UNIVERSITÀ DEGLI STUDI DI UDINE

CATALYSIS for ENERGY and ENVIRONMENT

Catalysts at nanoscale for environmental applications

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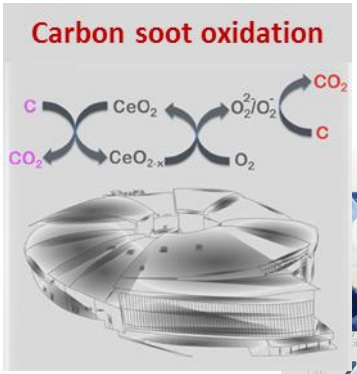
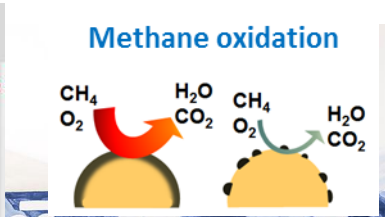
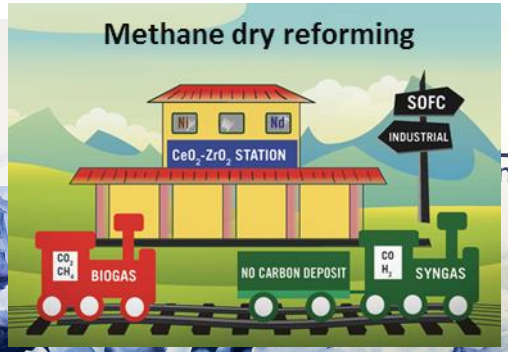
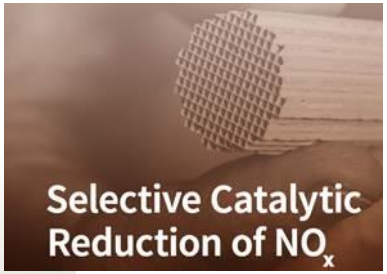
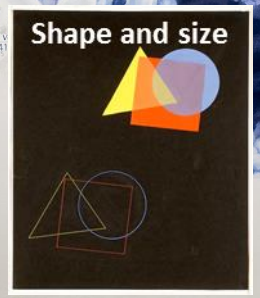
The group of CATALYSIS for ENERGY and ENVIRONMENT at the University of Udine is involved in the investigation and in the development of catalytic industrial processes, with a particular interest on rare earth based catalysts for applications in **Environmental Catalysis** and **Energy Production**

