Professor Gerhard Ertl has been awarded the Nobel Prize in Chemistry 2007 !

“for his studies of chemical processes on solid surfaces”

10 October 2007

KUNGL. VETENSKAPSAKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Scientific Background on the Nobel Prize in Chemistry 2007

Chemical Processes on Solid Surfaces

NOBEL COMMITTEE FOR CHEMISTRY 2007

Prof Dr Hakan Wennerstrom
Professor of Theoretical Physical Chemistry, Lund University
Member of the Nobel committee for Chemistry

Prof Dr Sven Lidin
Professor of Inorganic Chemistry, Stockholm University
Member of the Nobel Committee for Chemistry

1912: P Sebatier – hydrogenation of organic compounds

1918: Fritz Haber Ammonia synthesis

1932: I.Langmuir discoveries in surface chemistry

1956: C.N.Hinshelwood and N.N.Semenov, mechanisms of chemical reactions

1986: D R Herschbach, Y.T.Lee and J.C.Polanyi, Dynamics of chemical elementary processes

The three main areas considered for Nobel prize for Gerhard Ertl are:

1.Hydrogen absorption on solids

2. Details of ammonia Synthesis

3.Oscillations in catalytic reactions


n-tv

Education

From 1955 to 1957, he studied physics at the Technical University of Stuttgart and then at the University of Paris (1957-1958) and Ludwig Maximilians University in Munich (1958-1959). He completed his Diplom in Physics (equivalent to a Masters degree) at the Technical University of Stuttgart in 1961, followed his thesis advisor Heinz Gerischer from the Max Planck Institute for Metals Research in Stuttgart to Munich and received his PhD from the Technical University of Munich in 1965

Academic career

He became an assistant and lecturer at Technical University of Munich (1965-1968).
From 1968 to 1973, he was Professor and Director at Technical University of Hannover.
Then, he became a Professor at Institute for Physical Chemistry, Ludwig Maximilians University of Munich (1973-1986).
During the 1970s and 80s, he was also a Visiting Professor at the California Institute of Technology, the University of Wisconsin-Milwaukee and the University of California, Berkeley.
In 1986 he became professor at the Free University of Berlin and at the Technical University of Berlin.
He was director at the Fritz Haber Institute of the MPG from 1986 till his retirement in 2004.
He became professor at the Humboldt University of Berlin in 1996

Years	Function	Institution
2004-now	Professor emeritus	Dept. of Physical Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin
1986-2004	Director	Dept. of Physical Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin
1981-1982	Visiting Professor	Dept. of Chemistry, University of California, Berkeley
1979	Visiting Professor	Dept. of Physics, University of Wisconsin, Milwaukee
1976-1977	Visiting Professor	Dept. of Chemical Engineering, California Institute of Technology, Pasadena
1973-1986	Professor & Director	Inst. for Physical Chemistry, Ludwig Maximilians University, Munich
1968-1973	Professor & Director	Inst. for Physical Chemistry, Technical University, Hannover
1965-1968	Assistant & Lecturer	Technical University, Munich
1962-1965		Technical University, Munich: *Dr. rer. nat* in 1965
1959-1961		Technical University, Stuttgart: *Dipl. Phys.* in 1961
1958-1959		Ludwig Maximilians University, Munich
1957-1958		University of Paris
1955-1957		Technical University, Stuttgart
1936	born	October 10, in Stuttgart, Germany

RESEARCH IN SUMMARY

The detailed molecular mechanisms of the catalytic synthesis of ammonia over iron (Haber Bosch process)

The catalytic oxidation of carbon monoxide over palladium (catalytic converter).

During his research he discovered the important phenomenon of oscillatory reactions on platinum surfaces and, using photoelectron microscopy, was able to image for the first time, the oscillating changes in surface structure and coverage that occur during reaction.

New observation techniques like low-energy electron diffraction (**LEED**) at the beginning of his career, later ultraviolet photoelectron spectroscopy (**UPS**) and scanning tunneling microscope (**STM**) yielding ground breaking results.

He won the Wolf Prize in Chemistry in 1998 along with Gabor A. Somorjai of the University of California, Berkeley for "their outstanding contributions to the field of the surface science in general and for their elucidation of fundamental mechanisms of heterogeneous catalytic reactions at single crystal surface in particular."

REACTION

I am speechless," Ertl told The Associated Press from his office in Berlin. "I was not counting on this

Gerhard Ertl has, as no one else,
influenced the fate and
direction of surface science and we are
grateful for it.

Gerhard Ertl was born on **October 10, 1936, in Bad Cannstadt**, Germany, which today is part of **Stuttgart**.

Shortly after the family moved to Fellbach (Germany) he went to school at the **Kepler-Gymnasium in Bad Cannstadt**.

After his “Abitur”, he started studies in Physics **at the University of Stuttgart** in 1955. Interrupted by two short excursions to study at the **University of Paris** (1957/58) and the University of Munich (1958/59) he finished his studies with a diploma thesis entitled “Eine Temperatursprungmethode zur Untersuchung schneller Dissoziationsreaktionen mit Hilfe eines Mikrowellenimpulses” (“**Temperature jump experiments to study fast dissociation reactions using microwave pulses**”) in 1961, supervised by **Heinz Gerischer**, who at that time was working at the **Max Planck Institute of Metals Research in Stuttgart**. When **Heinz Gerischer** accepted an offer to join the Technical University of Munich faculty as a Professor of Physical Chemistry in 1962, Gerhard Ertl followed him as an “assistant” and worked under his supervision on a thesis that he finished in 1965, entitled “U¬ ber die Kinetik der katalytischen Oxidation von Wasserstoff an Germanium Einkristallen” (“**On the kinetics of the catalytic hydrogen oxidation on Germanium single crystals”).**

After the defense of his thesis and receiving a Ph.D. (Dr. rer. nat.) in physical chemistry, he started to work on a habilitation project. Only two years later, he finished this project and became private docent (“venia legendi in physical chemistry”).

First Publication

Eine Temperatursprungmethode zur Untersuchung schneller Dissoziationsreaktionen mit Hilfe eines Mikrowellen-Impulses

Von *G. ERTL* und *H. GERISCHER*

Aus dem Max-Planck-Institut für Metallforschung, Stuttgart

(Vorgetragen von G. Ertl anläßlich der 60. Hauptversammlung der Deutschen Bunsen-Gesellschaft für physikalische Chemie e.V. in Karlsruhe am 12. Mai 1961)

Bei der Störung eines chemischen Gleichgewichts durch eine sprungartige Temperaturerhöhung können durch Beobachtung des zeitlichen Verlaufs der neuen Gleichgewichtseinstellung Aussagen über die Kinetik des Reaktionssystems gewonnen werden. Es wird ein Verfahren beschrieben, in dem zur schnellen Aufheizung die mit der dielektrischen Relaxation verknüpfte Energieabsorption polarer Moleküle benutzt wird. Für Wasser liegt das Absorptionsmaximum bei 10^{10} Hz (= 3 cm Wellenlänge), einem Frequenzbereich, in dem Energiestrahler mit sehr hoher Leistung zur Verfügung stehen. In einer geeigneten Anordnung kann damit die Temperatur um 0,7°C innerhalb weniger µsec erhöht werden. Zur Erprobung der Methode wurden die Geschwindigkeitskonstanten der Dissoziationsreaktion des Wassers ermittelt.

HABILITATION

The topic of his habilitation thesis was “Surface structural and reactivity studies using low energy electron diffraction” (“Untersuchung von Oberfla¨chenstrukturen und -reaktionen mittels Beugung langsamer Elektronen”). He had been granted one of the first commercial LEED-UHV machines in Germany and thus introduced the field that today is known as “surface science” in the country. The first groundbreaking paper already appeared in 1966 in the journal *Surface Science* (whose regional editor he was from 1977 to 1986) and dealt with surface structures and reactions on copper single crystal surfaces.

