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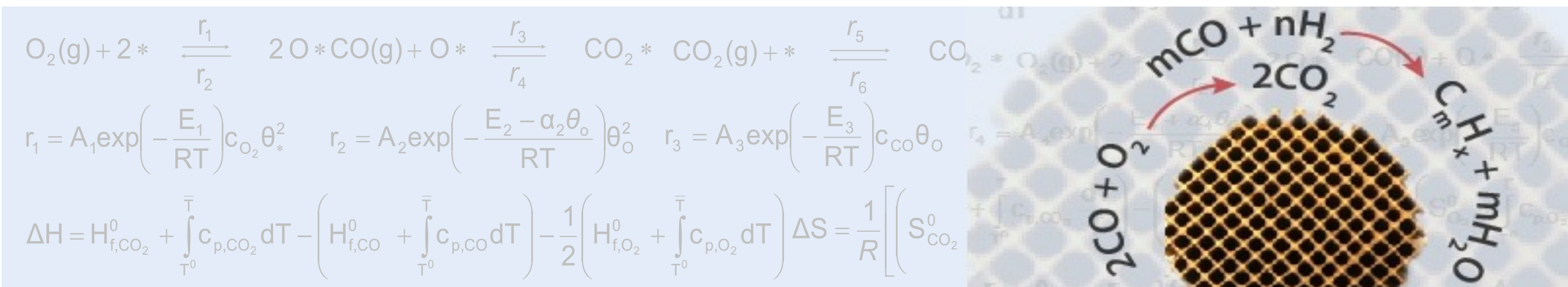
# Catalytic oxidation of CO, VOC and PM in $O_2$-rich exhaust of small scale fireplaces

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# Emissions from small scale fireplaces

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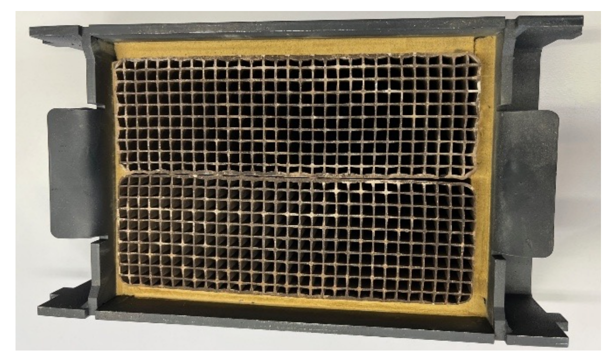
- Biomass is $CO_2$-neutral fuel and contributes to defossilization
- Issue: emission of pollutants

| Fuel | Emissions in kg $TJ^{-1}$ | | |
|---|---|---|---|
| | CO | PM | VOC |
| Wood | 2260 | 90 | 196 |
| Gas | 13 | 0.03 | 2.9 |
| Oil | 12 | 0.85 | 1.5 |

Source: Federal Environmental Agency, Germany, 2016

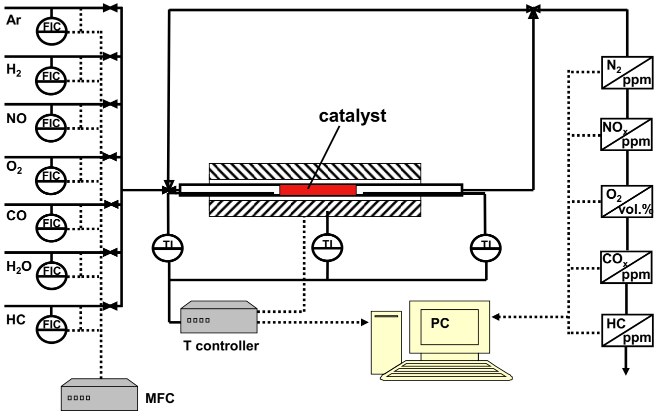
- For new small scale fireplaces (< 50 kW), oxidation catalysts based on noble metals available → CO/VOC removal

