



Universiteit  
Leiden  
The Netherlands

## A structural view of Pd model catalysts : high-pressure surface X-Ray diffraction

Rijn, R. van

### Citation

Rijn, R. van. (2012, May 8). *A structural view of Pd model catalysts : high-pressure surface X-Ray diffraction*. *Casimir PhD Series*. Retrieved from <https://hdl.handle.net/1887/18926>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/18926>

**Note:** To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/18926> holds various files of this Leiden University dissertation.

**Author:** Rijn, Richard van

**Title:** A structural view of Pd model catalysts : high-pressure surface X-Ray diffraction

**Date:** 2012-05-08

## Acknowledgements

Although this thesis has only my name printed on the cover, at the basis of its contents lies the joint effort of many people. Here I take the opportunity to thank them all for their support, help, and advice.

My promotor Joost Frenken and co-promotor Roberto Felici were both a source of ideas, enthusiasm, and valuable advice during the whole project. The novel flow reactor was designed at the department of fine mechanics in Leiden by Arjen Geluk. Lucien Petit improved and extended upon that design at the ESRF in France. The commissioning of the setup in record time was only possible through the help I received from Thomas Dufrane and Helena Isern. Herve Gonzalez and Armando Sole made sure that the electronic components of the setup were properly interfaced with the rest of the beamline. Many measurement runs have yielded good results due to the encyclopaedic knowledge and skills of Didier Wermeille, and the resourcefulness of Olivier Balmes. Andrea Resta has helped me during uncountable night shifts.

The initial work of Marcelo Ackermann and Bas Hendriksen on the reaction oscillations provided me with a good start, and the experiments resulted in a nice article and a chapter of this thesis. During experiments in Grenoble I often got help from colleagues from Leiden and elsewhere: Dunja Stoltz, Kees Herbschleb, Marta Cañas Ventura, Violeta Navarro, Uta Hejral, and master-students-turned-colleagues Sander Roobol and Willem Onderwaater.

The succes of the collaboration with Edvin Lundgren, Johan Gustafson, and Rasmus Westerström from Lund University is well reflected in the publication list. Maria Messing kindly provided the monodisperse nanoparticles without which Chapter 5 would not have been written.

The fast polishing and delivery of a palladium crystal within 24 hours by Rene Koper saved us a week of valuable beamtime.

Finally I want to thank the whole IP-group for the all the stimulating work discussions.



## List of publications

- *The active phase of palladium during methane oxidation*,  
A. Hellman, A. Resta, N.M. Martin, J. Gustafson, A. Trincherro, P.-A. Carlsson, O. Balmes, R. Felici, R. van Rijn, J. W. M. Frenken, J. N. Andersen, E. Lundgren, and H. Grönbeck,  
[Journal of Physical Chemistry Letters](#) **3**, 678682 (2012).
- *Reversible formation of a PdC<sub>x</sub> phase in Pd nanoparticles upon CO and O<sub>2</sub> exposure*,  
O. Balmes, A. Resta, D. Wermeille, R. Felici, M. E. Messing, K. Deppert, Z. Liu, M. E. Grass, H. Bluhm, R. van Rijn, E. Lundgren, R. Westerström, S. Blomberg, J. Gustafson, and J. N. Andersen,  
[Physical Chemistry Chemical Physics](#) **14**, 4796-801 (2012).
- *Oxidation and reduction of Pd(100) and aerosol-deposited Pd nanoparticles*,  
R. Westerström, M. E. Messing, S. Blomberg, A. Hellman, H. Grönbeck, J. Gustafson, N. M. Martin, O. Balmes, R. van Rijn, J. N. Andersen, K. Deppert, H. Bluhm, Z. Liu, M. E. Grass, M. Hävecker, and E. Lundgren,  
[Physical Review B: Condensed Matter and Materials Physics](#) **83**, 115440 (2011).
- *Surface structure and reactivity of Pd(100) during CO oxidation near ambient pressures*,  
R. van Rijn, O. Balmes, A. Resta, D. Wermeille, R. Westerström, J. Gustafson, R. Felici, E. Lundgren, and J. W. M. Frenken,  
[Physical Chemistry Chemical Physics](#) **13**, 13167-13171 (2011).