Obviously, it is one of Gerhard Ertl's many prominent abilities to recognize the potential of scientific developments early and then simply lead the field. In the year of his habilitation (1967), only **at the age of 31**, a chair of physical chemistry at the **University of Hannover** was offered to him. He accepted this offer in the same year and became Professor and Director at the Institute of Physical Chemistry and Electrochemistry of the Technical University of Hannover.
In Hannover a number of co-workers joined Gerhard Ertl's group, among them **Ju¨rgen Ku¨ppers, Klaus Christmann, and Klaus Wandelt**. When Gerhard Ertl, after not accepting an offer to join the Institute for Interface and Vacuum Physics (IGV) in the socalled Kernforschungsanlage Ju¨lich, became **Georg-Maria Schwab's** successor on the chair for physical chemistry at the **Ludwig-Maximilians University in Munich in 1973**, the entire crew followed along from Hannover to Munich.
Gerhard held guest professorships at **Caltech in Pasadena (1976/77**), in Milwaukee (1979), and at the **University of California at Berkeley** (1981/ 82), but he remained in Munich despite two very tempting offers by the **University of California at Santa Barbara and the University of Mu¨nster, both in 1983**.

Move to Berlin

It was only in 1985, after he was offered the succession of his teacher Heinz Gerischer as a Director at the Fritz-Haber-Institute in Berlin that he left Munich and took up the position. At the same time, he became Honorary Professor at the Technical University in Berlin and the Free University of Berlin. After the wall came down in 1989, he was also made Honorary Professor at the Humboldt-University of Berlin, becoming probably the first individual to be Honorary Professor at all three Berlin universities. When Gerhard decided to move to Berlin, again, the entire group followed him, bringing the Department of Physical Chemistry at the Fritz-Haber-Institute, that he leads, temporarily to a size of more than 100 co-workers including supporting staff and students.

Succesion

It is perhaps interesting to note that with Gerhard Ertl's coming to Berlin a cycle of scientific "family relations" is closed: One of Fritz Haber's scientific collaborators was Karl- Friedrich Bonhoeffer from 1923 to 1930 who became scientific director of the Fritz-Haber-Institute from 1948 to 1949. He was the thesis advisor of Heinz Gerischer who became director of the Fritz-Haber-Institute in 1973 as mentioned and who turned the directorship over to his former student Gerhard Ertl.

Ammonia synthesis

One could perhaps appreciate Gerhard's work on ammonia synthesis if one recalls some historic facts:
Since the discovery of ammonia synthesis by Fritz Haber during the years 1905-1908, who received the Nobel prize for this work in 1918, many researchers have tried to unravel and prove the mechanism of this reaction, which has had such far reaching technical and economic consequences.
It was only in 1975 when Paul Emmett himself stated on the occasion of a Batelle Colloquium on the physical foundation of heterogeneous catalysis "The experimental work of the past 50 years leads to the conclusion that the rate determining step in ammonia synthesis is the chemisorption of nitrogen. The question, however, as to whether the nitrogen species is molecular or atomic, is still not conclusively resolved". Shortly after, Gerhard Ertl's group showed via the application of surface science tools that the active species is dissociatively adsorbed (atomic) nitrogen, which is stepwise hydrogenated. Continuously, the understanding of the atomic structure of surfaces under the influences of adsorbates became clear.

Surface Science and Catalysis—Studies on the Mechanism of Ammonia Synthesis: The P. H. Emmett Award Address*

G. ERTL
Institut für Physikalische Chemie
Universität München
Munich, West Germany

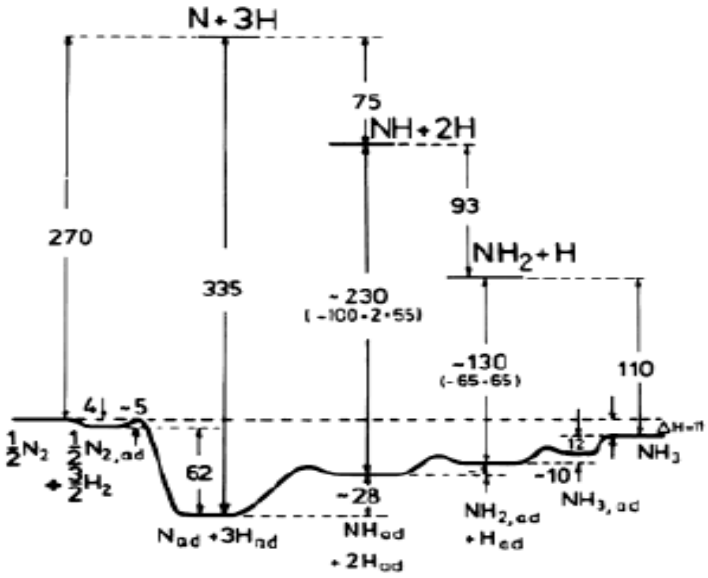


FIG. 14. Potential energy diagram for ammonia synthesis catalyzed by an iron surface. (Energy values in kcal/mole.)

Figure 2. Gerhard Ertl's paper on the occasion of the P. H. Emmett Award, 1979. Reprinted with permission of Marcel Dekker, Inc. Copyright 1980.

STM and UPS

Shortly after the scanning tunneling microscope was described in 1982 by Gerd Binning and Heinrich Rohrer, when many researchers were still very skeptical about the reliability of the method, Gerhard Ertl's group set up an STM to look at surface reconstructions under the influence of adsorbates. Parallel to the development of tools to investigate structure, the group also introduced very sensitive tools to investigate the electronic structure of surfaces.

Already in the early 70s, he set up a UV-photoelectron spectrometer from his startup funds in Munich. In the 80s it was the extremely surface sensitive scattering of metastable He* atoms and the subsequent measurement of the kinetic energy of emitted electrons (MIES) that led to new insight into the bonding of molecules to surfaces.

Oscillations in Chemical Reactions

One of the most intensively studied reactions in Gerhard Ertl's group has been CO oxidation. In this process, a chemisorbed CO molecule reacts with an also chemisorbed oxygen atom to form a very weakly bound CO2 molecule that under reaction conditions immediately leaves the surface. Already in 1982, Gerhard Ertl and his group reported kinetic oscillations in the course of CO oxidation reactions on single crystal surfaces, a phenomenon that had so far only been found in technical reactors. Such nonlinear phenomena express themselves in an oscillating rate of CO2 formation often measured as a CO2 pressure change above the solid surface. Gerhard and his group showed in a series of groundbreaking publications that a microscopic model for such oscillations may be developed. The interplay between adsorption of carbon monoxide, resulting in lifting of the reconstruction of the platinum surface, the reaction and the higher sticking probability of the non-reconstructed surface toward oxygen, inducing switching of the system between the reconstructed and non-reconstructed surface phases and therefore oscillations of reaction rate. Such oscillations may be regular, but can also, by changing the reaction conditions, become chaotic.

Chemical oscillations II

After Gerhard Ertl moved to Berlin, the investigation of nonlinear phenomena reached a second stage of detail:

The above-mentioned temporal oscillations represent the integral behavior of the system. Of course, however, the state variables of a system also depend on spatial coordinates in oscillating reactions. We know this from the Belousov- Zhabotinsky reaction, where the spatio-temporally resolved state of the reaction can be diagnosed by the color.

To image the spatio-temporal patterns at a surface, a photoelectron microscope was developed in the Fritz-Haber- Institute and it allowed us to follow the local variations of concentrations at a surface in real time under vacuum for the first time in history. As the spatio-temporal variations are mesoscopic phenomena, resolution just below the micrometer range was sufficient. Following the observations and their theoretical modeling the development of an ellipsometric microscope finally also allowed the observation of such phenomena in situ, i.e., in the presence of a gas phase up to atmospheric pressure.