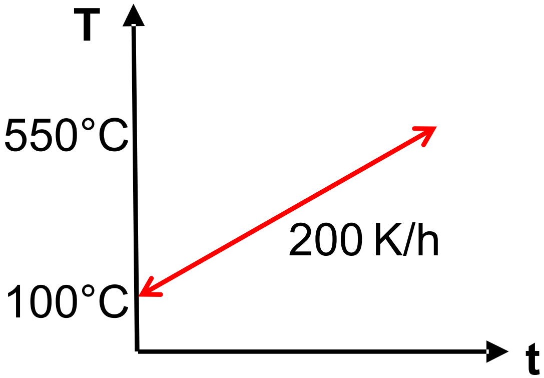


- In Germany 11.7 million small scale fireplaces exist → retrofitting with catalysts useful

# Non-noble metal catalysts for oxidation of CO, VOC and PM

- Based on previous studies on oxidation of pollutants Fe-Mn catalysts used
- Fe-Mn mixed oxide samples with different Fe fractions Fe (x=0…1) prepared by sol-gel method, calcination at 650°C
- Catalytic tests made in laboratory using TPO with catalyst granules



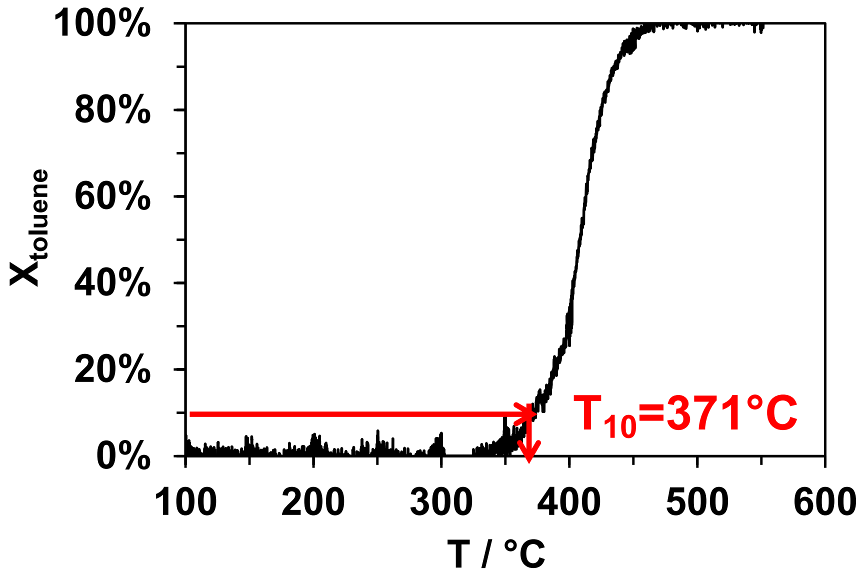




- TPO conditions
  - 200 mg catalyst, 500 ml/min total flow (191,000…273,000 $h^{-1}$)
  - 1000 ppm CO, 500 ppm $C_3H_6$, 250 ppm toluene, 10 vol% $H_2O$, 10 vol% $O_2$
  - Blend with 10 mg soot, 10 vol% $H_2O$, 10 vol% $O_2$

# Toluene oxidation performance



- Catalytic performance assessed based on light-off temperature $T_{10}$




**Toluene conversion on $Fe_2O_3$ (x=1)**

Conditions:

