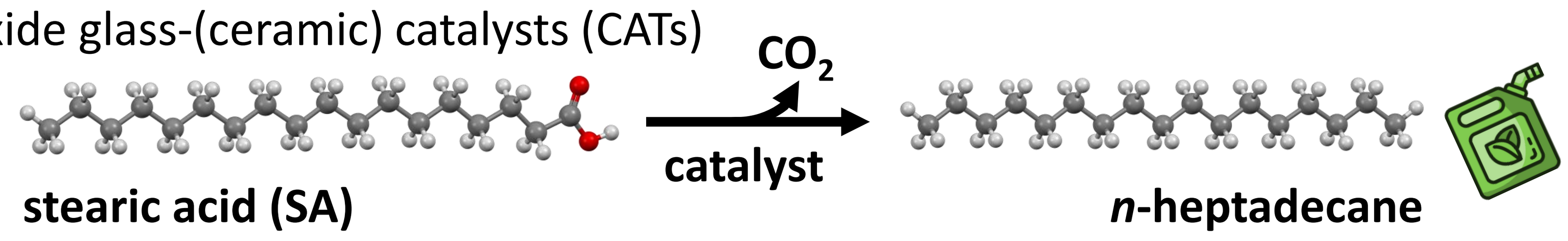
- fatty acids serve as a model system for studying the catalytic deoxygenation of lipids derived from biomass, a key step in renewable diesel production

Why glassy and glass-ceramic catalysts?

- glassy and glass-ceramic materials offer a combination of thermal and chemical stability, cost-effective and straightforward synthesis, and the flexibility to fine-tune catalyst properties through simple compositional adjustments, which is crucial for industrial applications [3,4]

AIMS & METHODS

- this study focuses on developing glass-(ceramic) catalysts derived from the Na_2O-V_2O_5-(Al_2O_3)-P_2O_5-Nb_2O_5 system, for the pyrolytic deoxygenation of long-chain fatty acids into alkanes
- stearic acid (SA) was selected as a model compound to investigate the thermal decomposition of fatty acids (FAs) and assess the catalytic performance of oxide glass-(ceramic) catalysts (CATs)



- catalytic activity was evaluated using thermogravimetric analysis/differential scanning calorimetry (TG/DSC), coupled thermogravimetry-infrared spectroscopy (TG-IR) and and simultaneous thermal analysis-quadrupole mass spectrometry (STA-QMS)

RESULTS & DISCUSSION

Table 1. Batch compositions and PXRD characterization of the studied glassy and glass-ceramic CATs.

Sample	x / mol%					PXRD
	Na_2O	V_2O_5	P_2O_5	Nb_2O_5	Al_2O_3	characterization
70V-10P-20Na	20	70	10	-	-	57% $Na_{0.33}V_2O_5$ (239391-ICSD) + 43% amorphous
70V-10P-20Nb	-	70	10	20	-	Amorphous
55V-10P-35Na	35	55	10	-	-	14% $Na_{1.164}V_3O_8$ (164514-ICSD) + 86% amorphous
35Na-25V-20P-20Nb	35	25	20	20	-	Amorphous
35Na-10V-35P-20Nb	35	10	35	20	-	Amorphous
35Na-45P-20Nb	35	-	45	20	-	Amorphous
35Na-10Al-35P-20Nb	35	-	35	20	10	Amorphous

