Rubber fires –
composition of effluents and influence of parameters

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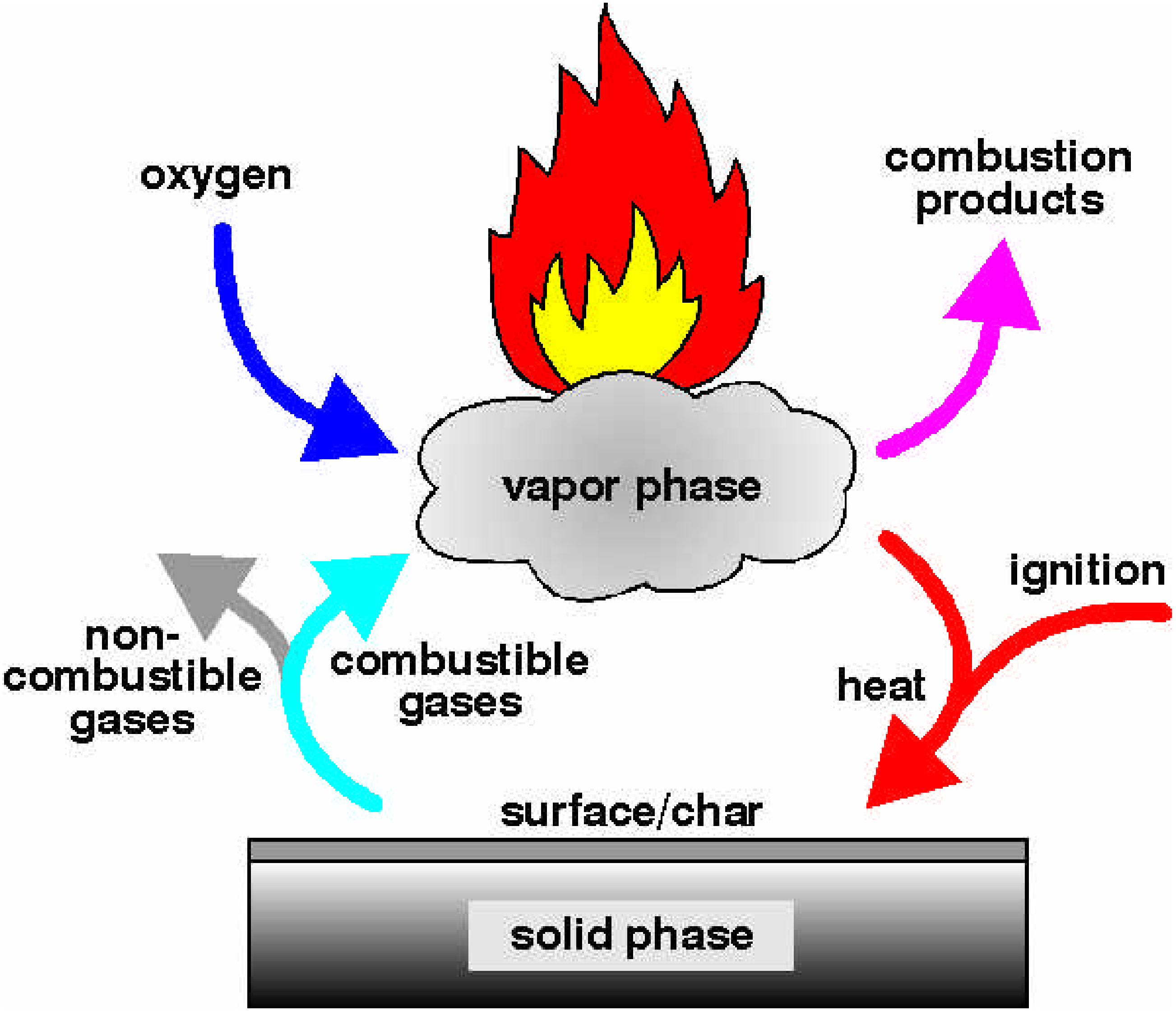
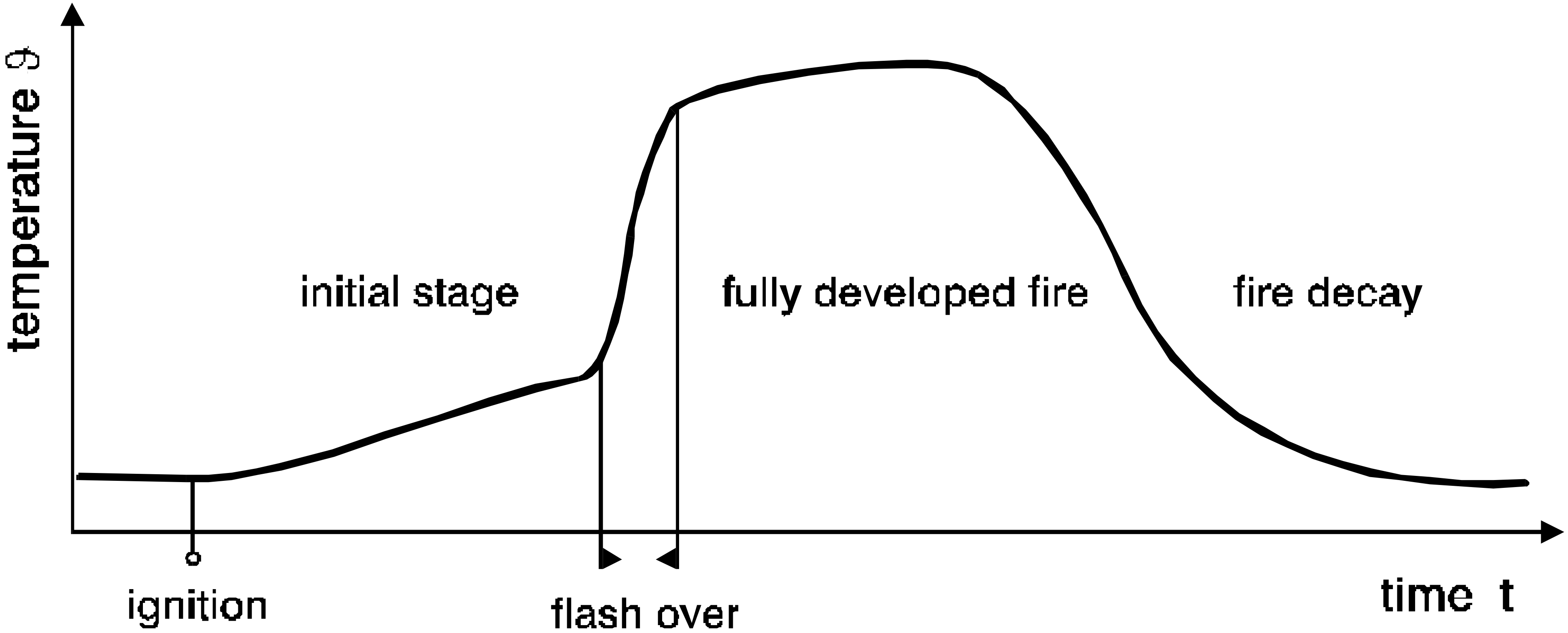
- Combustion theory
- Combustion simulation
- Macroscopic thermooxidative degradation of rubber
- High volatile combustion effluents
- Semi volatile combustion effluents
- Conclusion

