Pd-Ce-O_x/MWCNTs and Pt-Ce-O_x/MWCNTs Composite Materials for Low-temperature Oxidation of CO and CH_4

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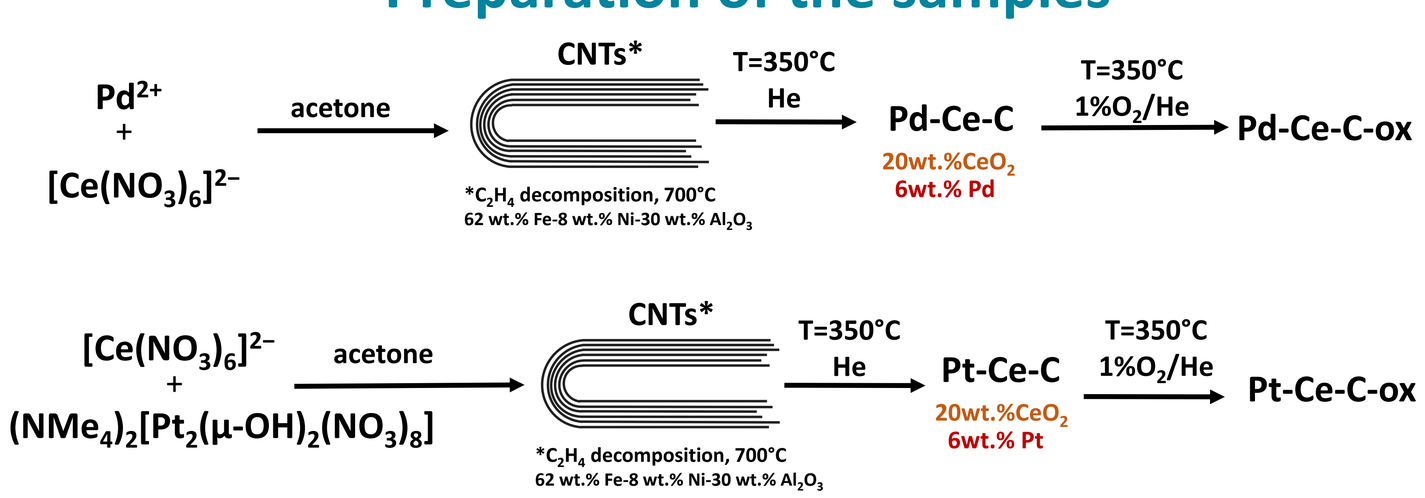
Scope

The catalysts based on the combination of the noble metals and CeO_2 have long proven their effectiveness in various industrially important reactions, including exhaust gas after-treatment and air purification in the enclosed spaces. The size of the active metal species and their oxidation state are one of the key factors influencing the catalytic activity of the systems in the low-temperature oxidation reactions. The use of the carbon nanomaterials as the supports for the stabilization of the active components in a highly dispersed state can be considered as a perspective approach for the preparation of the catalytic systems with high activity and stability. In this work, we studied the composite materials based on the multi-walled carbon nanotubes (MWCNTs), CeO_2, and Pd (Pt).

Preparation of the samples



Characterization of the samples structure

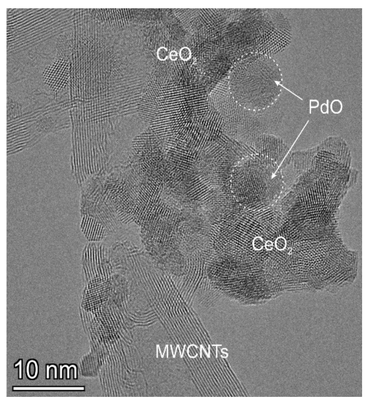
XRD

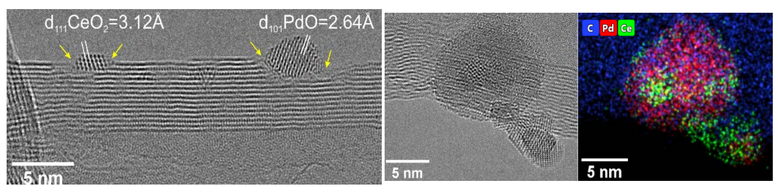
Sample	d(CeO_2), nm	a(CeO_2), Å	d(PdO), nm	d(Pt), nm	S_{BET}, m^2/g
Pd-Ce-C	3(1)	5.432(1)	8(1)	-	194
Pd-Ce-C-ox	8(1)	5.429(1)	8(1)	-	213
Pt-Ce-C	3(1)	5.425(1)	-	3(1)	168
Pt-Ce-C-ox	3(1)	5.434(1)	-	6(3)	215

XRD data show the formation of the dispersed ceria particles (d~3–8 nm). For the Pd-Ce-C samples the PdO nanoparticles about 8 nm in size can be detected. The Pt-Ce-C samples contain a small fraction of the metallic platinum particles (d~3-6 nm).