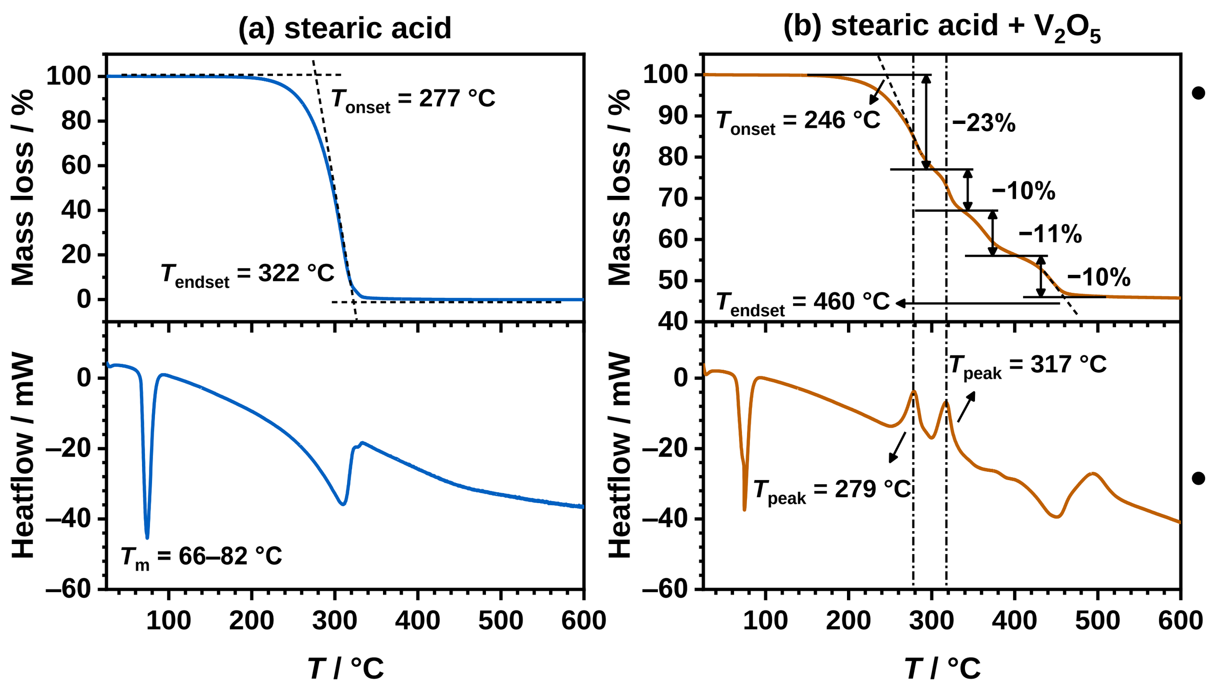
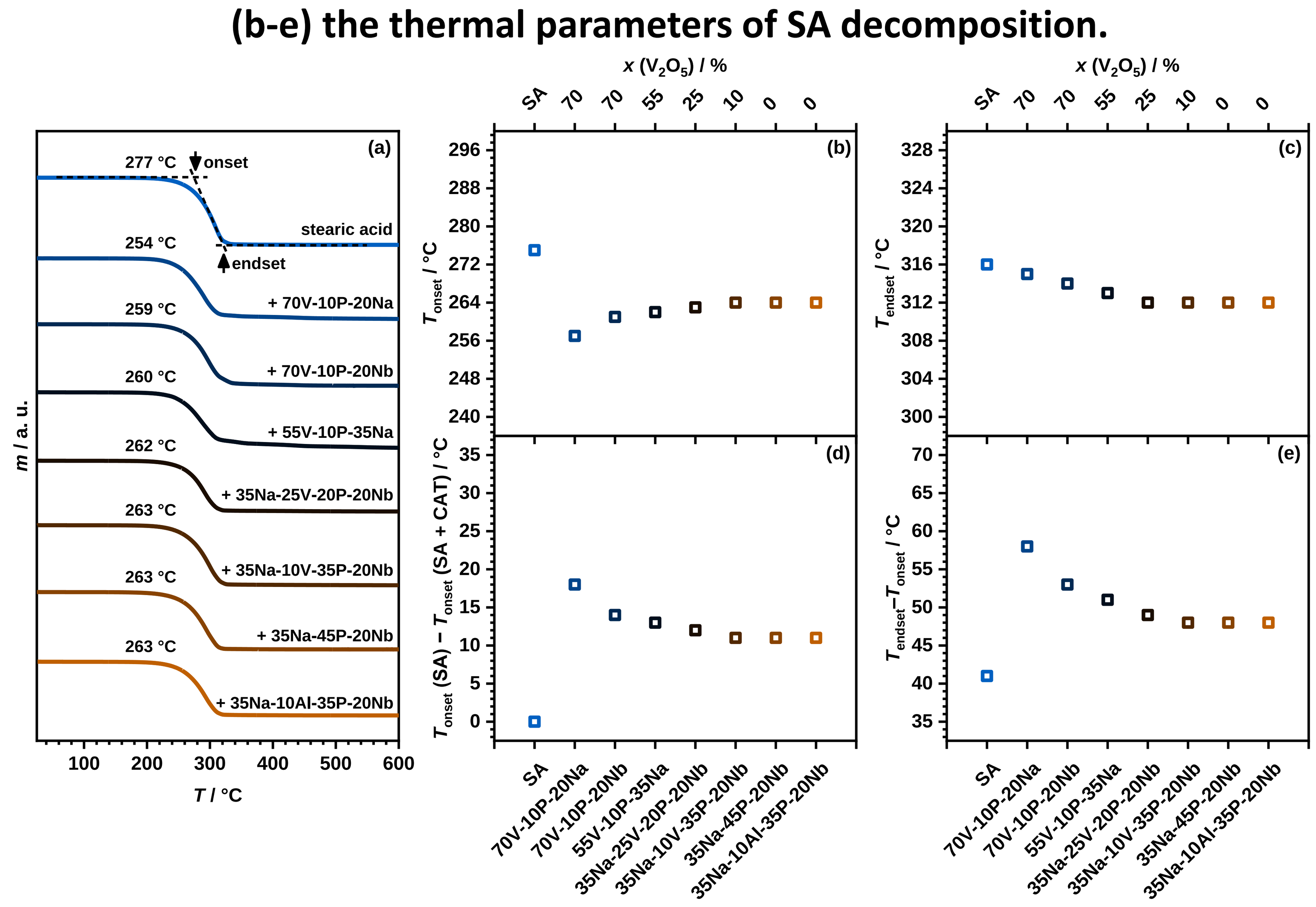