Combustion and flame



Combustion stages



Combustion stages - classification of fire types

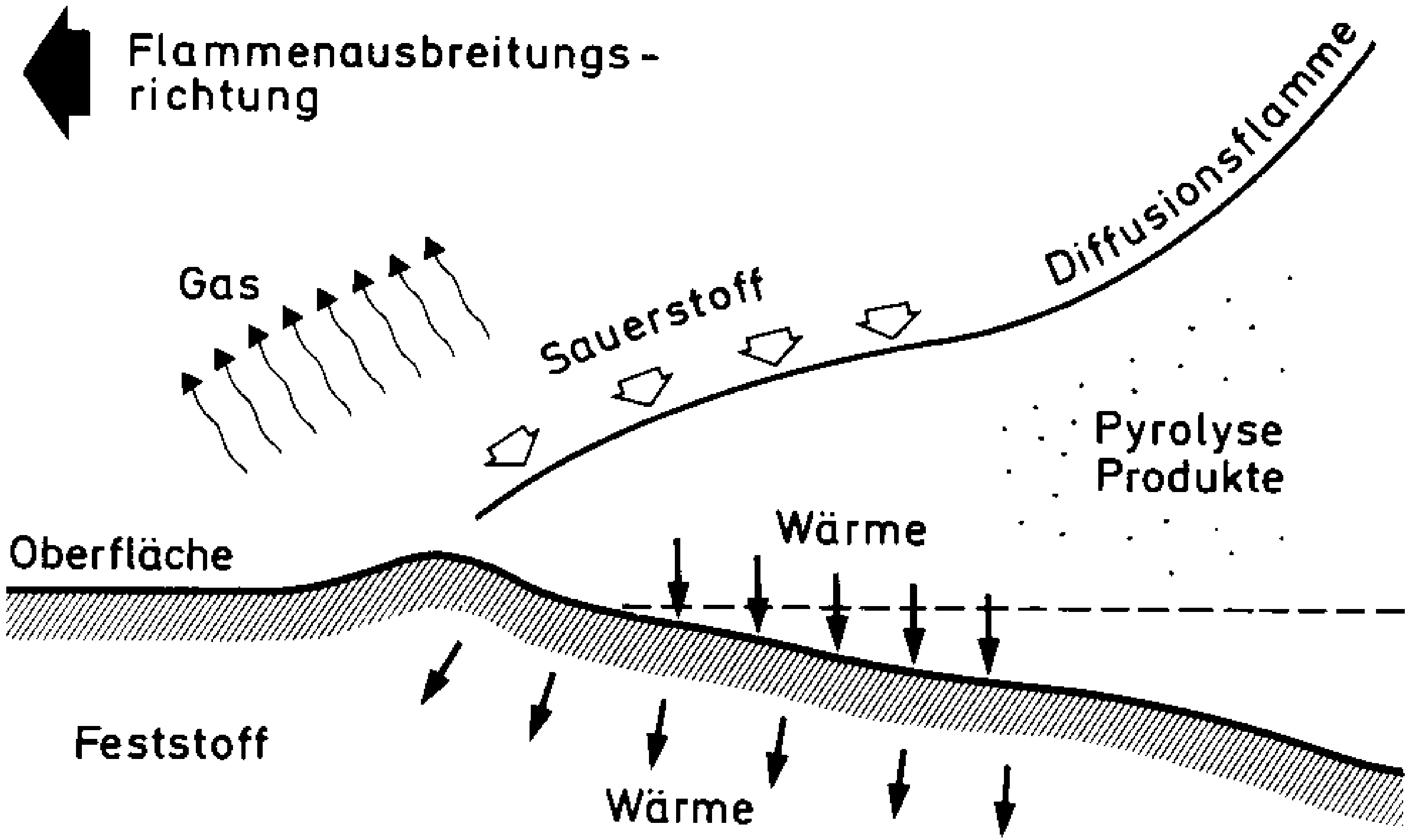
Fire type	Oxygen[1)] %	Ratio CO_2/CO[2)]	Temperature[1)] °C	Irradiance[3)] kW/m²
1 Decomposition **a) Smouldering (self-sustained)** **b) Non-flaming (oxidative)** **c) Non-flaming (pyrolytic)**	21 5 to 21 < 5	N/A N/A N/A	< 100 < 500 < 1000	N/A < 25 N/A
2 Developing fire (flaming)	10 to 15	100 to 200	400 to 600	20 to 40
3 Fully developed (flaming) **a) Relatively low ventilation** **b) Relatively high ventilation**	1 to 5 5 to 10	< 10 <100	600 to 900 600 to 1200	40 to 70 50 to 150

1) General environmental condition (average) within compartment.
2) Mean value in fire plume near to fire.
3) Incident irradiance on the sample (average).
N/A Not applicable.

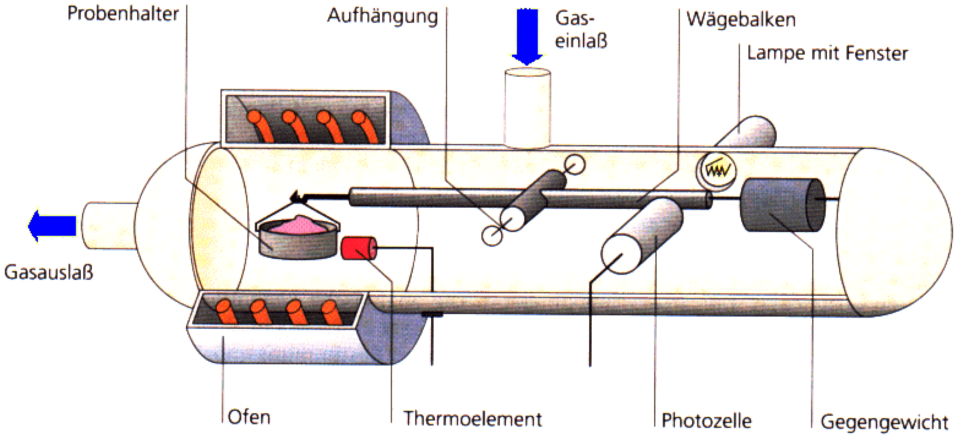
Combustion simulation

- Thermogravimetric analyzer (TGA)
  - to determine the macroscopic degradation behaviour under the influence of an approaching flame front
- TGA-infrared spectroscope coupling (TGA-IR)
  - to determine the formation kinetic of high volatile fire effluents
- VCI-combustion oven with different sampling and analysis methods
  - to determine the composition of fire effluents and emission potentials in dependence of burned material and fire conditions

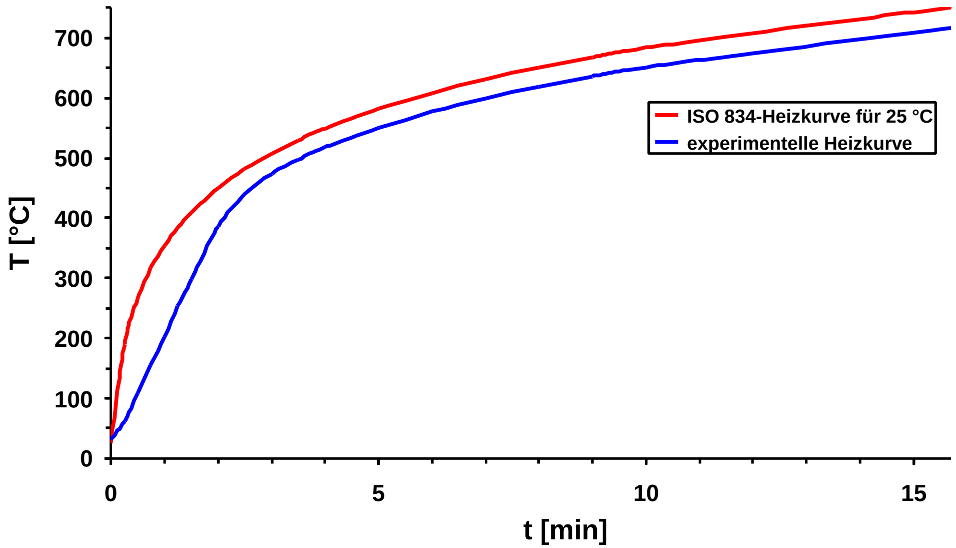
Flame spread



Flame spread simulation



Thermogravimetric Analyzer (TGA)