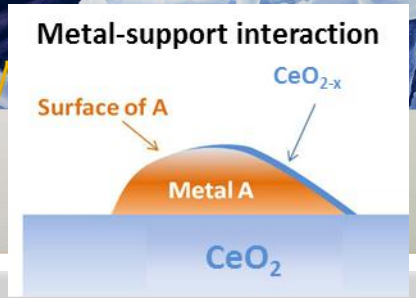


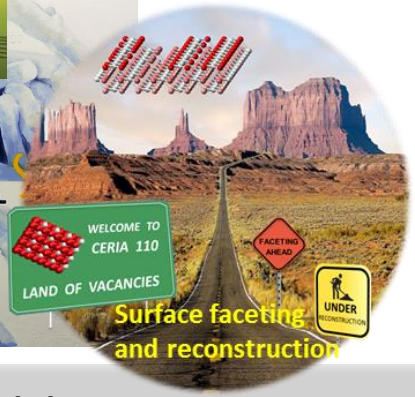












CeO_2-based catalysts

$$CeO_2 \rightarrow CeO_{2-x} + 1/2O_2(g)$$ **Oxygen deficient atmosphere**

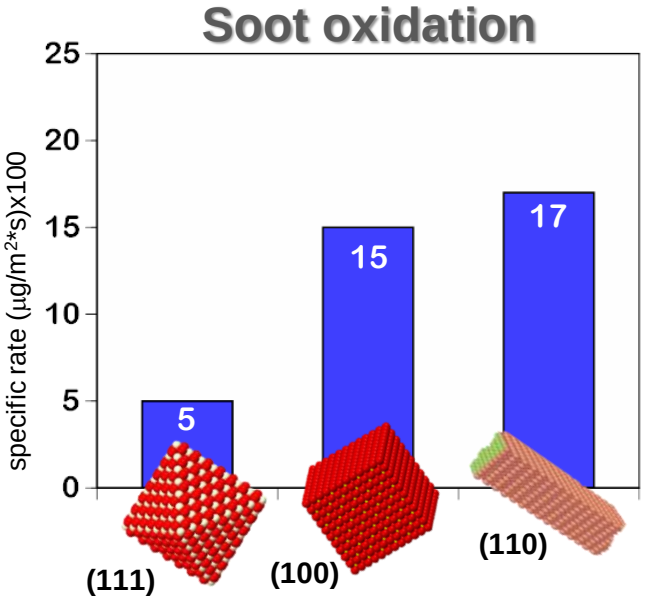
$$CeO_{2-x} + 1/2O_2(g) \rightarrow CeO_2$$ **Oxygen rich atmosphere**

Several reactions with environmental interest exploit the redox properties of ceria

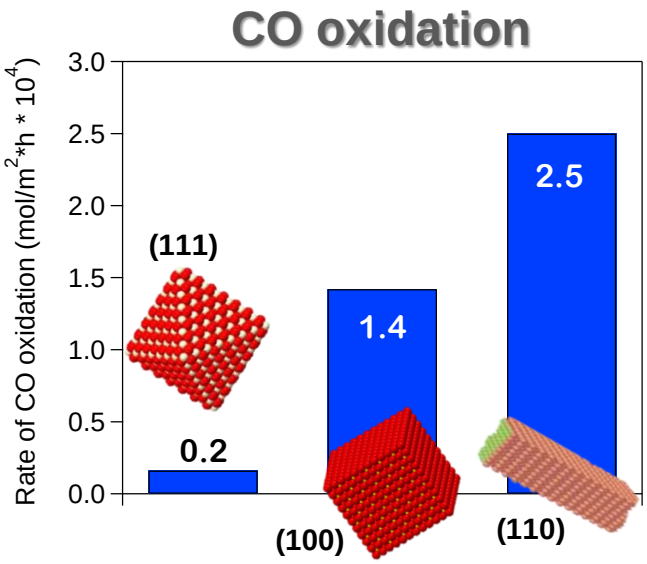
CO oxidation $CO(g) + CeO_2 \rightarrow CO_2(g) + CeO_{2-x}$