Figure 1. TG/DSC curves of the thermal decomposition of (a) pure SA and (b) SA mixed with V_2O_5 in a 1:1 ratio.

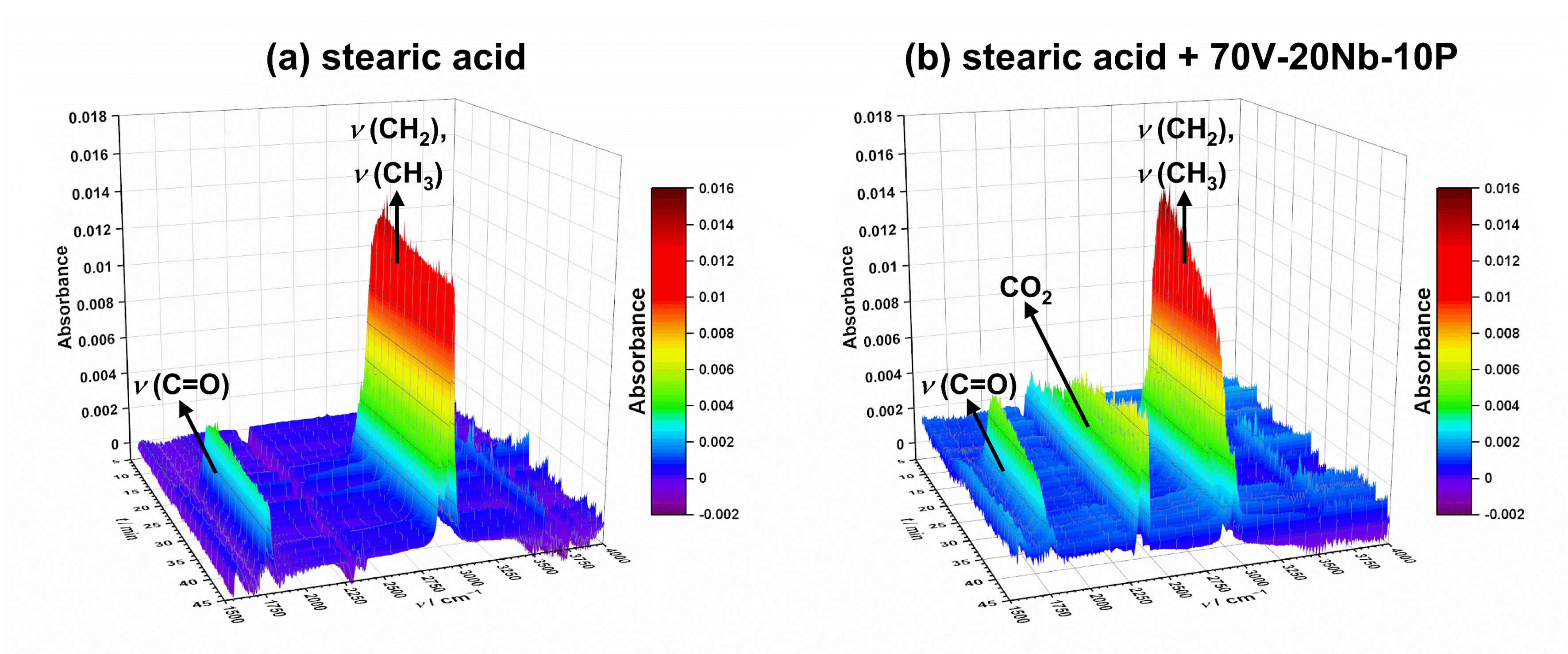
- commercial V_2O_5 was chosen as a standard reference material, as the glass-(ceramic) CATs contain up to 70 mol% V_2O_5
- despite lowering T_{onset}, V_2O_5 causes a complex decomposition process