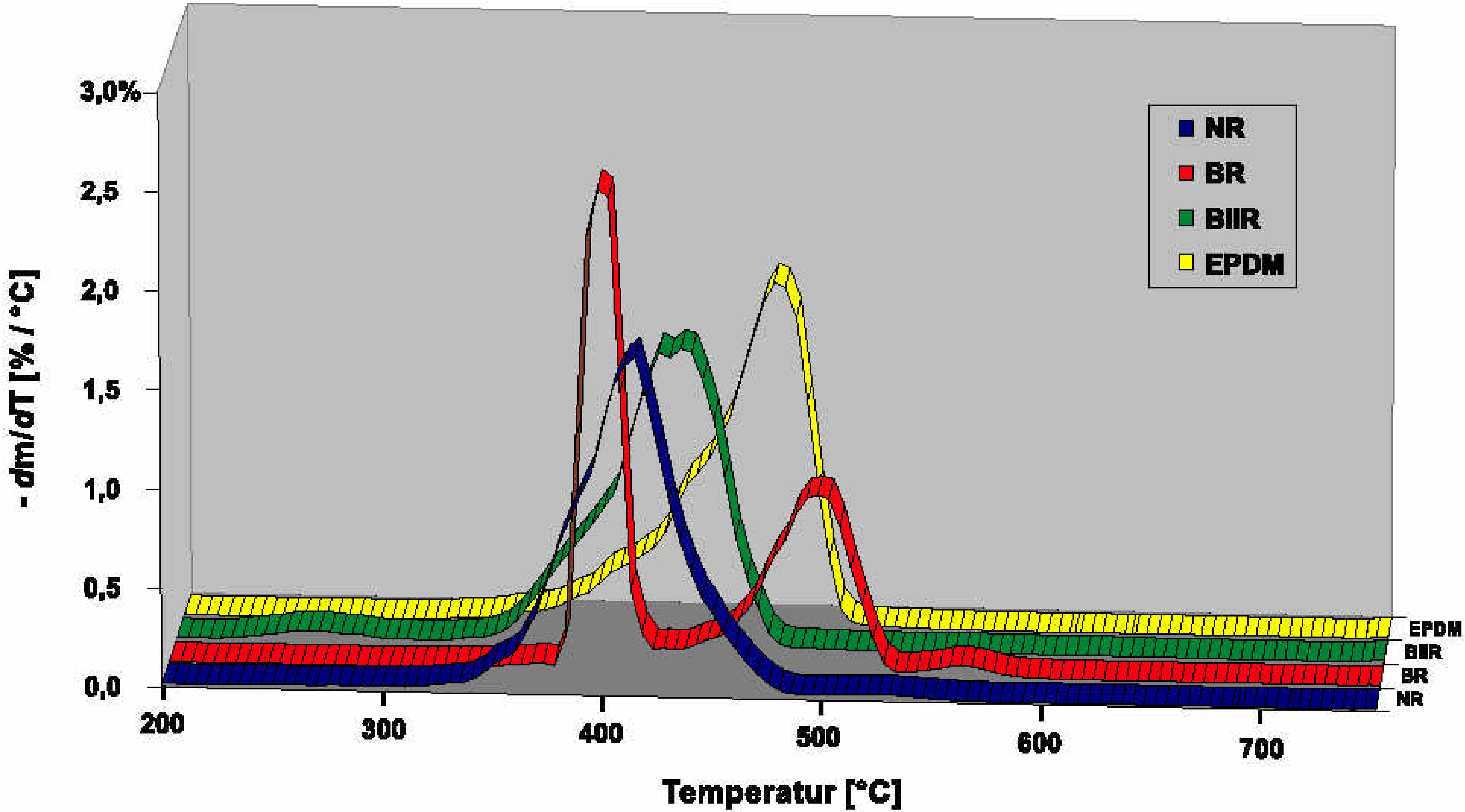


$T_t - T_0 = 345 \cdot \lg (8\,t + 1)$;

T_t = burning room temperature at time t,
T_0=burning room temperature at begin,
t = time [min]