Soot oxidation $C + CeO_2 \rightarrow CO_2(g) + CeO_{2-x}$

Both reactions are highly sensitive to ceria exposed facets

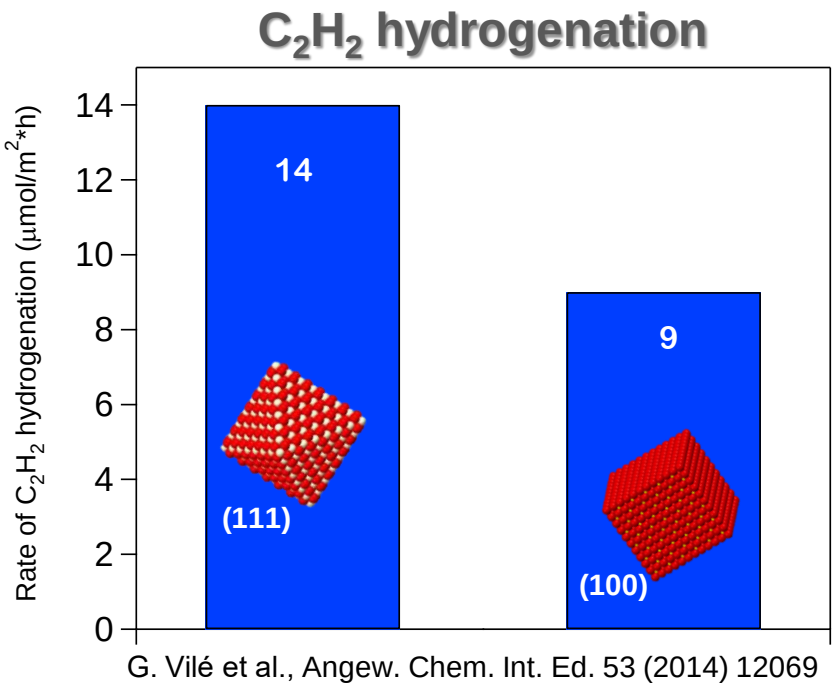


E. Aneggi et al., ACS Catal. 4 (2014) 172

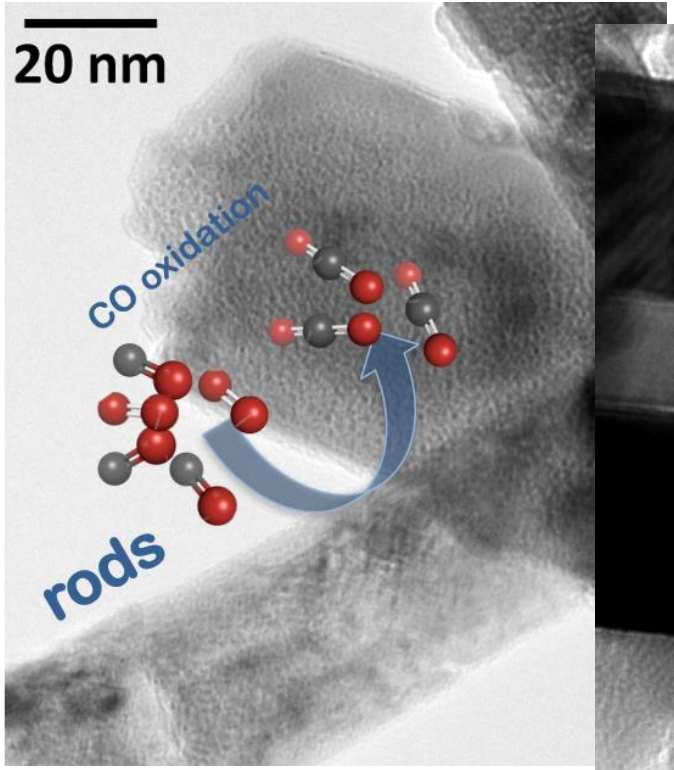


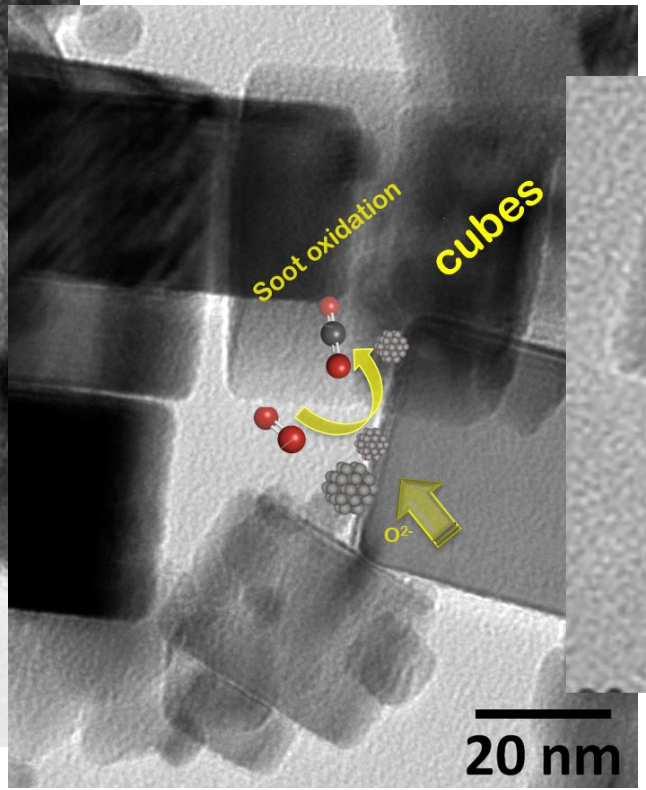
E. Aneggi et al., J. Catal. 234 (2005) 88
G. Vilé et al., Angew. Chem. Int. Ed. 53 (2014) 12069