What is the molecular mechanism behind the non-linear kinetics?

What other phenomena can be inferred in addition to the kinetic oscillations?

For the oxidation of CO on Pt there are several mechanisms operating but the most spectacular effects were caused by a surface reconstruction.

For the bare metal surfaces (100) and (111) there is a reconstruction to reduce the surface strain. However CO adsorbs more readily on the unmodified surface and at a certain coverage the difference in adsorption energy is sufficient to cause a reversal of the surface reconstruction. Now oxygen is also more chemisorbed on the reverted surfaces.

Then the rate of catalytic process increases leading to a lower coverage and a possibility for a surface reconstruction. This can in addition to an oscillatory kinetics also lead to a spatial organization on the surface with domains rich in CO and O2 respectively. Illustrations of adsorption patterns observed by PEEM illustrates this

The quickly developing STM techniques led to insight, thought to be impossible for a long time, into the structure and, particularly, the defect structure of metal surfaces. Gerhard's group made it possible to visualize directly diffusion processes using a high speed STM, and thus verify macroscopic laws,

Figure 3. Cover of the journal of the Max-Planck-Society printed upon its 50th birthday. One of the spatio-temporal patterns, i.e., a spiral, is depicted to represent a typical example. Reprinted with permission of the Max-Planck-Gesellschaft. Copyright 1999.

Diffusion studies

Fick's law of diffusion, directly at the atomic scale or to visualize the mesoscopic phenomena at a smaller length scale.

Moving to smaller and smaller length scales was accompanied by setting up a group within the Physical Chemistry Department of the Fritz-Haber-Institute in the late 80s, looking into ultrafast processes at surfaces. Pump-probe experiments using femtosecond laser technology opened deep insight into the electron dynamics during photon excitation and concomitantly into energy transfer processes upon adsorbate excitation, these phenomena are relevant in laser-induced desorption from surfaces, a field in which Gerhard Ertl and Manfred Neumann published a first paper in 1972.

INTEREST IN HETEROGENEOUS CATALYSIS

Parallel to those fundamental experiments on model substrates Gerhard Ertl always kept an interest in real catalysis. In his department a group performed groundbreaking mechanistically oriented experiments on real powder catalysts. Ammonia synthesis had in addition to other reactions, always been one of Gerhard's key interests, and it was reinforced when it became obvious that in addition to the classic iron based catalyst, also ruthenium based catalysts could be technically beneficial. Work in this and other directions has resulted in a variety of important contributions to the science of catalysis. He has edited together with Helmut Kno¨zinger and Jens Weitkamp the *Handbook of Heterogeneous Catalysis*, a five-volume encyclopedia on heterogeneous catalysis, which has set the standard in the field.

Academic Responsibilities

It is only natural that the advice and leadership of a scientist of Gerhard Ertl's caliber has been sought nationally and internationally. In **Hannover and in Munich** he has been **dean of the faculty**, in Munich he was **spokesperson of the center of excellence, financed by the German Science Foundation (DFG**). He has served the scientific community and its societies via memberships of numerous committees. In the beginning of the 1990s, he was very active in evaluating science in the former GDR, and was "**Kommissarischer Direktor**" of the **Max-Planck- Institute in Halle** until the new directors were installed. In Germany he advised the **German Science Foundation** in various committees as one of its elected referees (1988-1995), at last as one of its **vice presidents** (1995-2001), as well as the **ministry for science and technology (BMFT**) from 1981 to 1988 as a member in the committee responsible for **synchrotron radiation**
research. He has been on the advisory editorial board of many journals and he was the **chairman of the 8th International Congress on Catalysis held in Berlin** in 1984. He is an ordinary or foreign member of ten academies including the National Academy of Science of the United States (since 2001).

A Few Honours

Gerhard Ertl received many honors: In addition to his three honorary professorships, he received at least five honorary doctorates, the first one in 1992 from the Ruhr University in Bochum, and the latest in 2003 from Aarhus University in Denmark.
Out of the numerous awards he was honored with, we mention only the Liebig Denkmu¨nze of the German Society of Chemists in 1991, the Japan Prize in 1992, the Medard A. Welch Award of the American Vacuum Society in 1998, and in the same year, the Wolf Prize in Chemistry. In 1992, he received the “Grosse Verdienstkreuz der Bundesrepublik Deutschland”

Membership in Organizations:

Since	Position	Organization
2006	Honorary Member	Deutsche Bunsengesellschaft für Physikalische Chemie
2002	Foreign Associate	National Academy of Sciences
2001	Corresponding Member	Austrian Academy of Sciences
1998	Corresponding Member	Bavarian Academy of Sciences
1993	Member	Berlin-Brandenburg Academy of Sciences
1993	Foreign Honorary Member	American Academy of Arts and Sciences
1993	Corresponding Member	Nordrhein.-Westfal. Academy of Sciences
1992	Member	Academia Europaea
1986	Corresponding Member	Scientific Society of Braunschweig
1986	Member	German Academy of Sciences, "Leopoldina"
1985	Honorary Fellow	Royal Society of Edinburgh

2007	**Nobel Prize in Chemistry**	The Nobel Prize Foundation

Photo of Prof. Gerhard Ertl
(October 10, 2007)
(also available: 1000x1333 & 1851x2468 pixels)
see also Department main page

2007	Otto-Hahn-Preis	Gesellschaft Deutscher Chemiker, Deutsche Physikalische Gesellschaft, & the city of Frankfurt/M
2007	Gold Medal	Slovak Chemical Society
2007	Baker Lectureship	Cornell University, Ithaca (NY)
2007	Faraday Lectureship	Royal Society of Chemistry
2006	Guptill Lecture	Dalhousie University, Halifax
2005	Angström Lecture	University of Uppsala
2005	Linus Pauling Lecture	California Institute of Technology

2003	Dr. honoris causa	University of Aarhus
2003	Dr. honoris causa	Chalmers University of Technology, Goeteborg
2003	Dr. honoris causa	University of Leuven
2002	FMC Lectureship	Princeton University
2002	Karl Ziegler Visiting Professor	Max Planck Institute Mulheim
2002	Spiers Memorial Medal and Lectureship	Royal Society of Chemistry
2001	G.F. Smith Lecture	University of Illinois, Urbana
2001	Kelly Lecture	Purdue University
2001	Schuit Lecture	Technical University of Eindhoven
2001	Pitzer Lecture	University of California, Berkeley
2000	Dr. honoris causa	University of Münster
1999	Roessler Lectureship	Cornell University
1999	Le Bel Lecture	Université de Strasbourg
1999	Debye Lecture	Universiteit Utrecht
1998	Wolf Prize in Chemistry	Wolf Foundation
1998	Karl Ziegler Prize	German Chemical Society
1998	Francois Gault Lectureship	European Catalysis Society
1998	M. Curie Lectureship	Polish Chemical Society

1997	Laird Lecture	University of British Columbia
1997	A.D. Little Lectureship	Massachusetts Institute of Technology
1996	Honorary Professor	Humboldt University Berlin
1996	Carl Engler Medal	German Scientific Society for Coal and Petroleum Research (DGMK)
1996	Merck Lecture	Rutgers University
1996	Brdicka Lecture	Czech Academy of Sciences
1995	Medard W. Welch Award	American Vacuum Society
1995	Stauffer Lecture	University of Southern California
1994	Rolf Sammet Visiting Professor	University of Frankfurt
1992	Hewlett-Packard Europhysics Prize	European Physical Society
1992	Japan Prize	Science and Technology Foundation of Japan
1992	Bunsen Medal	German Bunsen Society for Physical Chemistry
1992	Dr. Honoris Causa	Ruhr-University of Bochum
1992	Großes Bundesverdienstkreuz	President of the Federal Republic of Germany
1992	Kolthoff Lectureship	University of Minnesota
1992	Kaufman Memorial Lecture	University of Pittsburgh