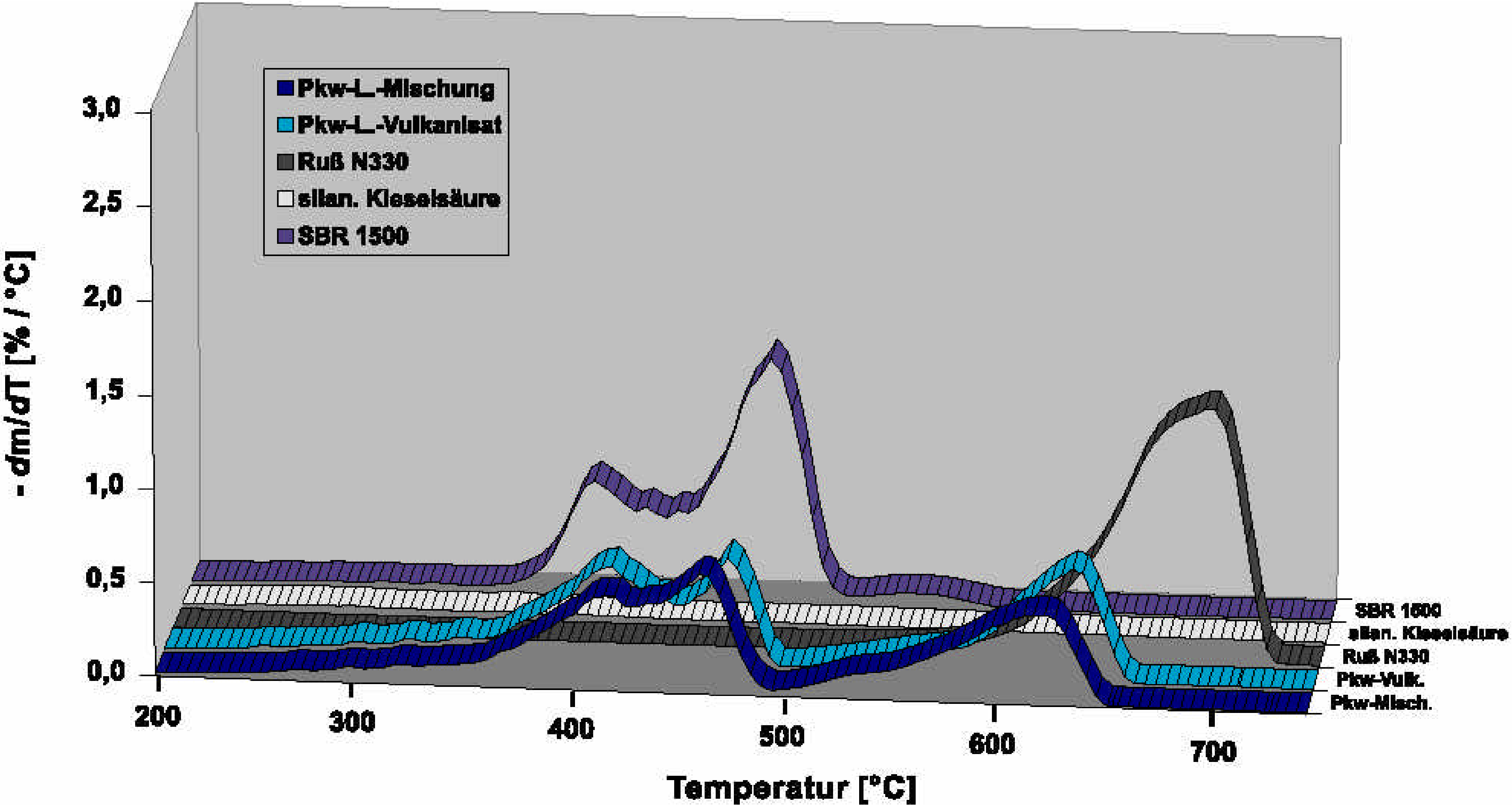
Macroscopic degradation behaviour

Raw rubber

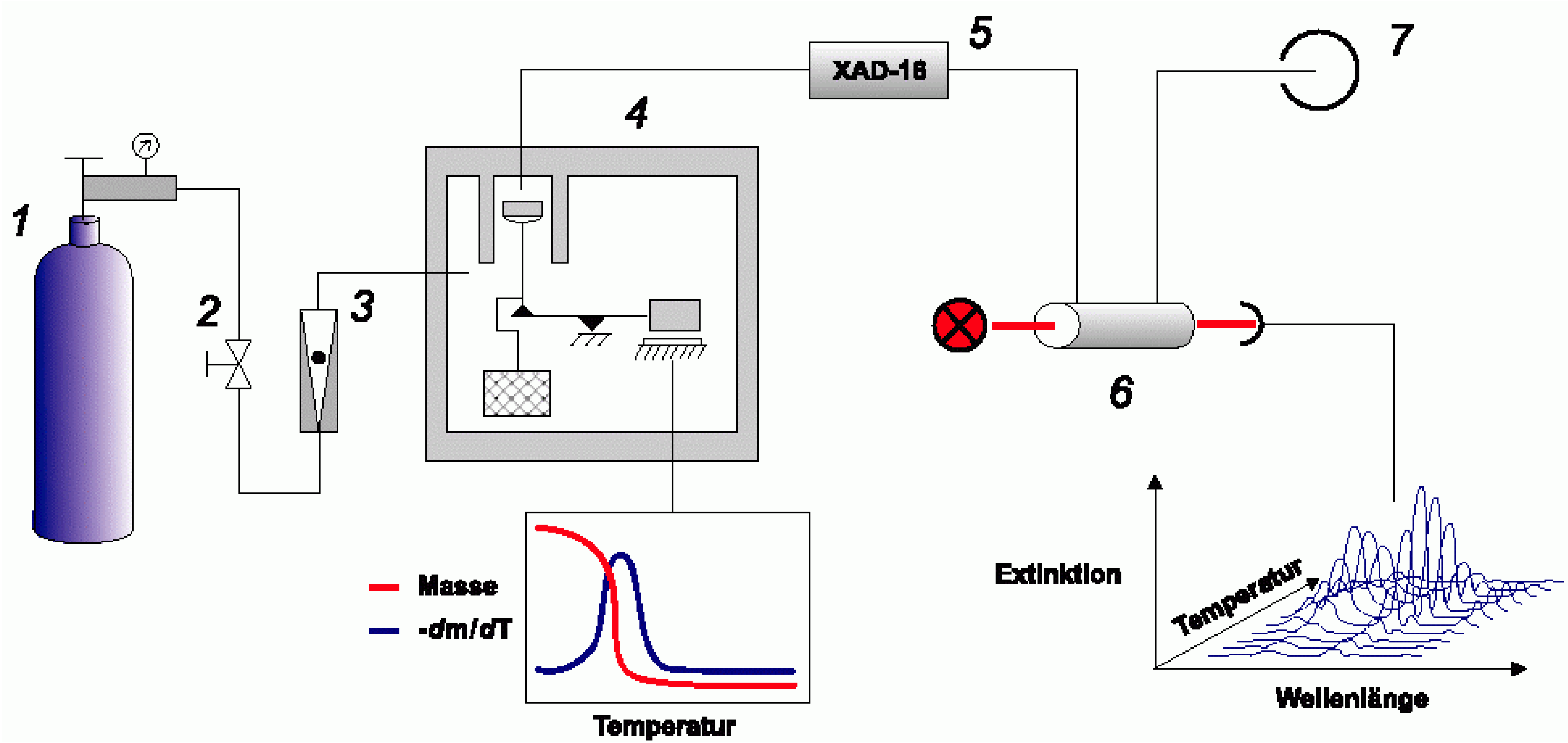


Macroscopic degradation behaviour

Passenger tire tread



TGA-IR spectroscope coupling

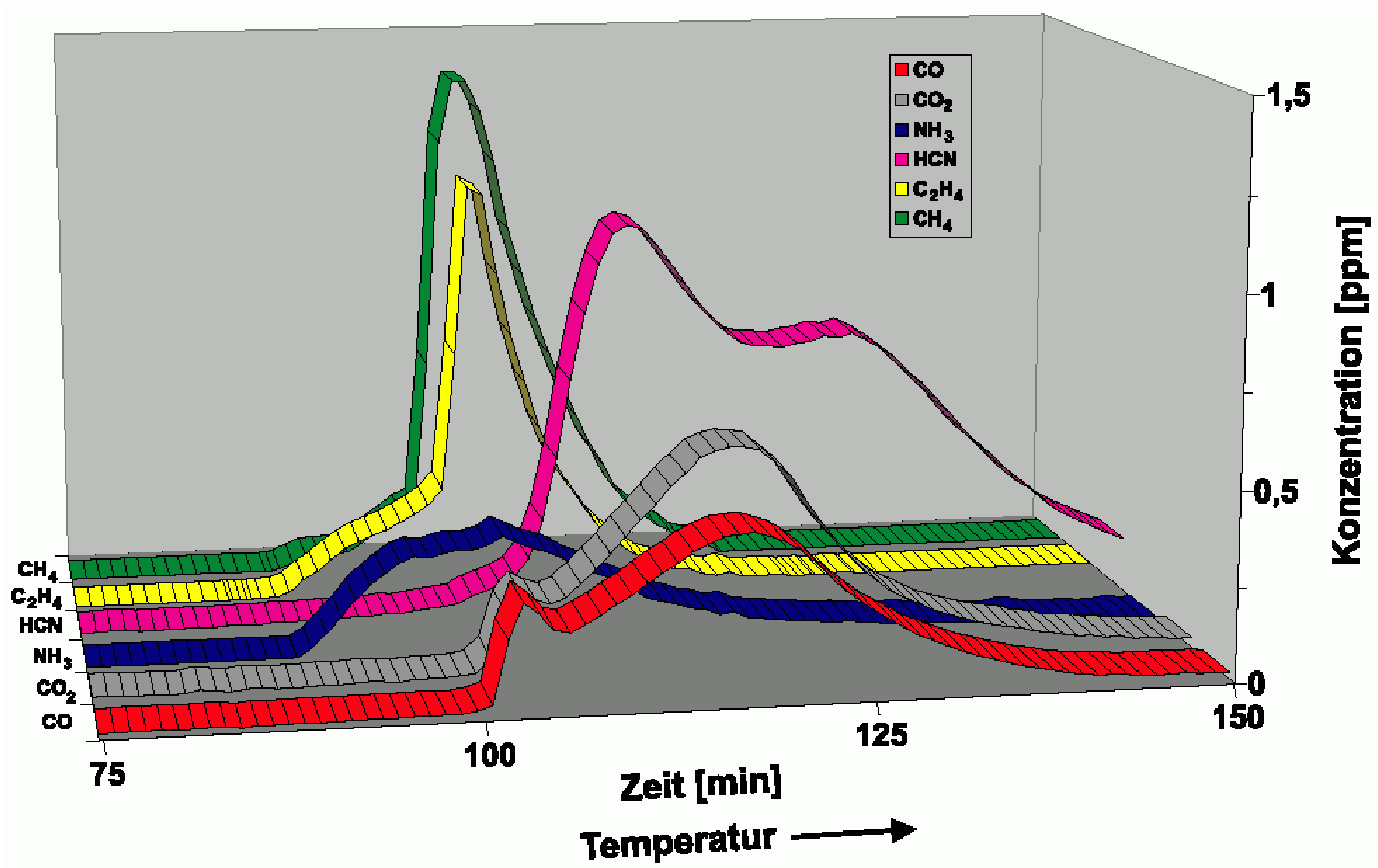


1 synthetic air bottle with pressure controller, *2* high precision flow regulator,
3 flowmeter, *4* TGA furnace with control unit, *5* heated transfer line with filter unit,
6 IR spektrometer equipped with heated gas cell, *7* waste