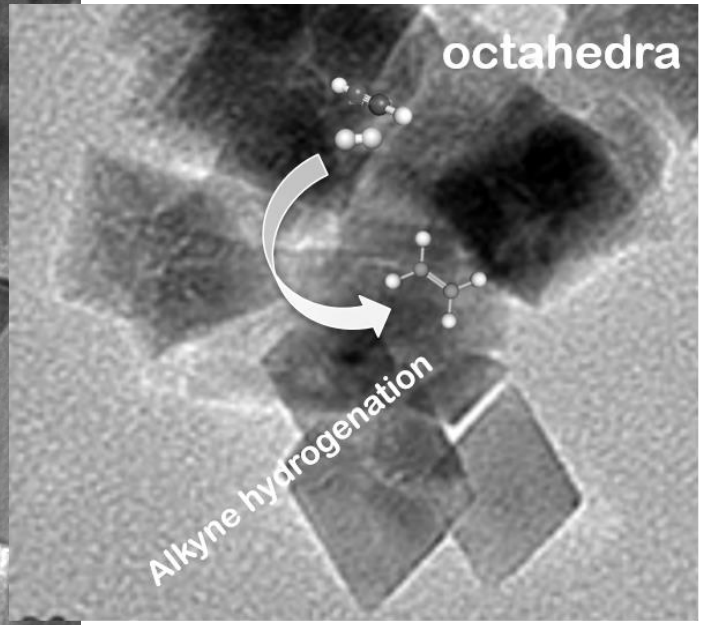
For hydrogenation reactions, things work the other way round



G. Vilé et al., Angew. Chem. Int. Ed. 53 (2014) 12069


20 nm
CO oxidation
rods


Soot oxidation
cubes
O2-
20 nm

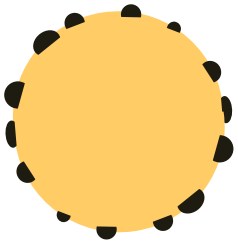

octahedra
Alkyne hydrogenation

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

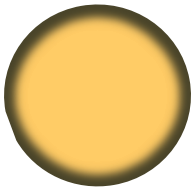
Methane oxidation on Pd/CeO_2 catalysts

Catalysts prepared by:

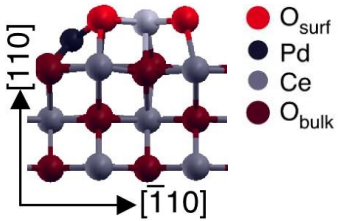
- conventional impregnation
- solution combustion synthesis
- dry mechanical milling