1991	Leibniz Prize	German Science Foundation
1991	Bourke Medal and Lectureship	Royal Society of Chemistry
1990	Alwin Mittasch Medal	German Federation of Chemical Engineers (DECHEMA)
1990	Dow Lectureship	University of Western Ontario
1990	Coover Lecture	Iowa State University
1989	Frontiers in Chemical Research Lectureship	Texas A&M University
1988	William Draper Harkins Lecture	University of Chicago
1988	Barre Lecture	University of Montreal
1987	Liebig Medal	German Chemical Society
1986	Honorary Professor	Free University of Berlin
1986	Honorary Professor	Technical University of Berlin
1986	Langmuir Lecture	American Chemical Society
1985	C.F. Gauss Medal	Scientific Society of Braunschweig
1985	Centenary Medal and Lectureship	Royal Society of Chemistry
1985	C.G.A. Schuit Lecture	University of Delaware

1984	FECS Lecture	Federation of European Chemical Societies
1984	Industry Lecture	Norwegian Chemical Society
1979	Paul H. Emmett Award in Fundamental Catalysis	American Catalysis Society
1979	E.W. Müller Award	University of Wisconsin-Milwaukee
1977	Frank Ciapetta National Lectureship	American Catalysis Society
1976	Sherman Fairchild Distinguished Scholar	California Institute of Technology

Ph D students and other details

S.No	Location and period	Number of PhD
1	**Technical University of Hannover 1968-1973**	11
2	**University of Munich 1973-1986**	32
3	**FHI-Berlin 1987-2003**	67
4	**Visiting Researchers and Postdoctoral Associates**	**346 (From over 35 countries)**

Some remarks on the famous

Fritz Haber Institut der MPG

4-6 Faraday Weg

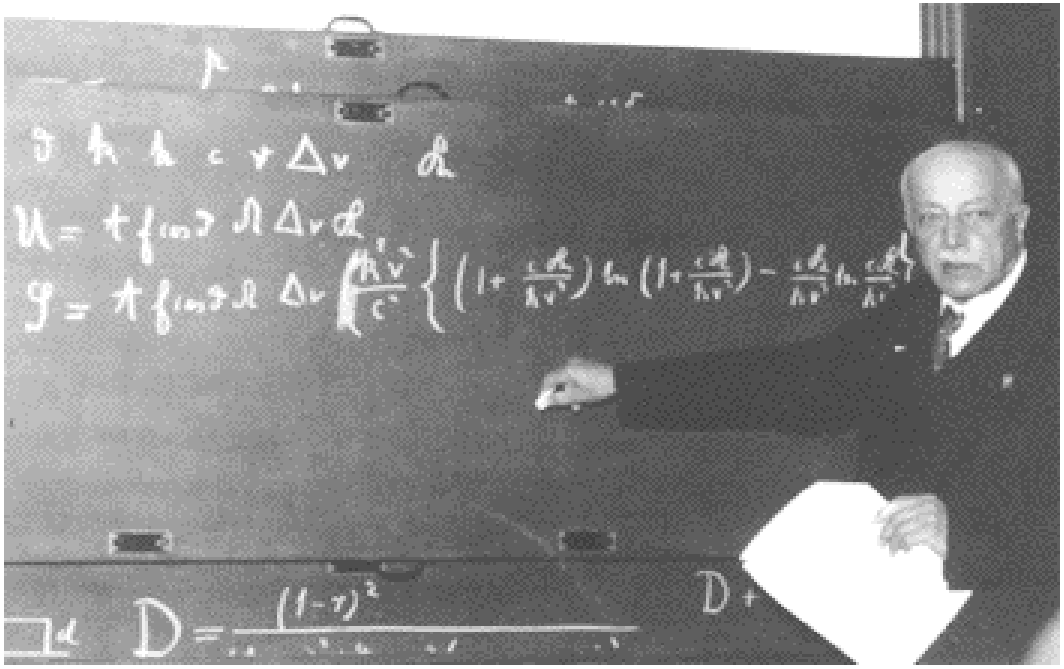
Berlin 33

The Kaiser-Wilhelm Institutes for Chemistry (left) and for Physical Chemistry and Electrochemistry (right) --(1913).

Kaiser Wilhelm II and Adolf von Harnack, followed by Emil Fischer and Fritz Haber walking to the opening ceremony of the first two KWG institutes (October 1912).

Fritz Haber (left) and Albert Einstein (right) at the "Fritz-Haber-Institut" (1915).

In 1913/14 the staff amounted to 5 scientists, 10 assistants, and 13 volunteers and students, with a personnel and operating budget of 70,000 Mark excluding the salary of the director



Max von Laue at a colloquium, 9. Oct. 1953

In 1951, at the age of 71, Max von Laue became chief director of the institute

In 1953 Max von Laue brought Gerhard Borrmann to the institute as a department head. Borrmann continued his studies on X-ray absorption in perfect crystals. He became a Scientific Fellow in 1956 and headed the department until his retirement in 1970. Rolf Hosemann, working as assistant to Max von Laue since 1951, studied X-ray diffraction phenomena in solids exhibiting statistical disorder and developed his theory of so-called paracrystals. In 1960 he became head of a department and was appointed Scientific Fellow of the institute in 1966.

In 1953 Max von Laue started to plan a major expansion of the institute. As a result, Ernst Ruska gave up his position in an industrial company in 1955 and became a Scientific Fellow of the institute heading an independent department. In 1957 this department became the "Institute for Electron Microscopy of the Fritz-Haber Institute". A new building for electron microscopy with an administrational and library annex was completed in 1959. The adjacent new lecture hall was not completed until 1963

In October 1958 Rudolf Brill was appointed director of the institute and in March 1959 he succeeded Max von Laue as chief institute director. Brill headed the institute until the spring of 1969. Amongst other subjects, his was engaged in studies of catalytic properties for heterogeneous reactions which were investigated using X-ray diffraction methods and kinetic measurements. He took a particular interest in catalysts used in the ammonia synthesis as well as in hydrogenation and oxidation catalysts. From 1955 to 1964 three new buildings on Faradayweg 16 were added to the institute, housing Ueberreiter's group and taken over later by the departments of **Profs. Block and Hosemann**. The buildings had been used previously by the Max-Planck Institute for Silicate Research housing a group working on micromorphology of silicates.

In November **1969 Heinz Gerischer** was appointed to succeed Brill as chief institute director. He headed the Department of Physical Chemistry and initiated research in the areas of electrochemistry, photo electrochemistry, and fast reactions. His department focused also on studies of solid surfaces under ultra-high vacuum conditions and their interaction with gases. Further, exploiting the low **temperature technology** already developed by von Laue at the institute, a research program on matrix isolation spectroscopy was started. Here the transition between atomic and metallic properties in clusters was investigated. When Gerischer was appointed, **Jochen H. Block became Scientific Fellow of the** institute. He had been hired by Brill in 1966 and had built up his own department in which kinetic processes on metal surfaces were **studied using field electron and field ion microscopies. In 1974 a new building for electron** microscopy was completed. This building was constructed in particular to isolate Ruska's ultrahigh resolution microscopes against external vibrations.