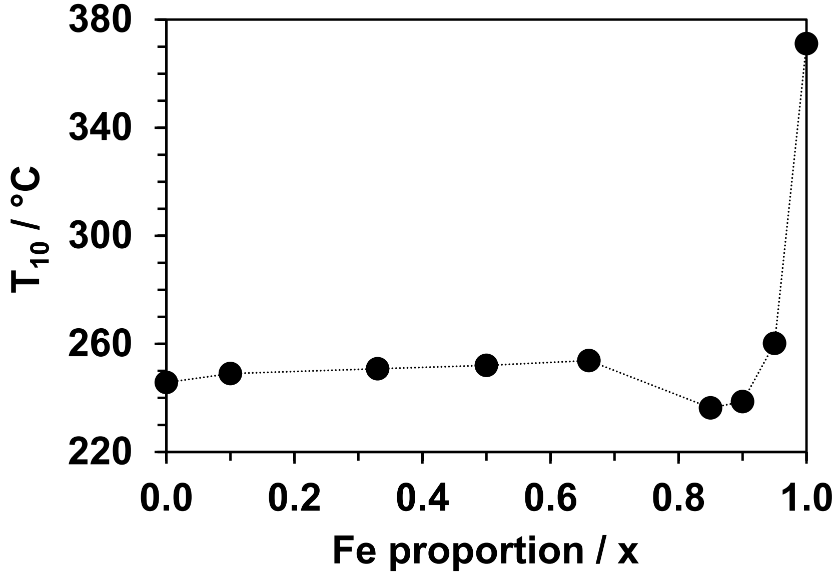
1000 ppm CO

500 ppm $C_3H_6$

250 ppm toluene

10 vol% $H_2O$

10 vol% $O_2$




**Light-off temperatures of catalysts**

→ Fe-rich catalysts (x=0.85 and 0.9) are most active

# Structure-activity relation in toluene oxidation

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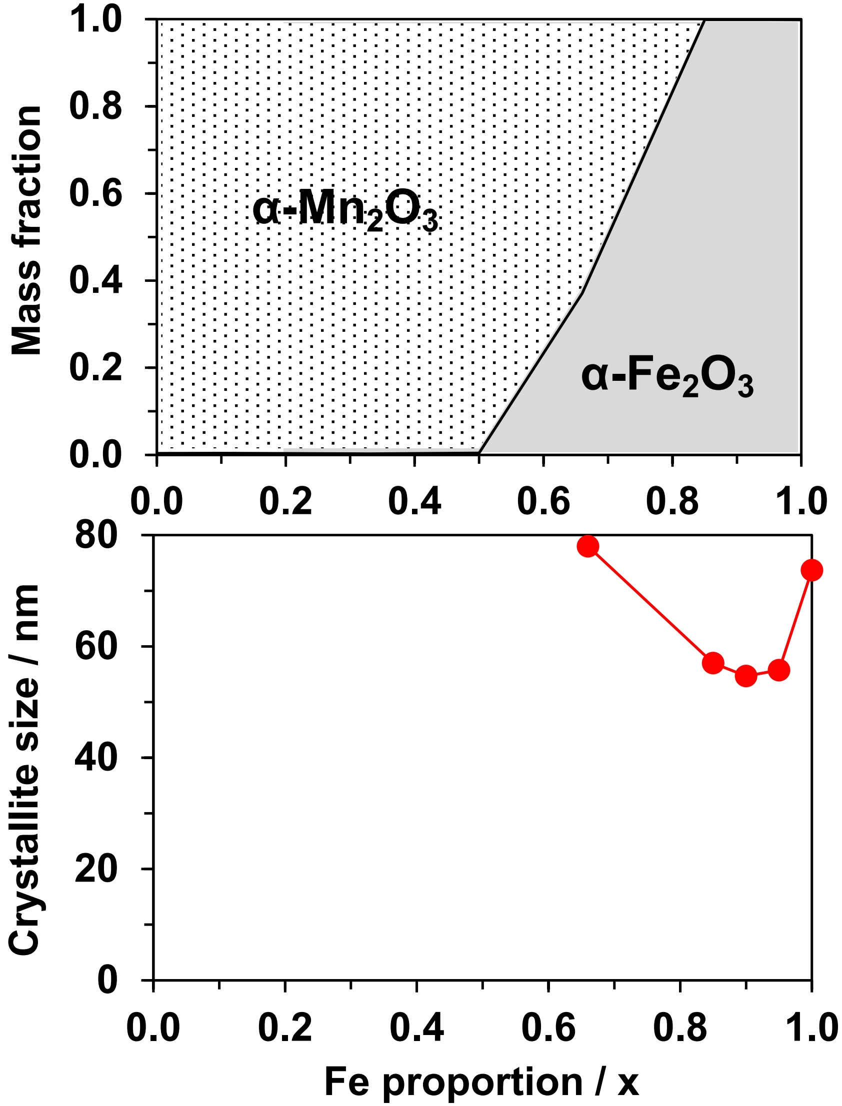
- Phase distribution and $\alpha$-$Fe_2O_3$ crystallite size of the catalysts (XRD / Rietveld)