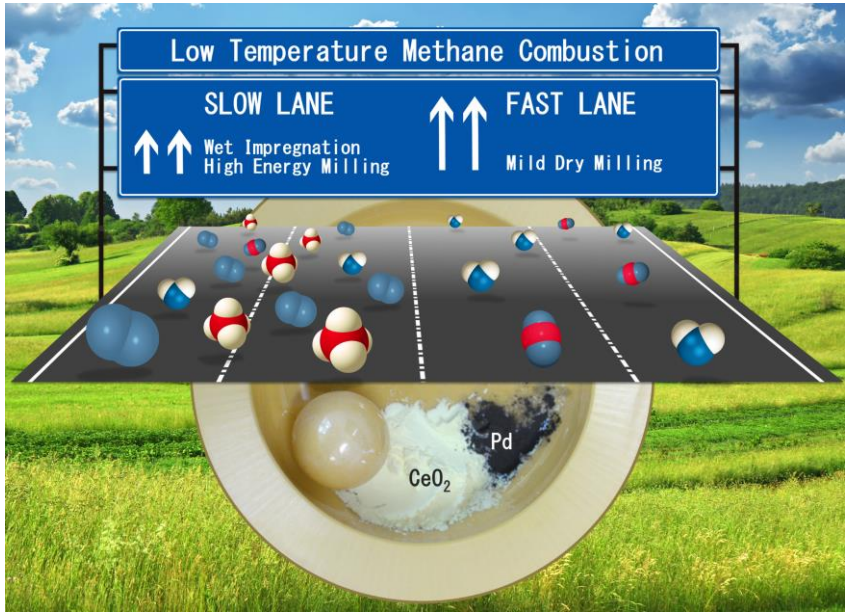
PdCe IW



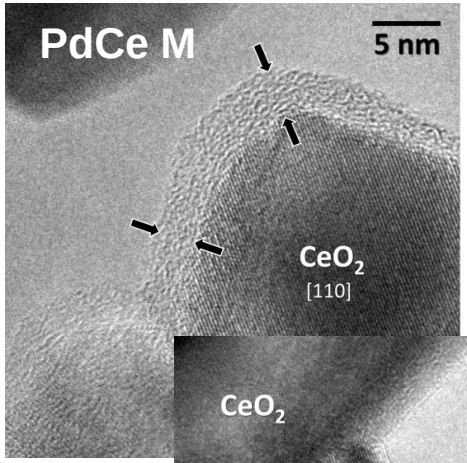
PdCe M

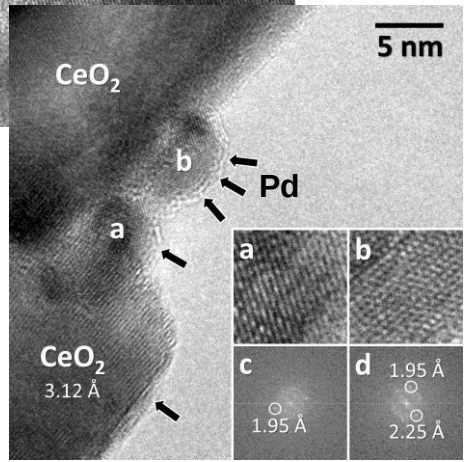


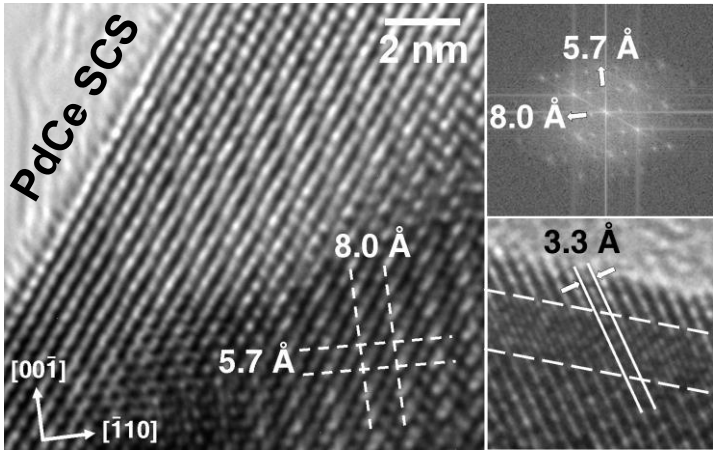
PdCe SCS

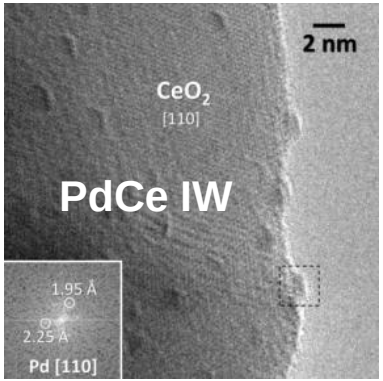


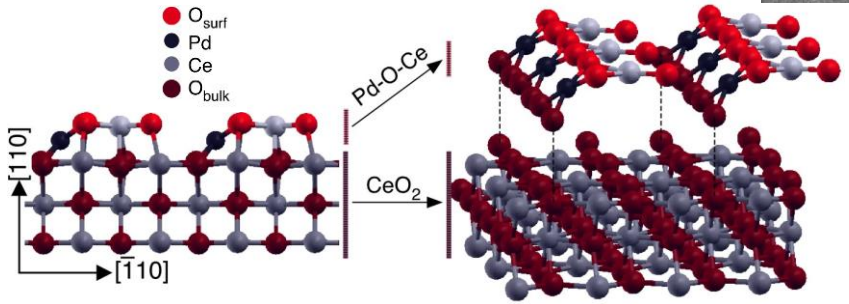
M. Danielis et al., Catal. Sci. Techn. 9 (2019) 4232