During this period two internal reorganizations were carried out (1974 and 1980). In 1974, the institute was restructured to consist of three sections which were to combine their collaborative efforts: Physical Chemistry (**directors: J. H. Block, H. Gerischer, K. Molière), Structure Research (directors: R. Hosemann**, Kurt Ueberreiter), and **Electron Microscopy (director: E. Ruska until 1974). H. Gerischer remained the chief institute director. In 1977 Elmar Zeitler was appointed Scientific Fellow and director at the institute as successor of Ernst Ruska.**

After the retirement of R. Hosemann, K. Molière, and Kurt Ueberreiter in 1980 a second reorganization introduced a collegiate structure for the institute with stronger emphasis on surface and interface science. **In November 1980 Alexander Bradshaw was appointed Scientific Fellow and director at the institute heading the Department of Surface Physics**. Since 1976 he had built up his own group in the Department of Physical Chemistry, with emphasis on the spectroscopy of solid surfaces and on the study of chemisorbed molecules. In 1999 Bradshaw accepted the request to become chief director of the Institute for Plasma Physics of the MPG in Garching and Greifswald, and in 2002 his Department of Surface Physics was terminated.

In 1977, on the initiative of the Fritz-Haber Institute and the German Federal Institute of Standards (PTB) planning started for a synchrotron-radiation light source in Berlin. A company (BESSY) was founded in 1979 to build and operate the necessary electron storage ring. Members of the company included the Max-Planck Society, the Hahn-Meitner Institute, the Fraunhofer Society, and the German Electron Synchrotron (DESY) in Hamburg as well as four industrial companies. The Fritz-Haber Institute provided the Scientific Director and was also concerned with administration in the initial phase. **Bradshaw was appointed Scientific Director** of BESSY in 1981 and again in 1988 after the tragical death of his successor Ernst-Eckard Koch. Since the start of experimental activities at BESSY in 1982 the radiation source has been intensively used by various groups at the institute. The new storage ring BESSY II, starting to operate in 1999, plays also a prominent role in the research program of the institute.

7. Development into a surface and interface science research center

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In November 1969 Heinz Gerischer was appointed to succeed Brill as chief institute director. He headed the Department of Physical Chemistry and initiated research in the areas of electrochemistry, photo electrochemistry, and fast reactions. His department focused also on studies of solid surfaces under ultra-high vacuum conditions and their interaction with gases. Further, exploiting the low temperature technology already developed by von Laue at the institute, a research program on matrix isolation spectroscopy was started. Here the transition between atomic and metallic properties in clusters was investigated. When Gerischer was appointed, Jochen H. Block became Scientific Fellow of the institute. He had been hired by Brill in 1966 and had built up his own department in which kinetic processes on metal surfaces were studied using field electron and field ion microscopies. In 1974 a new building for electron microscopy was completed. This building was constructed in particular to isolate Ruska's ultrahigh resolution microscopes against external vibrations.

During this period two internal reorganizations were carried out (1974 and 1980). In 1974, the institute was restructured to consist of three sections which were to combine their collaborative efforts: Physical Chemistry (directors: J. H. Block, H. Gerischer, K. Molière), Structure Research (directors: R. Hosemann, Kurt Ueberreiter), and Electron Microscopy (director: E. Ruska until 1974). H. Gerischer remained the chief institute director. In 1977 Elmar Zeitler was appointed Scientific Fellow and director at the institute as successor of Ernst Ruska.

After the retirement of R. Hosemann, K. Molière, and Kurt Ueberreiter in 1980 a second reorganization introduced a collegiate structure for the institute with stronger emphasis on surface and interface science. In November 1980 Alexander Bradshaw was appointed Scientific Fellow and director at the institute heading the Department of Surface Physics. Since 1976 he had built up his own group in the Department of Physical Chemistry, with emphasis on the spectroscopy of solid surfaces and on the study of chemisorbed molecules. In 1999 Bradshaw accepted the request to become chief director of the Institute for Plasma Physics of the MPG in Garching and Greifswald, and in 2002 his Department of Surface Physics was terminated.

In 1977, on the initiative of the Fritz-Haber Institute and the German Federal Institute of Standards (PTB) planning started for a synchrotron-radiation light source in Berlin. A company (BESSY) was founded in 1979 to build and operate the necessary electron storage ring. Members of the company included the Max-Planck Society, the Hahn-Meitner Institute, the Fraunhofer Society, and the German Electron Synchrotron (DESY) in Hamburg as well as four industrial companies. The Fritz-Haber Institute provided the Scientific Director and was also concerned with administration in the initial phase. Bradshaw was appointed Scientific Director of BESSY in 1981 and again in 1988 after the tragical death of his successor Ernst-Eckard Koch. Since the start of experimental activities at BESSY in 1982 the radiation source has been intensively used by various groups at the institute. The new storage ring BESSY II, starting to operate in 1999, plays also a prominent role in the research program of the institute.

In 1986 Gerhard Ertl succeeded Gerischer as director of the Department of Physical Chemistry and was appointed Scientific Fellow at the institute. His research interests focus on structure and chemical reactions at solid surfaces.

In 1986 Gerhard Ertl succeeded Gerischer as director of the Department of Physical Chemistry and was appointed Scientific Fellow at the institute. His research interests focus on structure and chemical reactions at solid surfaces. In 1986 Ernst Ruska was awarded the Nobel price for his scientific achievements in connection with the development of the electron microscopy

Shortly before the retirement of **Elmar Zeitler in 1995** **Robert Schloegl** was appointed Scientific Fellow of the institute. The Department of Electron Microscopy was closed and a new **Department of Inorganic Chemistry** was established. This department concentrates on heterogeneous reactions on inorganic surfaces. Oxidation reactions of carbons and metals are studied as well as a range of heterogeneous catalytic processes involving partial oxidation and dehydrogenation steps. The goal of this experimental research is to bridge the gap between surface physics and surface chemistry. To this end, a range of in-situ analytical techniques and synthetic efforts were established to create realistic model surfaces with defined catalytic functions. The tradition of electron microscopy has been continued with the installation of two new commercial high-resolution transmission electron microscopes in 1996.

After the unexpected death of Jochen Block in 1995, Hans-Joachim Freund became director of the Department of Surface Reactions and was appointed Scientific Fellow of the institute. The department was renamed into Department of Chemical Physics, its objectives being studies of adsorption and reaction on solids, in particular, on oxide surfaces.

In 2002 **Gerard Meijer** was appointed as a new director at the institute, and he installed the new Department of Molecular Physics. Respective renovations and rebuilding started in autumn 2002,

A Brief history of the Institute

- **No other institute in Kaiser-Wilhelm Society suffered like this institute.**
- **Fritz Haber resigned on his own in april 1933 to be officially relieved on 1st October 1933**
- **The Department heads Freundlich and Polanyi resigned and left Germany.**
- **His successor, the most likely candidate being James Franck**
- **After Haber's resignation Otto Hahn took over as director of the institute following Haber's request as well as a recommendation by Max Planck, the president of the KWG.**
- Gerhart Jander, formerly professor of inorganic chemistry at Göttingen, as temporary director. This was against the agreement with Haber and against the recommendation of the Kaiser-Wilhelm Society. The legally unjustified temporary solution was accepted by the Society only in the "firm expectation that the final choice of director would be made with the agreement of the Kaiser-Wilhelm Society".