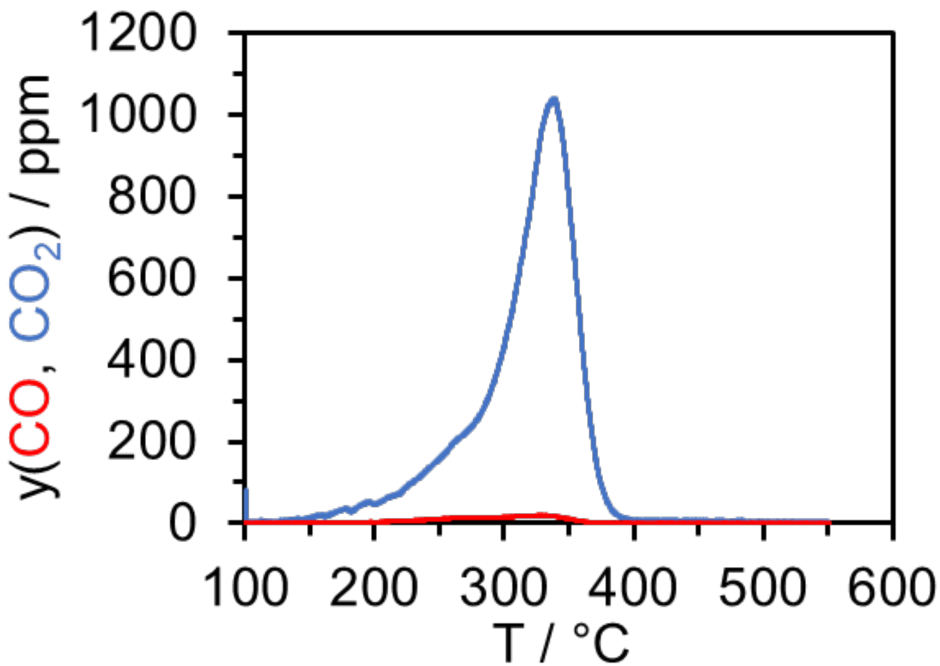



For most active catalysts (x=0.85/0.9) the solubility of Mn is low

→ $MnO_x$ entities primarily seggregated

Active catalysts reveal small $\alpha$-$Fe_2O_3$ crystallites

# Soot oxidation performance of Fe-Mn oxide catalyst with Fe proportion of x=0.9




Conditions:

