

Landolt-Börnstein

Numerical Data and Functional Relationships in Science and Technology

New Series / Editor in Chief: W. Martienssen

Group III: Condensed Matter

Volume 42

Physics of Covered Solid Surfaces

Subvolume A

Adsorbed Layers on Surfaces

Part 4

Adsorbed Species on Surfaces and Adsorbate-Induced Surface
Core Level Shifts

Editor

H.P. Bonzel

Authors

H.P. Bonzel, R. Denecke, W. Eck, A. Föhlisch, G. Held,

W. Jaegermann, N. Mårtensson, T. Mayer, H. Over, H.P. Steinrück

 Springer

ISSN 1615-1925 (Condensed Matter)

ISBN 3-540-20281-1 Springer Berlin Heidelberg New York

Library of Congress Cataloging in Publication Data

Zahlenwerte und Funktionen aus Naturwissenschaften und Technik, Neue Serie

Editor in Chief: W. Martienssen

Vol. III/42A4: Editor: H.P. Bonzel

At head of title: Landolt-Börnstein. Added t.p.: Numerical data and functional relationships in science and technology.

Tables chiefly in English.

Intended to supersede the Physikalisch-chemische Tabellen by H. Landolt and R. Börnstein of which the 6th ed. began publication in 1950 under title: Zahlenwerte und Funktionen aus Physik, Chemie, Astronomie, Geophysik und Technik.

Vols. published after v. 1 of group I have imprint: Berlin, New York, Springer-Verlag

Includes bibliographies.

1. Physics--Tables. 2. Chemistry--Tables. 3. Engineering--Tables.

I. Börnstein, R. (Richard), 1852-1913. II. Landolt, H. (Hans), 1831-1910.

III. Physikalisch-chemische Tabellen. IV. Title: Numerical data and functional relationships in science and technology.

QC61.23 502'.12 62-53136

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in other ways, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution act under German Copyright Law.

Springer is a part of Springer Science+Business Media

springeronline.com

© Springer-Verlag Berlin Heidelberg 2005

Printed in Germany

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Product Liability: The data and other information in this handbook have been carefully extracted and evaluated by experts from the original literature. Furthermore, they have been checked for correctness by authors and the editorial staff before printing. Nevertheless, the publisher can give no guarantee for the correctness of the data and information provided. In any individual case of application, the respective user must check the correctness by consulting other relevant sources of information.

Cover layout: Erich Kirchner, Heidelberg

Typesetting: Authors and Redaktion Landolt-Börnstein, Darmstadt

Printing and Binding: AZ Druck, Kempten

SPIN: 10932216 63/3020 - 5 4 3 2 1 0 – Printed on acid-free paper

Preface

Surface Science is understood as a relatively young scientific discipline, concerned with the physical and chemical properties of and phenomena on clean and covered solid surfaces, studied under a variety of conditions. The adsorption of atoms and molecules on solid surfaces is, for example, such a condition, connected with more or less drastic changes of all surface properties. An adsorption event is frequently observed in nature and found to be of technical importance in many industrial processes. For this reason, Surface Science is interdisciplinary by its very nature, and as such an important intermediary between fundamental and applied research. Intense world-wide research in this field over the last 50 years has lead to a considerable degree of maturity, such that a documentation of quantitative results in a single source seems desirable. Tribute is being paid to this effect by the renowned Series of LANDOLT-BÖRNSTEIN whose editor-in-chief Werner Martienssen, Frankfurt/ Main, has initiated several volumes of collected scientific data in the field of Surface Science.

The beginning has been made with LANDOLT-BÖRNSTEIN volume III/24, entitled *Physics of Solid Surfaces*. This volume, consisting of four subvolumes, appeared in 1993-96 and covers the properties of clean solid surfaces. The current volume III/42 is devoted to *Physics of Covered Solid Surfaces* and, in particular, to *Adsorbed Layers on Surfaces*. It is as such a collection of data obtained for adsorbates on well-defined crystalline surfaces. "Well-defined" means surfaces of known crystallographic structure and chemical composition. It was almost clear at the beginning, that the amount of general information and quantitative data on *Adsorbed Layers on Surfaces* is enormous, too large to fit into a single book. Hence several subvolumes had to be planned. Unfortunately, the chapters anticipated for each of the subvolumes did not arrive synchronously with the production schedule, such that the sequence of chapters actually printed in the subvolumes deviates from that in the original outline of the whole volume. We apologize for this inconvenience, but in the age of electronic information distribution this problem will be solved, once all volumes are available electronically. Search routines will guide the reader to the data of his desire. Until that time, the index of each subvolume will have to do.