- *Generation of Pd model catalyst nanoparticles by spark discharge*, M. E. Messing, R. Westerström, B. O. Meuller, S. Blomberg, J. Gustafson, J. N. Andersen, E. Lundgren, R. van Rijn, O. Balmes, H. Bluhm, and K. Deppert, *Journal of Physical Chemistry C* **114**, 9257-9263 (2010).
- *A new role for steps in catalysis and reaction oscillations*, B. L. M. Hendriksen, M. D. Ackermann, R. van Rijn, D. Stoltz, I. Popa, O. Balmes, A. Resta, D. Wermeille, R. Felici, S. Ferrer, and J. W. M. Frenken, *Nature Chemistry* **2**, 730-734 (2010).
- *Reply to “Comment on ‘Catalytic activity of the Rh surface oxide: CO oxidation over Rh(111) under realistic conditions’ ”*, J. Gustafson, R. Westerström, O. Balmes, A. Resta, R. van Rijn, X. Torrelles, C.T. Herbschleb, J. W. M. Frenken, and E. Lundgren, *Journal of Physical Chemistry C* **114**, 22372-22373 (2010).
- *Catalytic activity of the Rh Surface Oxide: CO oxidation over Rh(111) under realistic conditions*, J. Gustafson, R. Westerström, O. Balmes, A. Resta, R. van Rijn, X. Torrelles, C. T. Herbschleb, J. W. M. Frenken, and E. Lundgren, *Journal of Physical Chemistry C* **114**, 4580-4583 (2010).
- *Comment on “CO Oxidation on Pt-Group Metals from Ultrahigh Vacuum to Near Atmospheric Pressures. 2. Palladium and Platinum”*, R. van Rijn, O. Balmes, R. Felici, J. Gustafson, D. Wermeille, R. Westerström, E. Lundgren, and J. W. M. Frenken, *Journal of Physical Chemistry C* **114**, 6875-6876 (2010).
- *Ultrahigh vacuum/high-pressure flow reactor for surface x-ray diffraction and grazing incidence small angle x-ray scattering studies close to conditions for industrial catalysis*, R. van Rijn, M. D. Ackermann, O. Balmes, T. Dufrane, A. Geluk, H. Gonzalez, H. Isern, E. de Kuyper, L. Petit, V. A. Sole, D. Wermeille, R. Felici, and J. W. M. Frenken, *Review of Scientific Instruments* **81**, 014101 (2010).

- 
- *The ID03 surface diffraction beamline for in situ and real-time X-ray investigations of catalytic reactions at surfaces,*  
O. Balmes, R. van Rijn, D. Wermeille, A. Resta, L. Petit, H. Isern, T. Dufrane,  
and R. Felici,  
*Catalysis Today* **145**, 220-226 (2009).





## Curriculum vitae

Richard van Rijn was born on July 5, 1983 in Delft . He obtained his VWO diploma from the Westland College in Naalwijk in 2001 and enrolled at Leiden University to study physics. After completing the undergraduate courses in 2005, he started studying the formation and diffusion of single-atom thick gold wires on a gold surface in the framework of a M.Sc. thesis project under the supervision of Dr. M. J. Rost. After this project he spent 5 months assembling, testing and designing parts of a flow reactor for the in situ study of model catalysts with surface x-ray diffraction at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. This work was done under the supervision of Dr. R. Felici. In 2007 he received his M.Sc. degree (cum laude) in physics from Leiden University.

In September 2007 he continued his work on the flow reactor under the joint supervision of Dr. R. Felici at the ESRF and Prof. dr. J. W. M. Frenken at Leiden University. The research project aimed at developing and using the flow reactor for in situ measurements of heterogeneous model catalysts. The results of this project are described in this thesis.