- **Jander** notified all scientists in question who had not yet voluntarily resigned and the existing lines of research at the institute were abruptly terminated. While the 1933 yearbook of the institute still included 68 papers by 45 authors published in 1932, the year 1934 produced only 8 papers by 6 authors, all in the field of inorganic chemical analysis. Amongst the authors no name could be found from the time before 1933.
- Since the appointment of Jander by the Prussian Ministry for Science, Art, and Education and the Ministry for the Armed Forces was only temporary, Max Planck submitted nominations of other scientists as Haber's successors to the Ministry, naming **Karl Friedrich Bonhoeffer, Arnold Eucken** or **Max Volmer** as suitable candidates. This had, however, no consequences. Eventually, it became clear to the Ministry for the Armed Services, who took great interest in the institute, that Jander was no longer a suitable director for the projects assigned to the institute. Therefore, the minister agreed to the appointment of Peter **Adolf Thiessen** as director. Thiessen had already been installed by Jander as a Department Head at the institute and enjoyed the full trust of the political authorities.
- The Senate of the Kaiser-Wilhelm Society had no choice other than to agree to this appointment. Thiessen set up additional departments and gradually reinstated scientific work covering a broad spectrum of chemistry. Projects of technical and commercial significance acceptable to the authorities had always preference but he allowed the members of the institute considerable freedom to carry out basic research. P. A. Thiessen himself headed a Department of Colloid Chemistry. A new Department of Physical Chemistry was started by **Ernst Jenckel** where properties of glasses and polymers were investigated. In addition, there was a Department of Inorganic Chemistry led by **August Winkel**, a Department of Organic Chemistry under Arthur **Lüttringhaus,** a Department of Fine structure Research under Otto Kratzer and later a project team for macromolecule chemistry under **Kurt Ueberreiter**. **Bernhard Baule and Kurt Molière** were working at the institute as mathematician and theoretical physicist, respectively.

- After the outbreak of the Second World War (in September 1939) the institute was, for the second time, almost entirely directed to projects of military interest. Only few basic science investigations could by carried on. Here theoretical studies on Ray interference and electron diffraction by Kurt Molière deserve special mention, as do the investigations by Otto Kratky who developed X-ray small angle scattering. **In 1944 Iwan N. Stranski**, having worked as Professor of Physical Chemistry in Sofia until 1941 and later at the Technical University in Breslau, was appointed Scientific Fellow of the institute and performed pioneering studies on crystal growth and phase formation.
- Towards the end of the war some of the experimental and workshop equipment as well as the contents of the library had to be evacuated. The latter provided the basis for the Otto-Hahn Library in Göttingen, which is now located in the Max-Planck Institute for Biophysical Chemistry. The buildings of the institute, however, escaped extensive damage. Only the striking pointed roof of the main building fell victim to the bombing. After the occupation of Berlin by the Soviet army the equipment remaining in the institute was confiscated and transferred to the Soviet Union. This occurred before the American army had set up its Berlin sector in which the institute was located. Of all scientists only **Iwan N. Stranski, Kurt Molière, and Kurt Ueberreiter** remained in Berlin. Their courageous protection of the institute during this chaotic time deserves much praise. P. A. **Thiessen went to the Soviet Union. He returned to the German Democratic Republic (Deutsche Demokratische Republik, DDR**) in the mid 50's as a Fellow of the Academy of Sciences and became President of the DDR Research Council.

- The early years after the Second World War In the early post-war years the institute was supported by the Berlin City Council. However, scientific work was only barely possible. Robert Havemann, who had held a scholarship at the institute in 1932 and 1933, was appointed head of the institute by the City Council. In Hitler Germany time Havemann had played a key role in the antifascist group "European Union". He was caught by the Nazis, and in 1943 sentenced to death. The execution was postponed, and he was luckily freed from prison by the Soviet troops in 1945. I. N. Stranski, K. Molière and K. Ueberreiter resumed their work at the institute as best as possible considering the external conditions. Hartmut Kallmann, who had worked with Haber for many years before 1933, returned to the institute from his industrial refuge for a short time. In 1948, however, he accepted an offer to become Professor of Physics at the New York University.

•The districts within the U.S. occupation zone did not resume responsibility and financing of the institute until June 1947. At that time the institute received a grant for the "German Research Colleges of Berlin-Dahlem". This organization included the institute together with Otto Warburg's Institute for Cell Physiology and a group of several other Kaiser-Wilhelm Institutes. In January 1948 R. Havemann was charged with being an active member of the communist party, and by order of the American authorities he was dismissed as director of the institute, but was still retained as a Department Head. His department, however, was closed in the beginning of 1950, when he was accused of communist propaganda and banned from the institute. He subsequently moved to East Berlin, where he already had held a professorship for physical chemistry at the Humboldt university since 1947. In the spring of 1948 a department was set up in the institute for Karl Friedrich Bonhoeffer who was at the same time director of the Institute for Physical Chemistry at the Humboldt-University of East-Berlin. In December 1948 he was appointed director of the institute, but in 1949 he accepted the invitation of the newly founded Max-Planck Society to become director of the new Max-Planck Institute for Physical Chemistry in Göttingen. Nevertheless, he continued to lead the institute until March 31, 1951. He brought Ernst Ruska, the inventor of the electron microscope, to the institute as leader of a Department of Electron Microscopy. Ruska was to set up this new department (while still retaining his employment at Siemens) in order to encourage fundamental research and further development in the field of electron microscopy.

•In his Department of Physical Chemistry and Electrochemistry, Bonhoeffer attracted young scientists to work in new fields of research. **Georg Manecke** developed new ion and electron exchange type polymers, and produced the first immobilized enzymes, i. e. enzymes coupled to polymer matrices, which are now of great importance in biotechnology. Klaus J. Vetter built up a successful team in electrochemistry. He developed new methods for the analysis of the kinetics of electrochemical reactions and made an important contribution to the understanding of the resistance of metals to corrosion. In 1961 both **Manecke and Vetter moved to the Free University, as Professors of Organic Chemistry and Physical** Chemistry, respectively, but they still kept some institute laboratories as External Scientific Fellows of the institute. Apart from the department of the institute director there was a large department headed by **Iwan N. Stranski** who held also a position as Professor of Physical Chemistry at the Technical University of Berlin. His department focused on investigations concerning crystal structure, nucleation and crystal growth processes. **At a later stage, also studies on properties of zeolites and of catalytic processes in such microporous solids** were performed. In 1954 I. N. Stranski became Deputy Director of the institute. **Erwin W. Müller, the inventor of the field electron microscope, had been working as an assistant in Stranski's department since 1947. During this period he developed the field ion** microscope which could achieve extremely high resolution of atomic structures. In 1950 E. W. Müller was given his own department in the institute but in 1952 he took up an appointment in the USA. He remained connected with the institute as an External Scientific Fellow until his death in 1977.

- **Prof. Dr. Iwan Nicolá Stranski**

Director of the

Dept. of Physical Chemistry 1953 – 1967

The three main areas considered for Nobel prize for Gerhard Ertl are:

