Catalysts at nanoscale for environmental applications

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The group at the University of Udine is involved in the investigation and in the development of catalytic industrial processes, with a particular interest on rare earth based catalysts for applications in Environmental Catalysis and Energy Production.
CeO$_2$-based catalysts

\[ \text{CeO}_2 \rightarrow \text{CeO}_{2-x} + \frac{1}{2}\text{O}_2(g) \]

Oxygen deficient atmosphere

\[ \text{CeO}_{2-x} + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CeO}_2 \]

Oxygen rich atmosphere

Several reactions with environmental interest exploit the redox properties of ceria

**CO oxidation**

\[ \text{CO}(g) + \text{CeO}_2 \rightarrow \text{CO}_2(g) + \text{CeO}_{2-x} \]

**Soot oxidation**

\[ \text{C} + \text{CeO}_2 \rightarrow \text{CO}_2(g) + \text{CeO}_{2-x} \]
Both reactions are highly sensitive to ceria exposed facets

Soot oxidation

CO oxidation

E. Aneggi et al., ACS Catal. 4 (2014) 172

For hydrogenation reactions, things work the other way round

**C$_2$H$_2$ hydrogenation**

<table>
<thead>
<tr>
<th>Rate of C$_2$H$_2$ hydrogenation (µmol/m$^2$·h)</th>
<th>14</th>
<th>12</th>
<th>10</th>
<th>8</th>
<th>6</th>
<th>4</th>
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</thead>
</table>

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February 6th 2020

Bilateral Workshop
NANOTECHNOLOGY AND NANOAPPLICATION

20 nm

CO oxidation

rods

Soot oxidation

cubes

oxygen

octahedra

20 nm

Alkyne hydrogenation
Ceria can also affect the reactivity and stability of supported metal nanoparticles, especially those having a strong nanoscale interaction with ceria surface

### Methane oxidation on Pd/CeO$_2$ catalysts

Catalysts prepared by:
- conventional impregnation
- solution combustion synthesis
- dry mechanical milling

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M. Danielis et al., Catal. Sci. Techn. 9 (2019) 4232

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Dry mechanical milling of CeO$_2$ and Pd black powders

M. Danielis et al., Catal. Commun. 135 (2020) 105899
$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$

**OPEN QUESTION:** what happens at nanoscale between Pd and CeO$_2$?

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Ongoing research activities

- Application of the dry milling procedure to other metal-support systems
- Synthesis of thermally stable pure and doped ceria
- Bimetallic catalysts for methane oxidation in presence of water
- Soot oxidation
- Influence of exposed ceria planes on methane oxidation
Expertise and facilities

- Ceria-based materials
- synthesis of support oxides (co-precipitation, hydrothermal synthesis, solution combustion synthesis etc.)
- metal deposition (impregnation, dry milling etc.)
- material characterization
- temperature programmed techniques
- catalytic tests

- XRD with high temperature reaction chamber
- Raman and DRIFT spectroscopy with high temperature reaction cell
- BET surface area measurements
- TPR-TPO
- CO chemisorption
- lab scale reactors for catalytic tests with MS, GC and FTIR gas analyzers
Thank you for your attention!