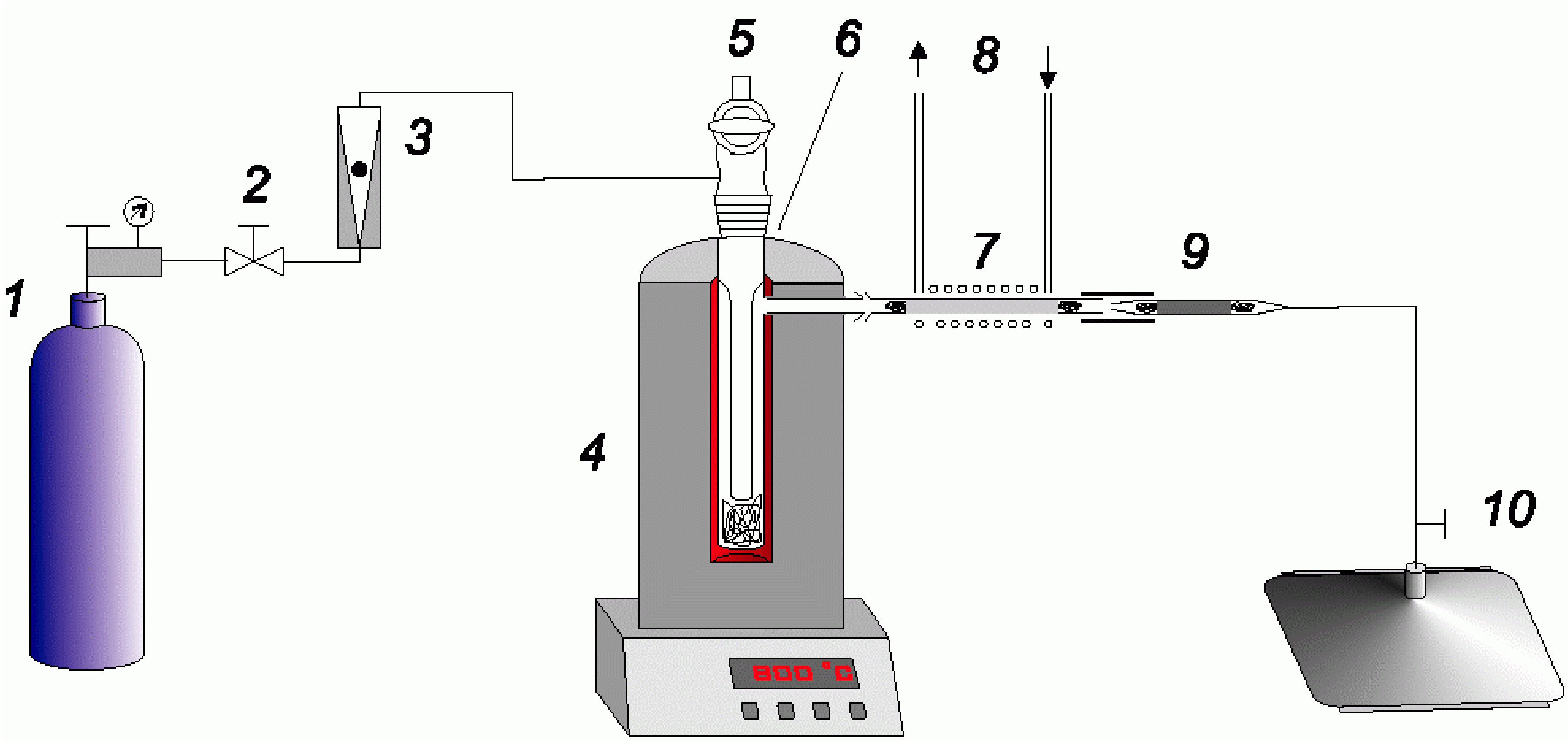
Thermooxidative degradation kinetic

Thermooxidative degradation kinetic

High volatile combustion effluents of NBR



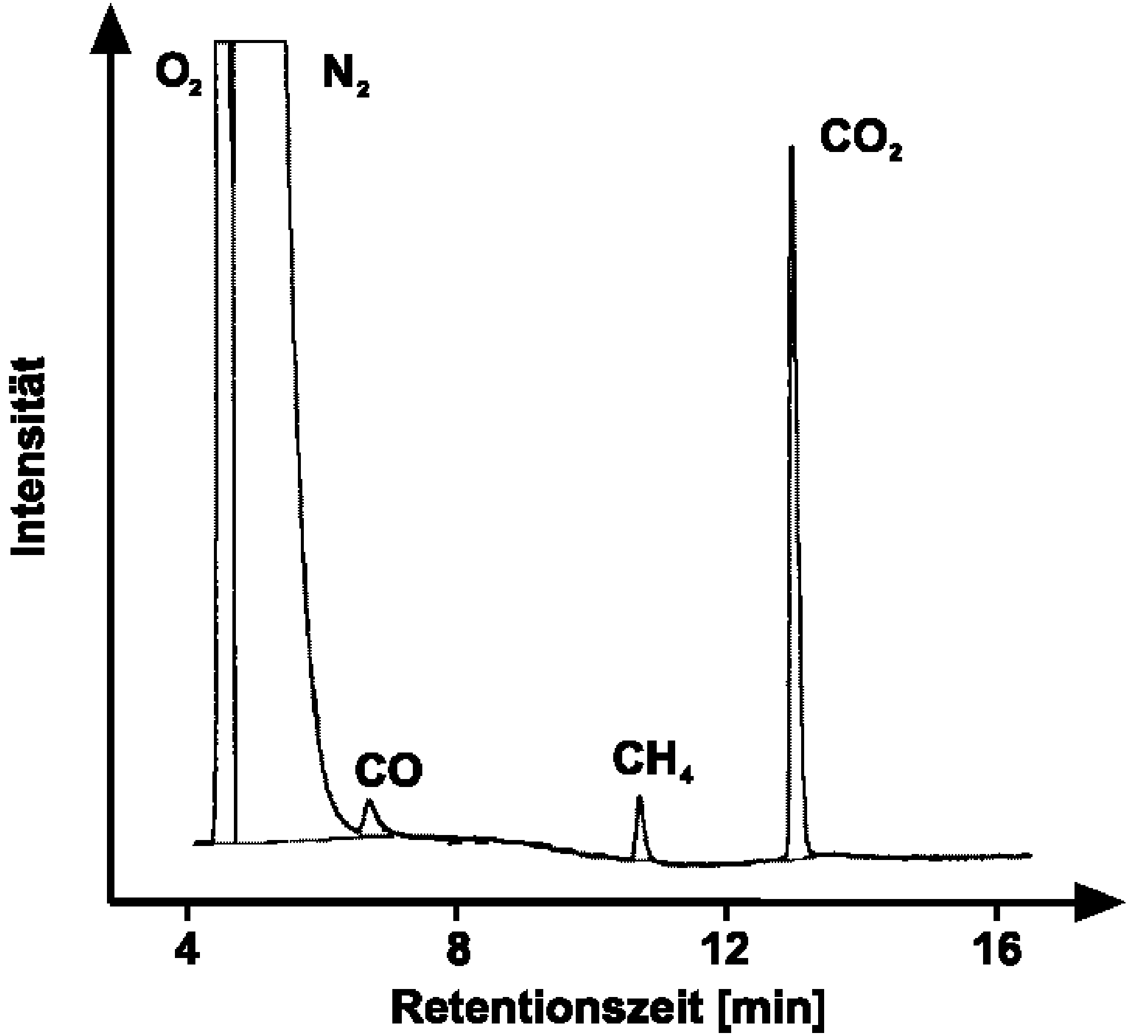
VCI combustion oven



1 synthetic air bottle with pressure controller, *2* high precision flow regulator, *3* flowmeter, *4* VCI combustion chamber with digital temperature control unit, *5* sample inlet, *6* double wall burn tube with side outlet, *7* XAD-2 adsorption tube, *8* cooling, *9* charcoal adsorption tube, *10* aluminium-coated gas sampling bag