1.Hydrogen absorption on solids

2. Details of ammonia Synthesis

3.Oscillations in catalytic reactions

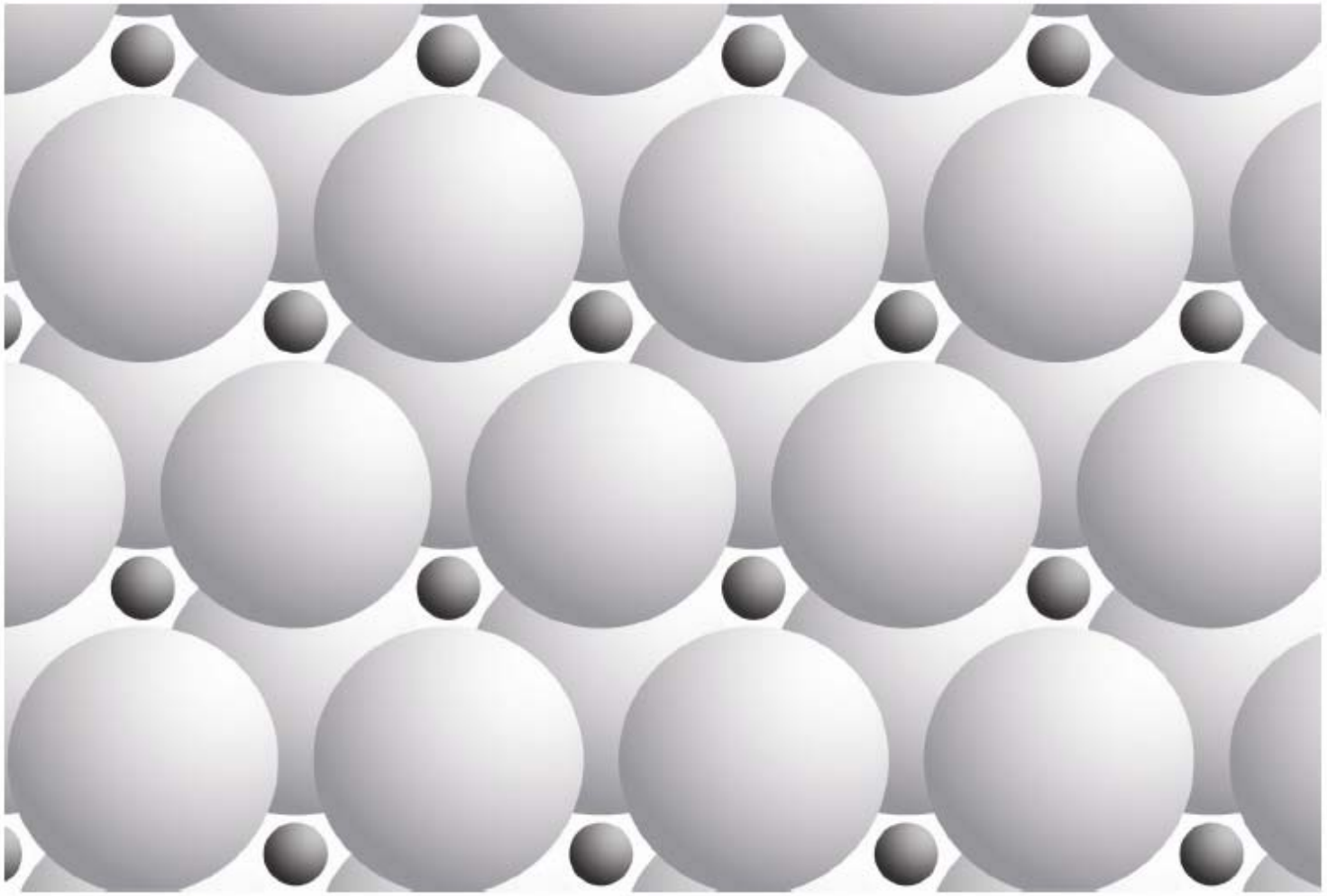
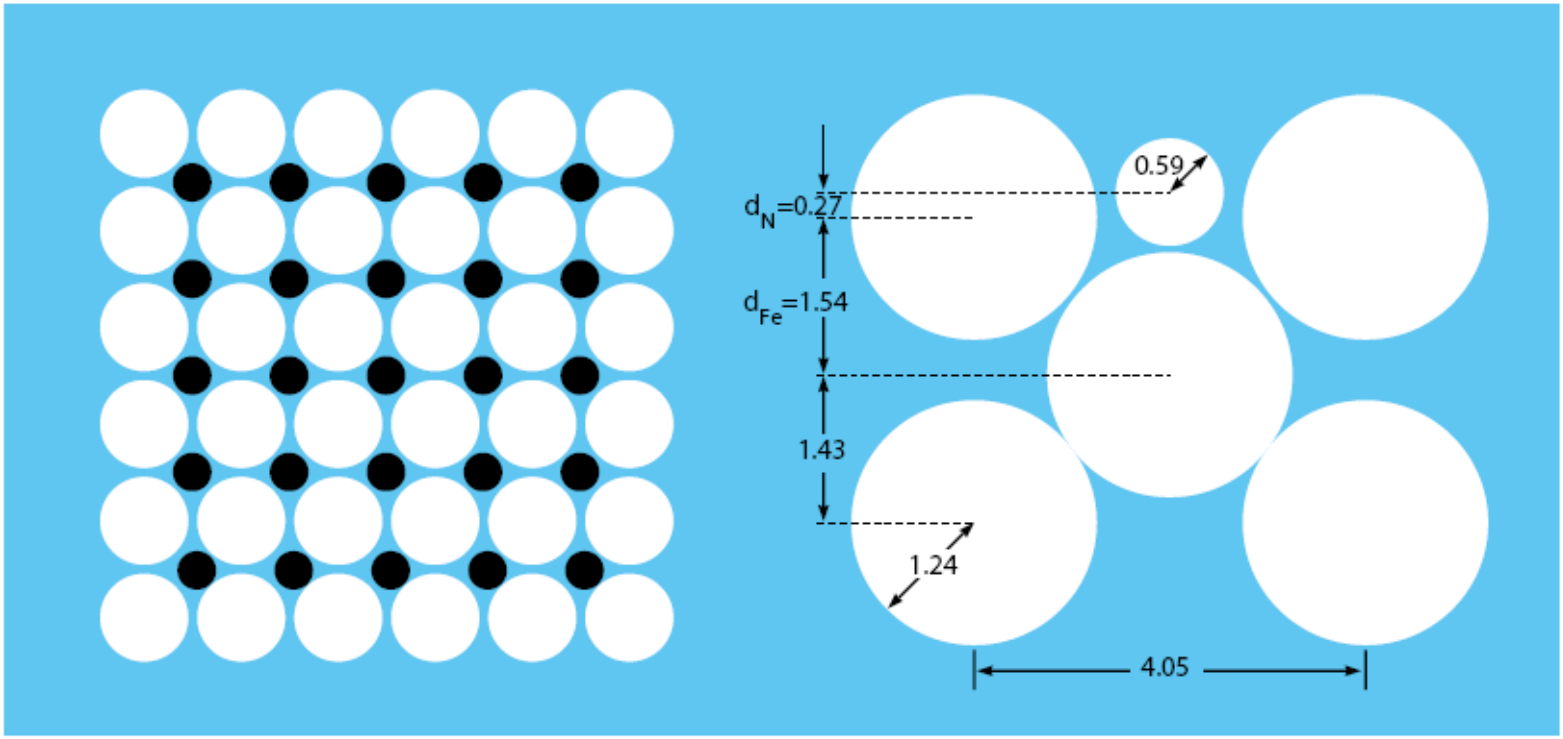


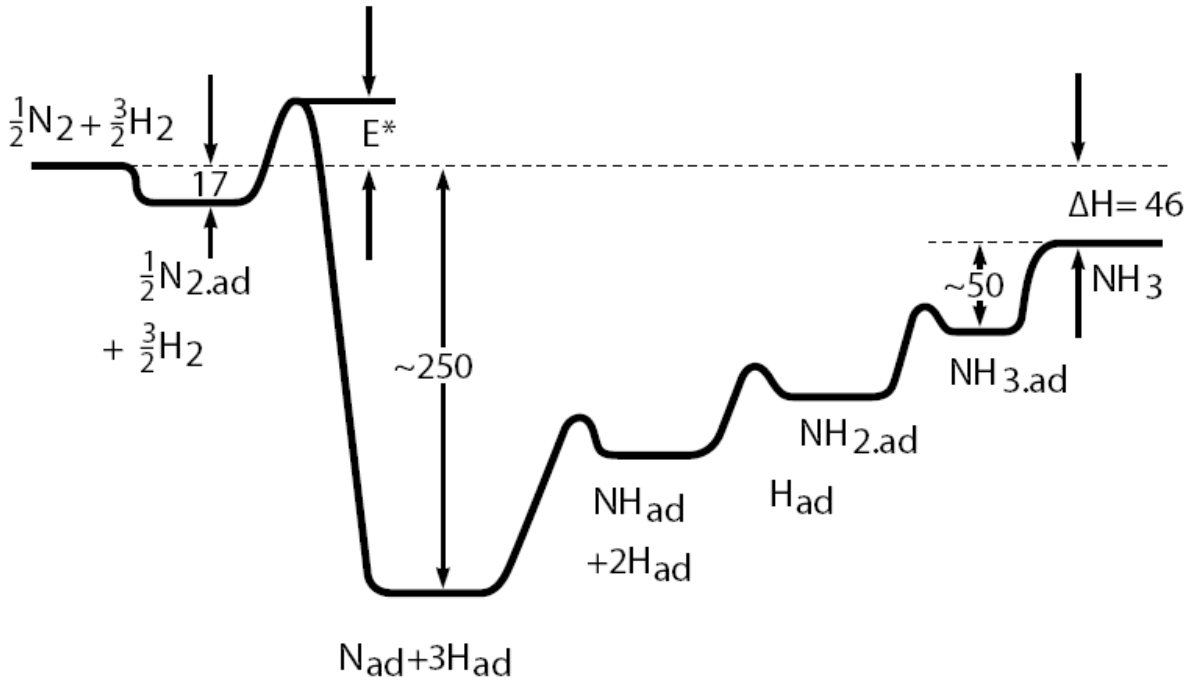
Illustration of how the hydrogen atoms, small spheres, are organized in a monolayer on a (111) platinum surface. (Adapted from Badescu et al. 2003)