Three subvolumes A1 to A3 of volume III/42 have already appeared in the years 2001-2003. The present subvolume A4 entitled *Adsorbed Species on Surfaces and Adsorbate-Induced Surface Core Level Shifts* is the fourth in this sequence. Another final subvolume is currently in preparation.

Finally, it is again my pleasure to thank all authors of this volume for their excellent contributions, and the editing and production offices of the Landolt-Börnstein Office of the Springer-Verlag for efficient cooperation and excellent support.

Jülich, June 2004

Hans P. Bonzel

Editor

H.P. Bonzel

Forschungszentrum Jülich
Institut für Schichten und Grenzflächen (ISG 3)
52425 Jülich
Germany

Authors

E.I. Altman

Department of Chemical Engineering
Yale University
New Haven, CT 06520
USA
3.4.3 Halogens on metals and semiconductors

M. Bienfait

CRMC2/CNRS
Faculté de Luminy
Physique - Case 910
F-13288 Marseille Cedex 9
FRANCE
3.1.2 Noble gases on graphite, lamellar halides, MgO, NaCl

H.P. Bonzel

Forschungszentrum Jülich
Institut für Schichten und Grenzflächen (ISG 3)
52425 Jülich
Germany
1 Introduction to physical and chemical properties of adlayer/substrate systems
3.7.1 CO and N₂ on metals

W.A. Brown

Department of Chemistry
University College London
London WC1H 0AJ
U.K.
3.7.2 NO, CN, O₂ on metals

H. Brune

Institut de Physique Expérimentale (IPE)
École Polytechnique Fédérale de Lausanne (EPFL)
PHB-Ecublens
CH-1015 Lausanne
3.3.1 Metals on metals

K. Christmann

Institut für Physikalische und Theoretische Chemie
Freie Universität Berlin
14195 Berlin
Germany

3.4.1 Chemisorbed hydrogen on metals and semiconductors

R. Denecke

Universität Erlangen-Nürnberg
Lehrstuhl für Physikalische Chemie II
Egerlandstraße 3
91058 Erlangen
Germany

4.3 Adsorbate induced surface core level shifts of metals

R.D. Diehl

Department of Physics
Pennsylvania State University
University Park, PA 16802
USA

3.2.1 Alkali metals on metals

W. Eck

Universität Heidelberg
Angewandte Physikalische Chemie
Abteilung Materialchemie
Im Neuenheimer Feld 253
69120 Heidelberg
Germany

M. Enachescu

Candescent Technologies
6320 San Ignacio Ave.
San José, CA 95119
USA

3.4.4 P, S, As, Sb on metals and semiconductors

N. Esser

Institut für Festkörperphysik
Technische Universität Berlin
D-10623 Berlin
Germany

4.6 Surface optical properties

J.E. Fieberg

Department of Chemistry
Georgetown College
Georgetown, KY 40324
USA

3.8.9 Halogen-substituted hydrocarbons on metals and semiconductors

A. Föhlisch

Institut für Experimentalphysik
Universität Hamburg
Luruper Chaussee 149
D-22761 Hamburg
Germany
3.7.1 CO and N₂ on metals

H.-J. Freund

Fritz-Haber-Institut der Max Planck Gesellschaft (MPG)
D-14195 Berlin
Germany
3.9 Adsorption on oxides

H.J. Grabke

Max-Planck Institut (MPI) für Eisenforschung GmbH
D-40074 Düsseldorf
Germany
3.5 Surface segregation of atomic species (non-metal on metal)

E. Hasselbrink

Institut für Physikalische und Theoretische Chemie
Universität Essen
D-45117 Essen
Germany
3.8.3 NH₃ and PF₃ on metals and semiconductors