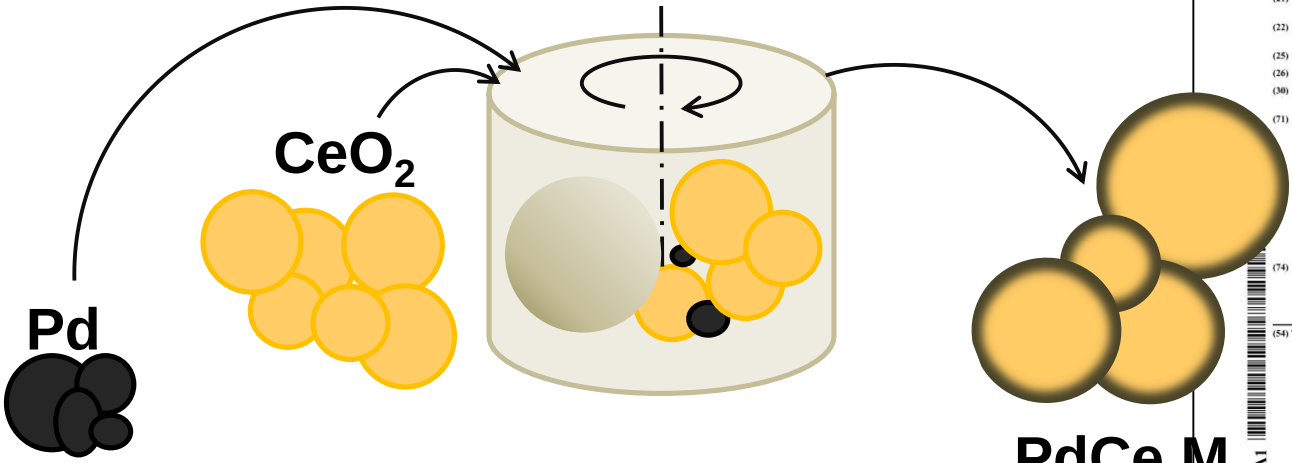


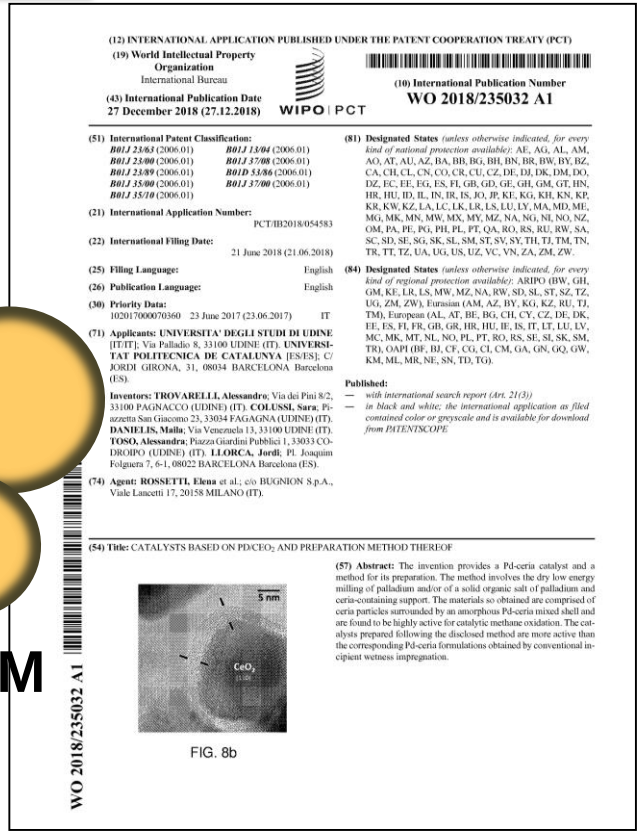




S. Colussi et al., Angew. Chem. Int. Ed. 48 (2009) 8481

Dry mechanical milling of CeO_2 and Pd black powders





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(54) Title: CATALYSTS BASED ON PD/CeO_2 AND PREPARATION METHOD THEREOF