Composition of fire effluents - GC-TCD chromatogram

SBR 1500



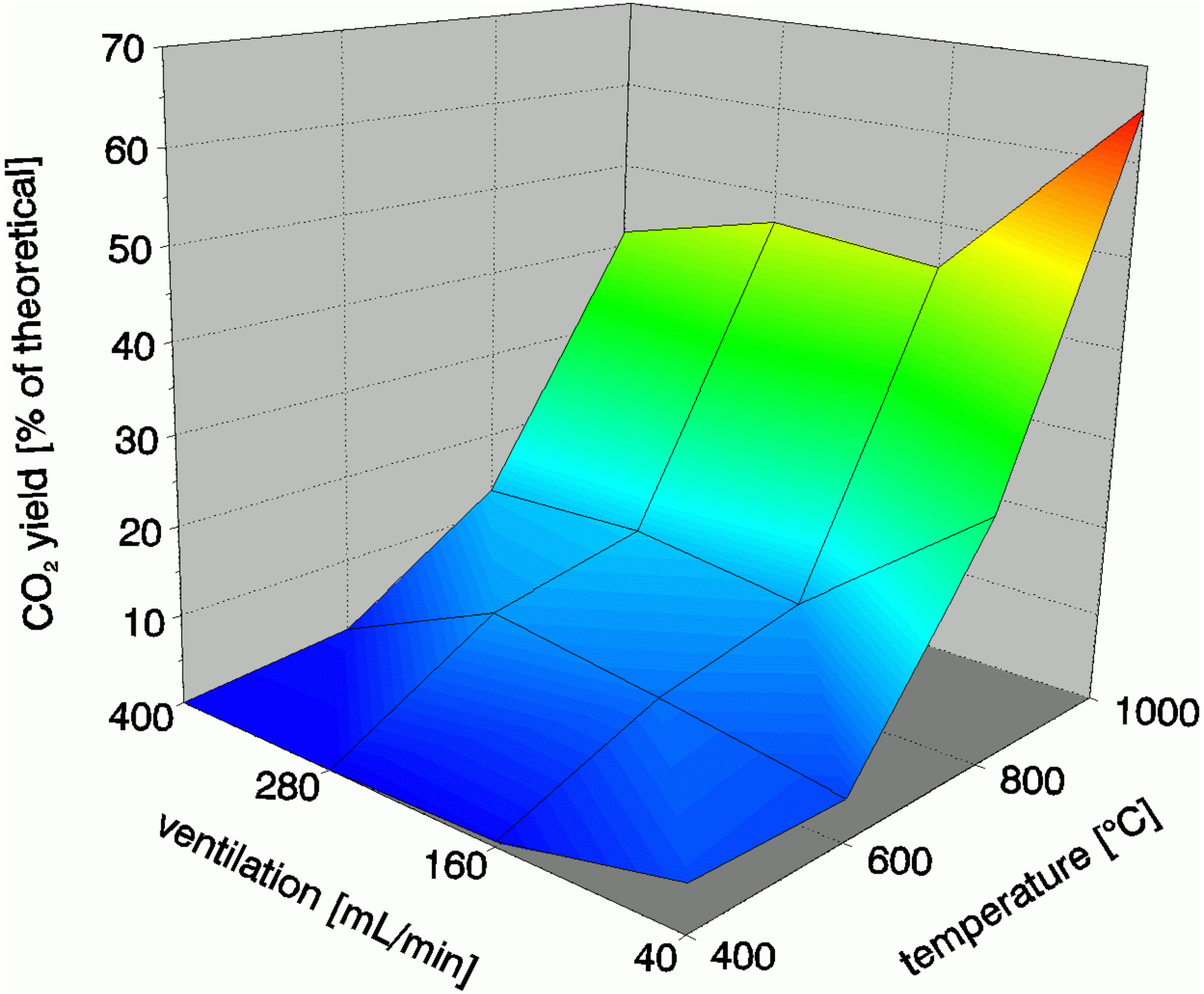
Composition of fire effluents - high volatile fraction

- raw polymers
  - CO_2, CO, alkanes, alkenes, aldehydes
  - Cl containg: HCl, chlorinated alkanes and alkenes
  - N containg: HCN, NH_3, NO_x
- mixtures and vulcanizates
  - additionally SO_x, H_2S, small amounts of NO_x, HCN depending on recipe and fire conditions