G. Held

University of Cambridge
Department of Chemistry
Lensfield Road
Cambridge CB2 1EW
United Kingdom
3.8.7 Cyclic hydrocarbons on metals and semiconductors

K. Hermann

Fritz-Haber-Institut der Max-Planck Gesellschaft (MPG)
Abteilung Theorie
D-14195 Berlin
Germany
4.1 Surface structure on metals and semiconductors

H. Ibach

Institut für Schichten und Grenzflächen (ISG 3)
Forschungszentrum Jülich
D-52425 Jülich
Germany
4.4 Surface free energy and surface stress

K. Jacobi

Fritz-Haber-Institut der Max-Planck Gesellschaft (MPG)
D-14195 Berlin
Germany

4.2 Electron work function of metals and semiconductors

W. Jaegermann

Fachbereich Materialwissenschaft
Fachgebiet Oberflächenforschung
Technische Universität Darmstadt
D-64287 Darmstadt
Germany

3.8.2 H₂O and OH on semiconductors

M.Y.L. Jung

Department of Chemical Engineering
University of Illinois
Urbana, IL 61801
USA

3.11 Surface diffusion on metals, semiconductors and insulators

B.E. Koel

Department of Chemistry, SSC 606
University of Southern California
Los Angeles, CA 90089-0482
USA

3.8.4 CO₂, NO₂, SO₂, OCS, N₂O, O₃ on metals and semiconductors

H. Kühlenbeck

Fritz-Haber-Institut der Max-Planck Gesellschaft (MPG)
Abteilung Chemische Physik
D-14195 Berlin
Germany

3.9 Adsorption on oxides

V.G. Lifshits

Institute of Automation and Control Processes
690041 Vladivostok
Russia

3.3.2 Metals on semiconductors

N. Mårtensson

Department of Physics
Uppsala University
S-751 21 Uppsala
Sweden

4.3 Adsorbate induced surface core level shifts of metals

T. Mayer

Fachbereich Materialwissenschaft

Fachgebiet Oberflächenforschung

Technische Universität Darmstadt

D-64287 Darmstadt

Germany

3.8.2 H₂O and OH on semiconductors

R. McGrath

Surface Science Research Centre and Department of Physics

The University of Liverpool

Liverpool L69 3BX

U.K.

3.2.1 Alkali metals on metals

E.G. Michel

Departamento Fisica de la Materia Condensada C-III

Instituto Universitario de Ciencia de Materiales "Nicolas Cabrera"

Universidad Autonoma de Madrid

28049 Madrid

Spain

3.2.2 Alkali metals on semiconductors

R. Miranda

Departamento Fisica de la Materia Condensada C-III

Instituto Universitario de Ciencia de Materiales "Nicolas Cabrera"

Universidad Autonoma de Madrid

28049 Madrid

Spain

3.2.2 Alkali metals on semiconductors

D.R. Mullins

Oak Ridge National Laboratory

Oak Ridge, TN 37831-6201

USA

3.8.5 Substituted hydrocarbons on metals

B.E. Nieuwenhuys

Gorlaeus Laboratory

Leiden University

NL 2300 Ra Leiden

The Netherlands

3.7.3 Diatomic molecules on alloys

K. Oura

Department of Electronic Engineering

Faculty of Engineering

Osaka University

Osaka 565-0871

Japan

3.3.2 Metals on semiconductors

H. Over

Physikalisch-Chemisches Institut
Justus Liebig Universität Gießen
Heinrich-Buff Ring 58
D-35392 Gießen
Germany

3.4.2 C, N, O on metals

G. Pirug

Institut für Schichten und Grenzflächen (ISG 3)
Forschungszentrum Jülich
D-52425 Jülich
Germany

3.8.1 H₂O and OH on metals

W. Richter

Institut für Festkörperphysik
Technische Universität Berlin
D-10623 Berlin
Germany

4.6 Surface optical properties

M.A. Rocca

Centro di Fisica delle Superfici e Basse Temperature del CNR
Istituto Nazionale di Fisica della Materia
I-16146 Genova
Italy