Figure 2. The influence of the addition of glass-(ceramic) CATs on: (a) TG curves of the thermal decomposition of SA and (b-e) the thermal parameters of SA decomposition.



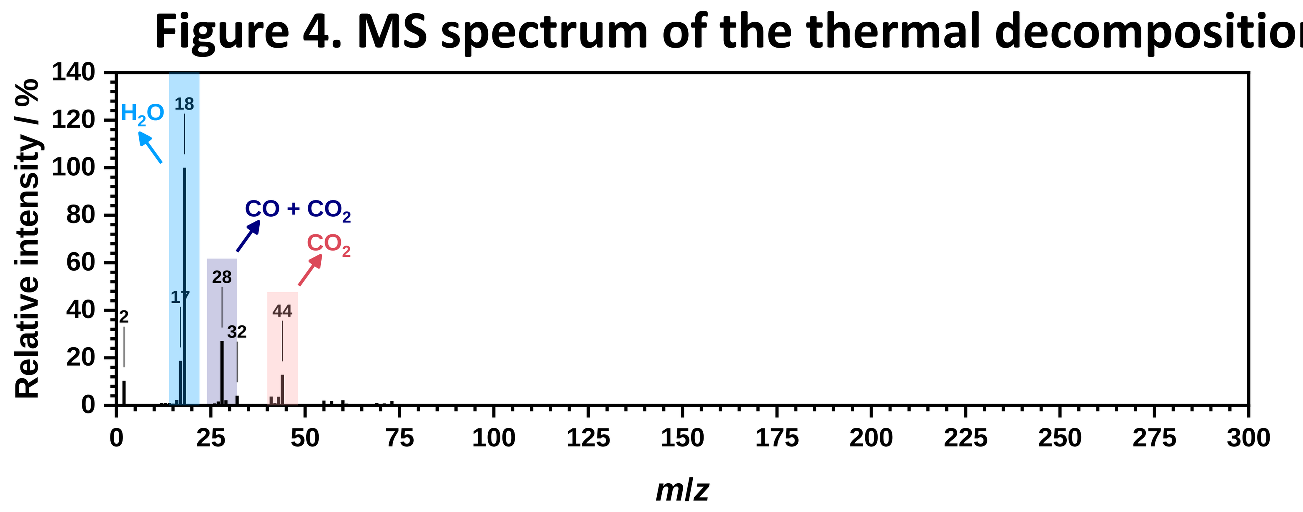
- tested CATs show a single-step weight loss, indicating a more controlled and reliable catalytic behaviour in the thermal decomposition of SA than V_2O_5
- CATs with ≥55 mol% V_2O_5 significantly enhance SA decomposition by lowering both the T_{onset} and T_{endset} values
- the correlation between V_2O_5 content and thermal parameters of SA decomposition highlights the pivotal role of vanadium in catalytic activity

Figure 3. 3D color maps showing the change in absorbance values of FT-IR spectra as a function of wavenumber, ν, and time, t, for the thermal decomposition of (a) pure SA and (b) SA mixed with 70V-10P-20Nb in a 1:1 ratio at 250 °C.



- pure SA (without a catalyst):
  - decarboxylation to a minimal extent
  - confirmed by STA-QMS experiment
- SA + **70V-10P-20Nb** glass:
  - strong CO_2 signals → decarboxylation of stearic acid

Figure 4. MS spectrum of the thermal decomposition of pure SA.



- pure SA at 230 °C undergoes partial decarboxylation/decarbonylation to a small extent

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