15 min ball milling

200 mg catalyst, 10 mg $C_3H_6$-soot

10 vol% $H_2O$

10 vol% $O_2$

→ Fe-Mn catalyst is also active in soot oxidation

→ Light-off trempearture below 300°C

# CO/VOC/PM oxidation performance
# Comparison with Pt/Pd reference

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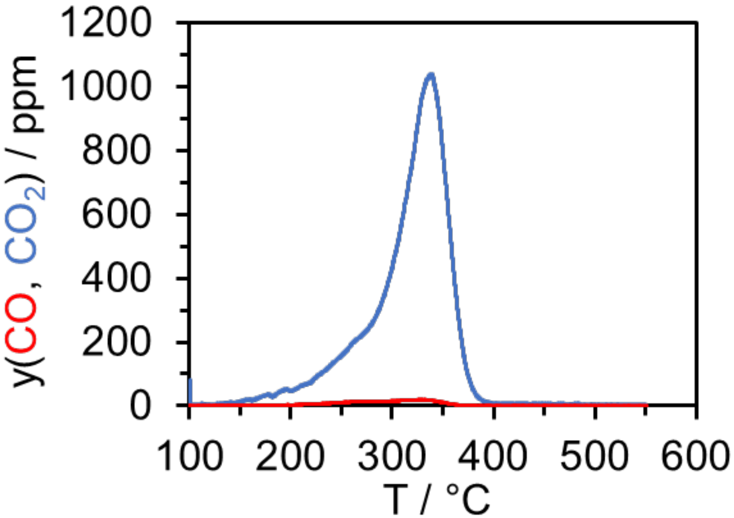
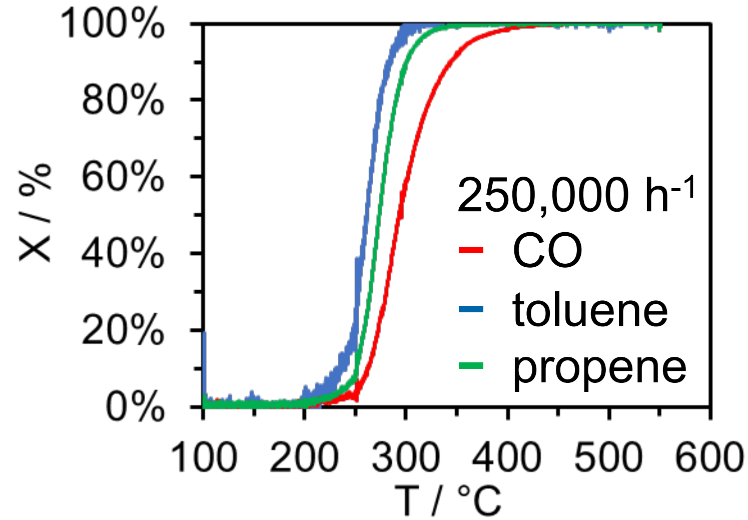
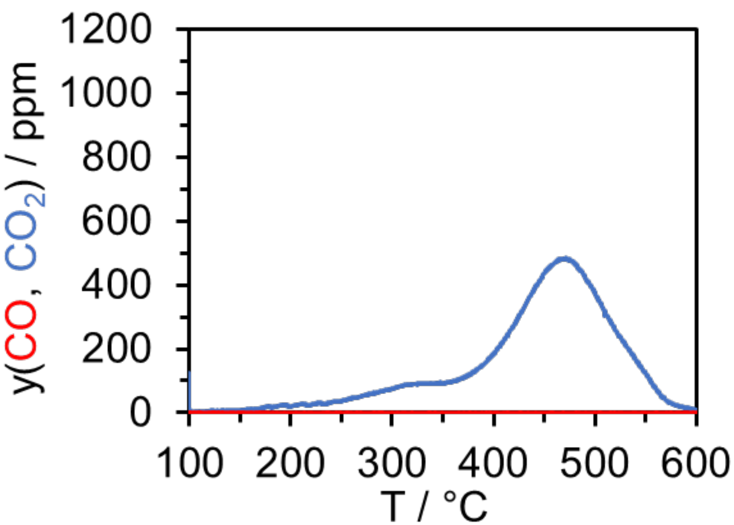
## Soot oxidation | CO/VOC oxidation

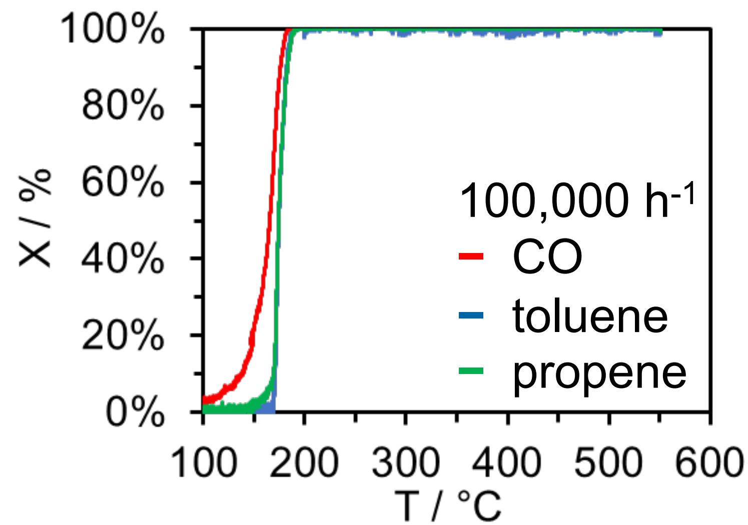
**Fe-Mn oxide (x=0.9)**




**0.59Pt/4.9Pd/$Al_2O_3$**



# Summary


**Fe-Mn mixed oxides:**

- Simultaneous oxidation of CO, VOC and PM with light-off temperatures < 300°C
- High activity of Fe-rich catalysts is due to dissolved and/or coexisting $MnO_x$
- Low-cost and harmless catalyst for retrofitting and introduction into new small scale fireplaces
- Transfer to honeycomb substrates and assessment in real exhaust gas required

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# Thank you for your attention!