Pd-Ce-C

TEM

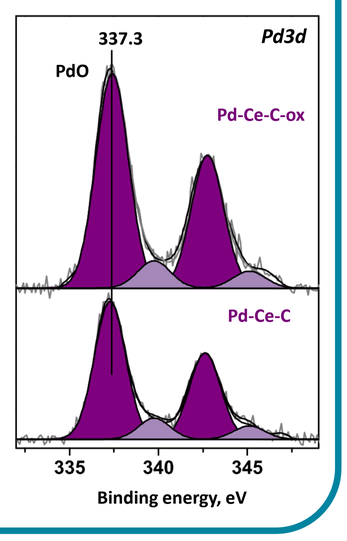




Pd-based samples contain individual PdO and CeO_2 nanoparticles about 1–8 nm in size, as well as PdO-CeO_2 agglomerates. The fraction of Pd^{2+} ions stabilized in CeO_2 lattice is small.

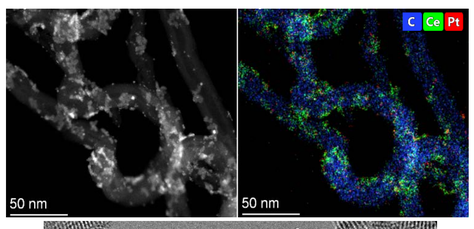
The oxidative pretreatment does not have a significant influence on the structure of the samples.