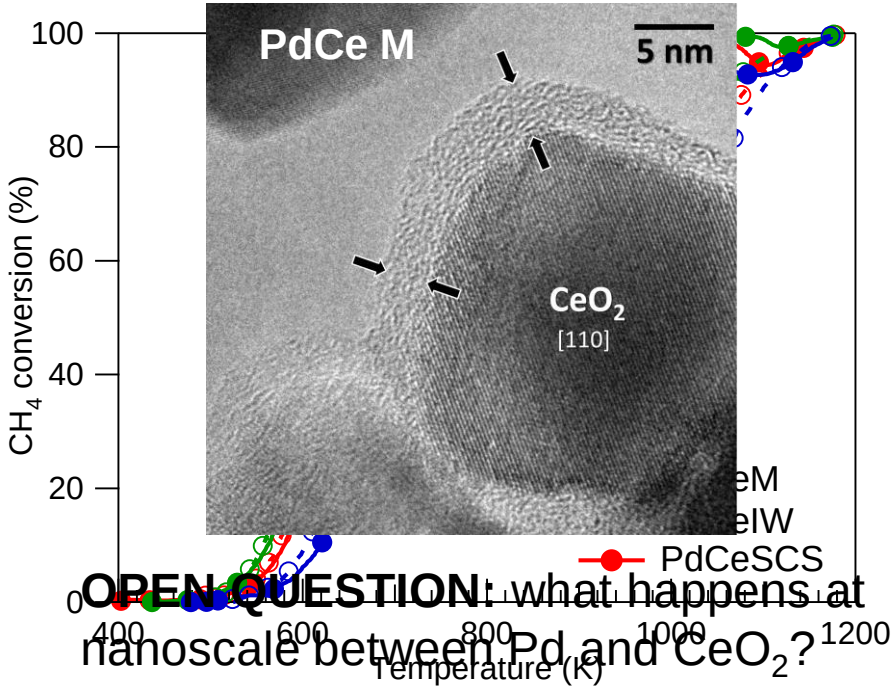
(57) **Abstract:** The invention provides a Pd-ceria catalyst and a method for its preparation. The method involves the dry low energy milling of palladium and/or of a solid organic salt of palladium and ceria-containing support. The materials so obtained are comprised of ceria particles surrounded by an amorphous Pd-ceria mixed shell and are found to be highly active for catalytic methane oxidation. The catalysts prepared following the disclosed method are more active than the corresponding Pd-ceria formulations obtained by conventional incipient wetness impregnation.

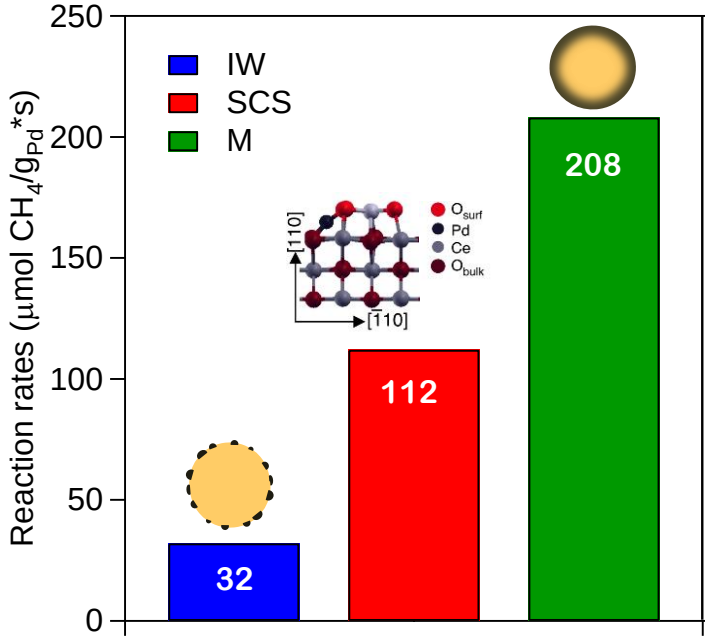
FIG. 8b

WO 2018/235032 A1

M. Danielis et al., Angew. Chem. Int. Ed. 57 (2018) 10212
M. Danielis et al., Catal. Commun. 135 (2020) 105899

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$





OPEN QUESTION: what happens at nanoscale between Pd and CeO_2?

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

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Thank you for your attention!

February 6th 2020

Catalysts at nanoscale for environmental applications

Bilateral Workshop
NANOTECHNOLOGY AND NANOAPPLICATION