Composition of fire effluents - high volatile fraction

Composition of fire effluents - high volatile fraction

CO_2 emission of SBR in dependency of temperature and ventilation



Composition of fire effluents - high volatile fraction

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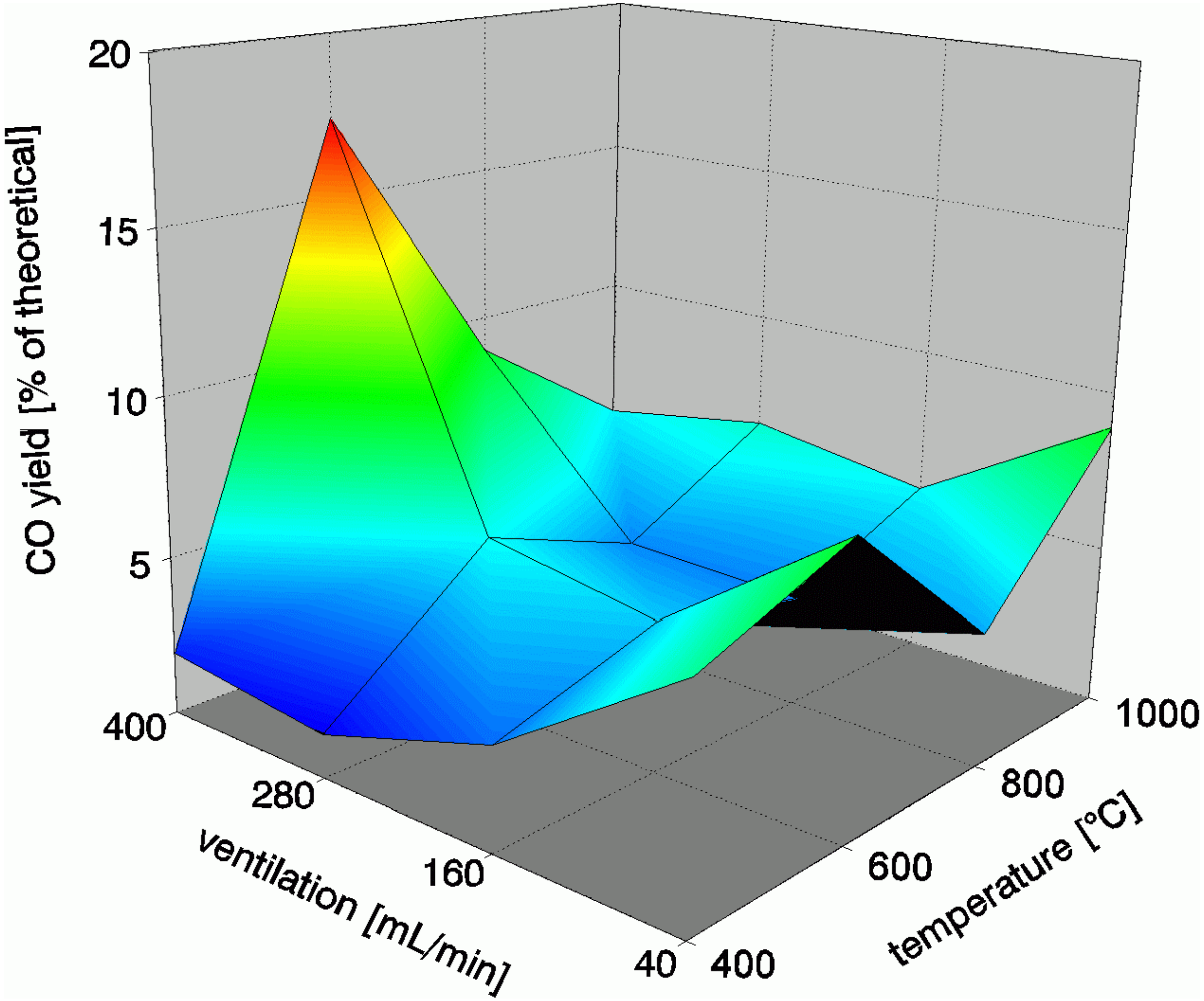
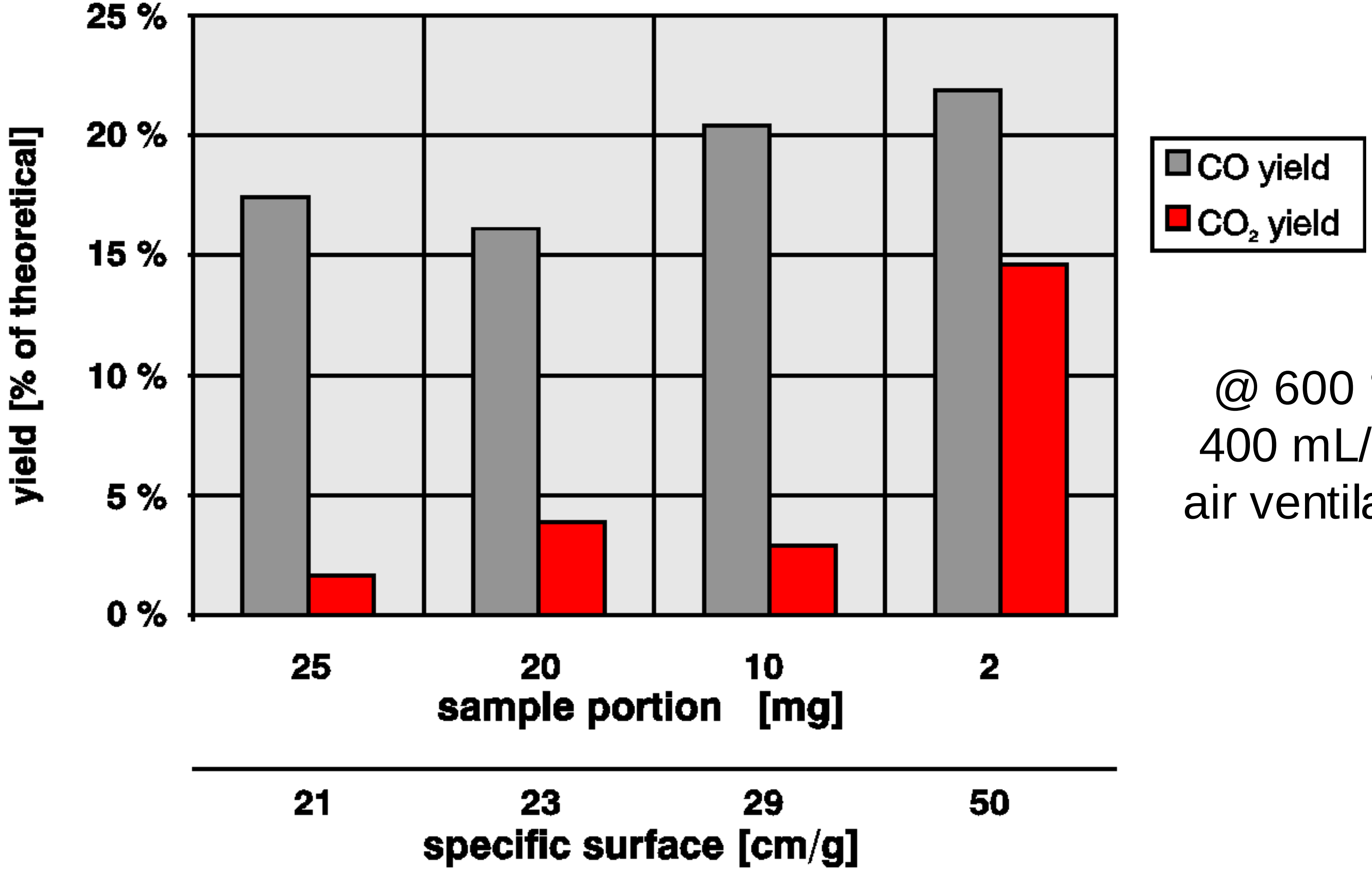
CO emission of SBR in dependency of temperature and ventilation