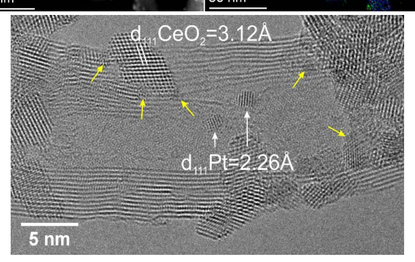
XPS

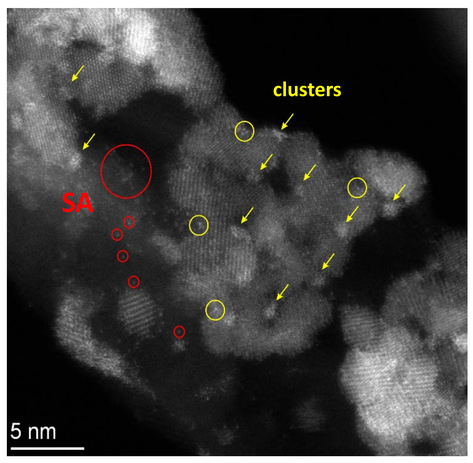


Pt-Ce-C

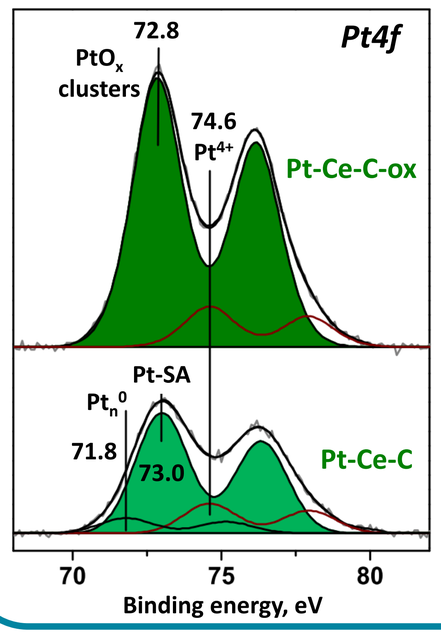
TEM







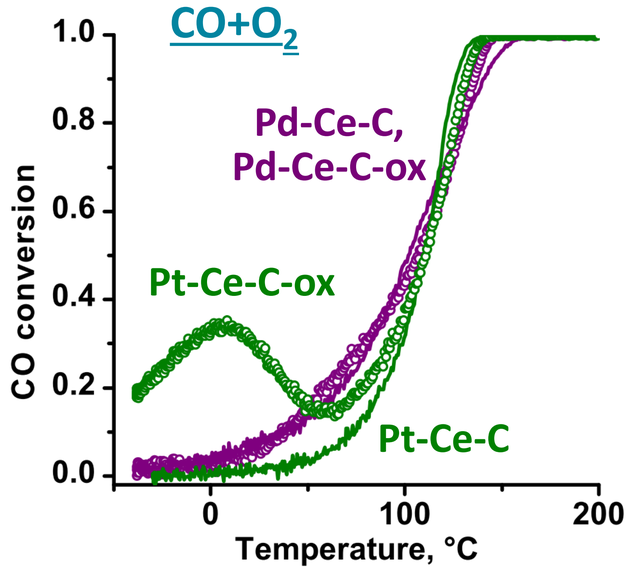
XPS



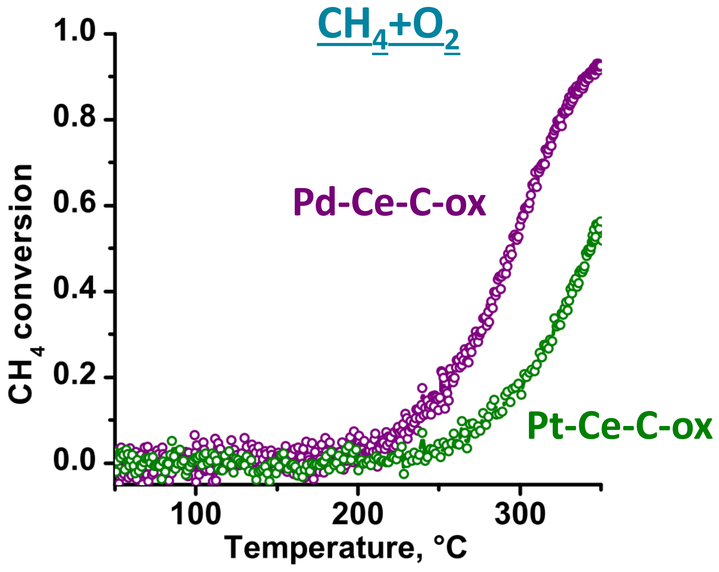
TEM and XPS data show that in the Pt-based samples, platinum is mostly present in a highly dispersed state: the single Pt^{2+} ions and PtO_x clusters less than 1 nm in size.

Oxidative pretreatment results in the increase in the fraction of the PtO_x clusters.

Temperature-programmed reactions



Reaction mixture: 0.2vol.%CO, 1 vol.%O_2, 0.5vol.%Ne (He-balance). Rate: 1000 cm^3/min.



Reaction mixture: 0.1vol.%CH_4, 1 vol.%O_2, 0.5vol.%Ne (He-balance). Rate: 100 cm^3/min.

The activity of the Pd-Ce-C samples in CO oxidation is not influenced by the oxidative preatreatment. The Pt-Ce-C sample shows activity only at T>50°C. However, the oxidative treatment leads to a significant increase in the sample's activity at T< 0°C.

The Pd-Ce-C samples are active in CH_4 oxidation reaction at T>200°C. The Pt-Ce-C samples show activity at the higher temperature. The temperature of the 50% conversion of CH_4 is about 50°C higher for the Pt-Ce-C-ox sample in comparison with the Pd-Ce-C-ox sample.

Thus, the Me-Ce-O_x/MWCNTs composites can be considered as promising systems for various catalytic applications. In the Pd-Ce-O_x/MWCNTs composites the palladium species are stabilized on the surface of CeO_2 and/or MWCNTs as PdO nanoparticles, which demonstrate high activity in methane oxidation reaction at T < 300°C.

The highly dispersed PtO_x clusters provide high activity of the Pt-Ce-O_x/MWCNTs catalysts in CO oxidation reaction in the temperature range below 0°C.

For more information:

Kibis et al. *Materials*, ***15*** **(2022) 7485, doi: 10.3390/ma15217485**
Stonkus et al. *Materials*, ***16*** **(2023) 4257, doi:10.3390/ma16124257**
Kibis et al. *Applied Surface Science*, ***611*** **(2023)** 155750**, doi:10.1016/j.apsusc.2022.155750**

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