4.5 Surface phonon dispersion

G. Rupprechter

Fritz-Haber-Institut der Max-Planck Gesellschaft (MPG)
Abteilung Chemische Physik
D-14195 Berlin
Germany

3.8.6 Linear hydrocarbons and CH₄ on metals and semiconductors

M. Salmeron

Lawrence Berkeley Laboratory
Materials Science Bldg. 66/208
Berkeley, CA 94720
USA

3.4.4 P, S, As, Sb on metals and semiconductors

D. Sander

Max-Planck Institut (MPI) für Strukturphysik
D-06120 Halle
Germany

4.4 Surface free energy and surface stress

A.A. Saranin

Institute of Automation and Control Processes
690041 Vladivostok
Faculty of Physics and Engineering
Far Eastern State University
690000 Vladivostok
Russia

3.3.2 Metals on semiconductors

E.G. Seebauer

Department of Chemical Engineering
University of Illinois
Urbana, IL 61801
USA

3.11 Surface diffusion on metals, semiconductors and insulators

G.A. Somorjai

Department of Chemistry
University of California
Berkeley, CA 94720
USA

3.8.6 Linear hydrocarbons and CH₄ on metals and semiconductors

H.-P. Steinrück

Lehrstuhl für Physikalische Chemie II
Universität Erlangen-Nürnberg
D-91058 Erlangen
Germany

3.8.7 Cyclic hydrocarbons on metals and semiconductors

J. Suzanne

Département de Physique
CRMC2 - Centre National de la Recherche Scientifique (CNRS)
Faculté des Sciences de Luminy
F-13288 Marseille, Cedex 9
France

3.6 Molecules on graphite, BN, MgO (except noble gases)

W.T. Tysoe

Department of Chemistry and Laboratory for Surface Studies
University of Wisconsin - Milwaukee
Milwaukee, WI 53211
USA

3.8.5 Substituted hydrocarbons on metals

Ch. Uebing

Department of Physics and Astronomy
Rutgers, The State University of New Jersey
Piscataway, NJ 08854-8019
USA

3.5 Surface segregation of atomic species (non-metal on metal)

H. Viehhaus

Max-Planck Institut (MPI) für Eisenforschung GmbH
D-40074 Düsseldorf
Germany

3.5 Surface segregation of atomic species (non-metal on metal)

J.M. Vohs

Department of Chemical Engineering
University of Pennsylvania
Philadelphia, PA 19104-6315
USA

3.8.8 Oxygenated hydrocarbons on metals and semiconductors

M.A. Van Hove

Lawrence Berkeley National Laboratory
Materials Science 66
Berkeley, CA 94720
and Department of Physics
University of California-Davis
Davis, CA 95616
USA

4.1 Surface structure on metals and semiconductors

P.R. Watson

Department of Chemistry
Oregon State University
Corvallis, OR 97331
USA

4.1 Surface structure on metals and semiconductors

J.M. White

Department of Chemistry and Biochemistry
University of Texas at Austin
Austin, TX 78712
USA

3.8.9 Halogen-substituted hydrocarbons on metals and semiconductors

H. Wiechert

Institut für Physik der Johann Gutenberg-Universität
D-55099 Mainz
Germany

Molecules on graphite, BN, MgO (except noble gases)

Ch. Wöll

Lehrstuhl für Physikalische Chemie I
Ruhr-Universität Bochum
D-44801 Bochum
Germany

2 Characterization of adsorbate overlayers: Measuring techniques

P. Zeppenfeld

Institut für Experimentalphysik Atom- und Oberflächenphysik
Johannes-Kepler-Universität Linz
A-4040 Linz,
Austria

3.1.1 Noble gases on metals and semiconductors

A.V. Zotov

Faculty of Electronics
Vladivostok State University of Economics and Service
690600 Vladivostok, Russia
Institute of Automation and Control Processes
690041 Vladivostok , Russia

3.3.2 Metals on semiconductors

Landolt-Börnstein**Editorial Office**

Gagernstr. 8, D-64283 Darmstadt, Germany
fax: +49 (6151) 171760
e-mail: lb@springer-sbm.com

Internet

<http://www.landolt-boernstein.com>