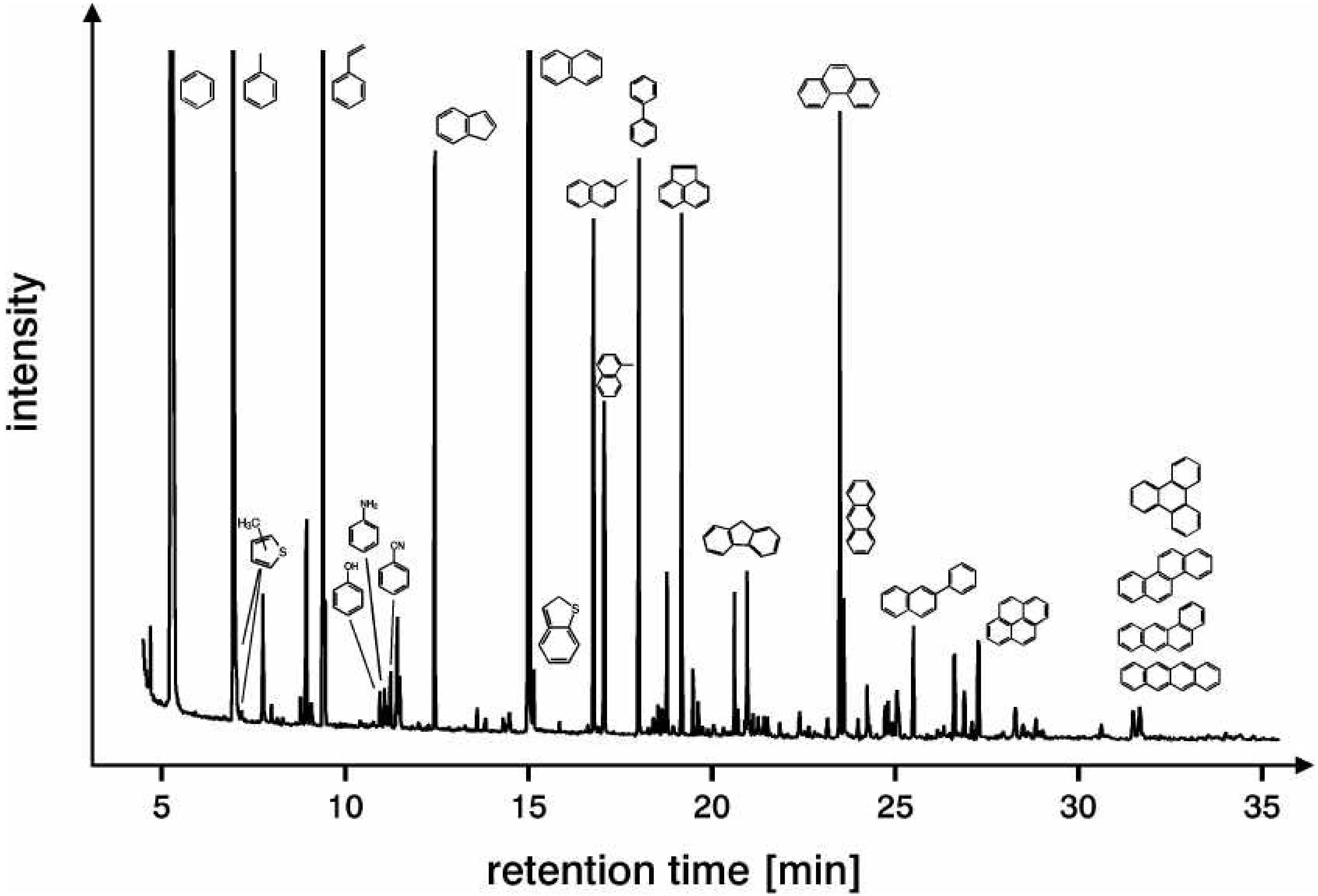
Composition of fire effluents - high volatile fraction

CO/CO_2 emission of SBR in dependency of specific surface



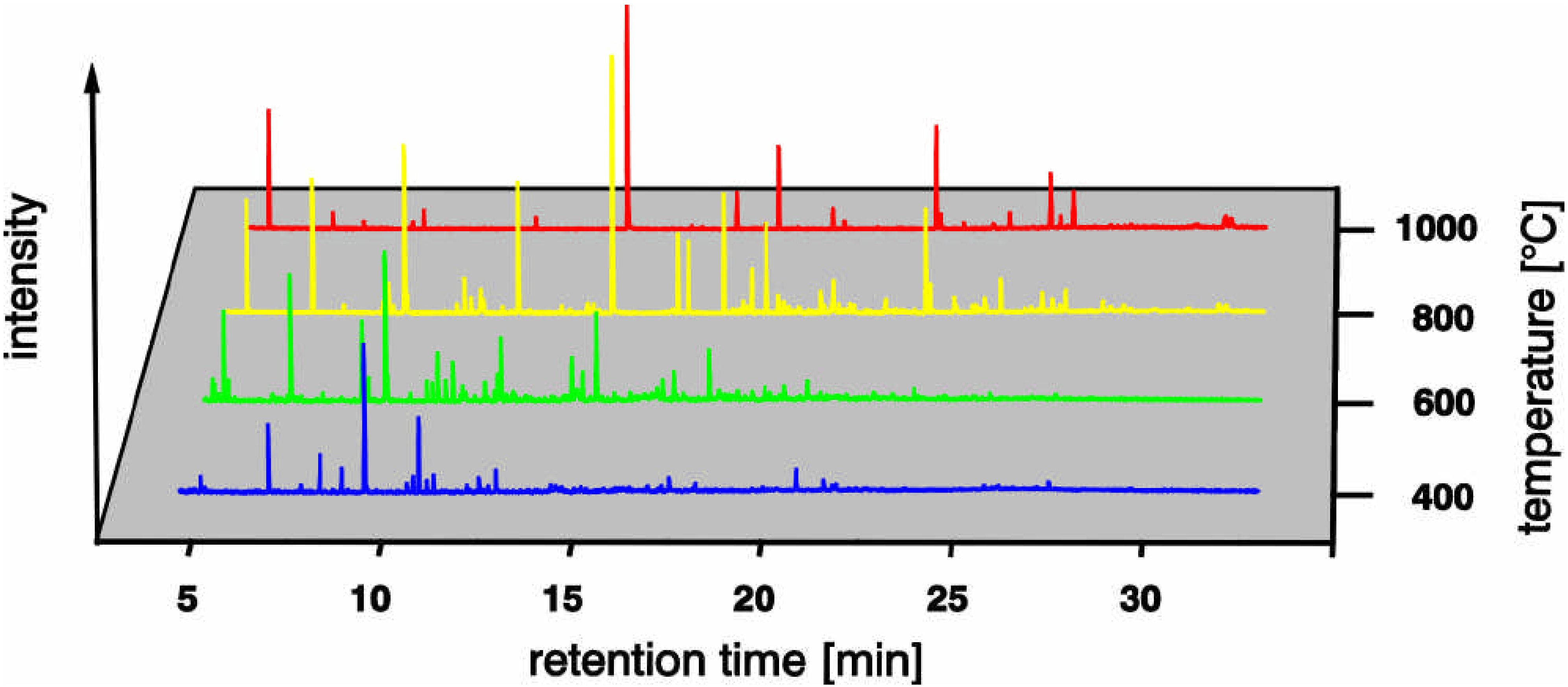
@ 600 °C,
400 mL/min
air ventilation

Passenger tire tread (SBR based) - semi volatile fraction at 800°C



Products of incomplete combustion - temperature dependency

SBR 1500



Composition of fire effluents - semi volatile fraction

Elastomer	Products at low temperatures	Products at high temperatures
Raw polymers	Monomers, oligomers, partially oxygenated, low molecular ketones, aldehydes, products of cyclisation reactions of chain fragments	benzene and polynuclear aromatics, partially saturated, alkylated
CR additionally	hydrogen chloride, chlorine containing aromatics	
NBR additionally	hydrogen cyanide, aromatics containing cyano groups	
Mixtures and vulcanizates additionally	fragments of additives; carbon black and zinc oxide remain as residue	S- and N-containing aromatics like benzothiazole; zinc oxide remains as residue

Conclusion

- Rubber materials are easy ignitable
  and nearly inextinguishable
- The composition of combustion effluents of rubber is strongly dependent on the burned material **and** the fire conditions (mainly temperature)
- Effluents of an uncontrolled rubber fire are acute toxic
- Chlorine and nitrogen containg materials possess an additional toxicity
- The lowest toxicity and the least problematic residues are produced at the fire stage of a relatively high ventilated fully developed fire

Acknowledgement and references

- Acknowledgment

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- References

IRC `98 poster and this presentation:

http://www.buethe.onlinehome.de/research.htm

Complete study: N. Büthe; „Elastomerbrände –Modellbrandversuche, Analytik und Bewertung“, doctoral thesis, University of Hannover 1999 (in german) at

http://www.DIKautschuk.de