combining experimental studies using LEED (for explanations of acronyms see end of reference list) with measurements of desorption and also using modeling Ertl was able to provide a quantitative description of how hydrogen is exposed on these metal surfaces (Conrad et al., 1974; Christmann et al. 1974; Christmann et al. 1976; Christmann et al. 1979). This was a highly relevant issue for the current discussion of catalytic mechanisms. In the studies of hydrogen adsorption Ertl not only gave a number of answers to questions that had been posed for a long time, but he also demonstrated how one could utilize the LEED method in combination with other experimental approaches. In order to answer the most relevant chemical questions it was clearly insufficient to concentrate on one method only. It is a feature of Ertl's approach to science that when new opportunities appeared he would revisit fundamental problems that he had analyzed previously. Thus his latest publication on the hydrogen adsorption on a metal surface concerns the vibrational spectrum (Badescu et al. 2002; Badescu et al. 2003). The figure illustrates the organization of a monolayer of hydrogen atoms on a Pt(111) surface.

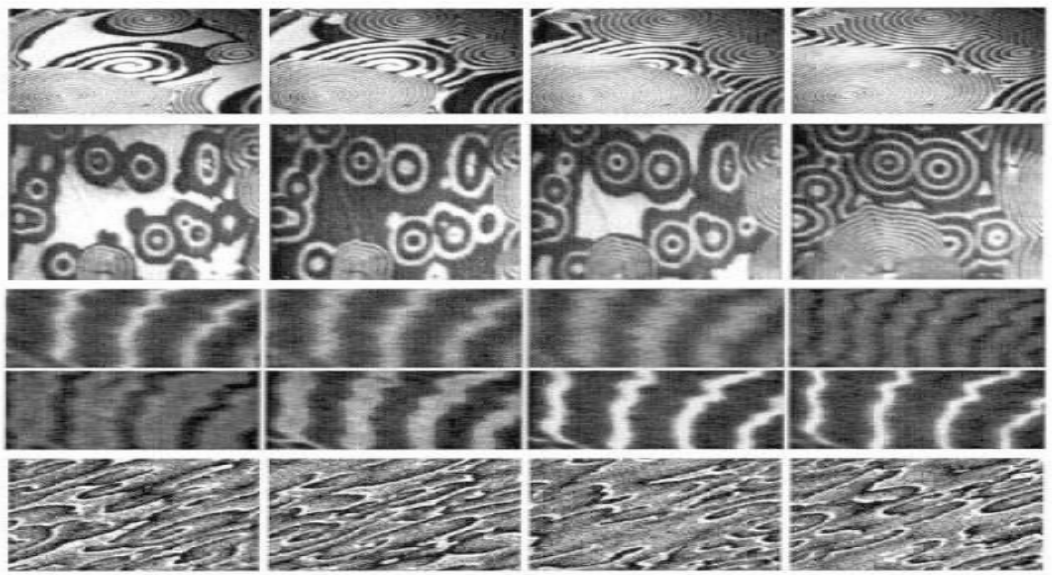


Structure of an overlayer of nitrogen atoms (small filled circles) on a (100) surface of iron (large open circles). Left: top view; right: side view. (Adapted from Imbihl et al. 1982)

Energy profile for ammonia synthesis



An energy diagram showing the progression of the reaction from the reactants N_2 and H_2 to the product NH_3. Energies are given in units of kJ/mol. (Adapted from Ertl 1983)



Spiral patterns

Target patterns

Standing waves

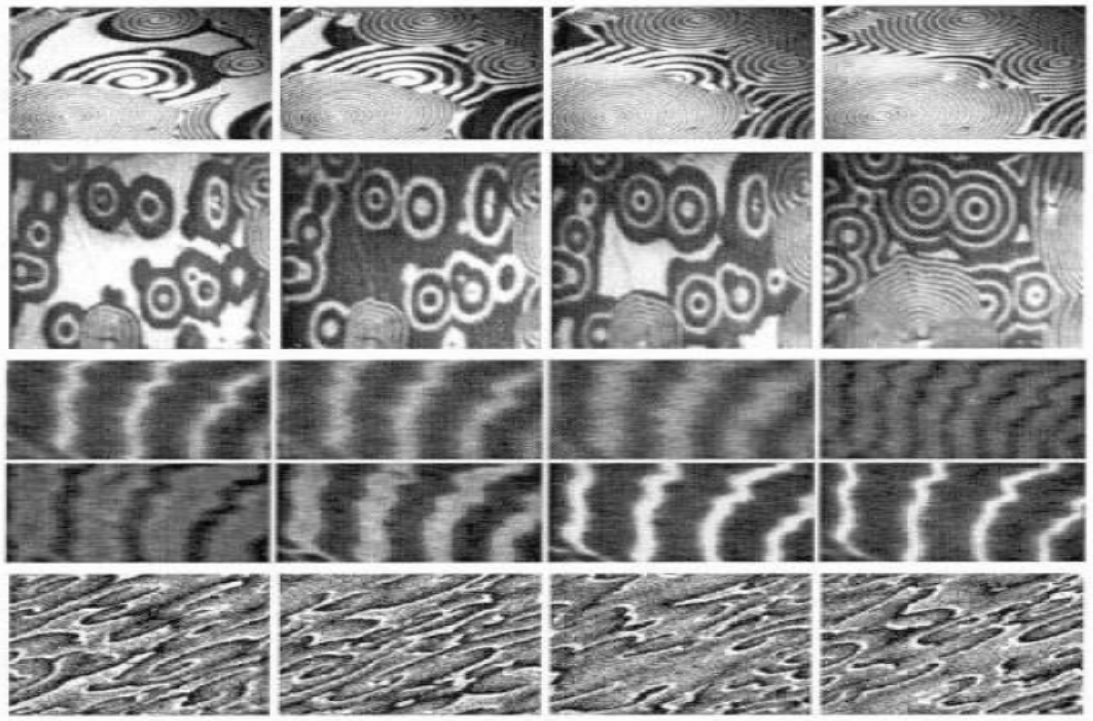
Chaos

Progression of time => => => =>=> => => =>

Platinum surface imaged by photoemission electron microscopy. Dark areas are rich in CO while light areas are O_2 rich. Note the oscillatory behavior of the domain extensions. Time scale ~10s, length scale ~0.1mm (The Surface Imaging Group, Dept. of Physical Chemistry, Fritz-Haber-Institute of the Max-Planck-Society, www.fhi-berlin.mpg.de/surfimag)

Through these studies Ertl has demonstrated that his methodology is applicable not only to systems where the kinetics are dominated by a single rate-limiting step as is the case in the Haber-Bosch process, but also to systems where non-linear dynamics prevail. His methodology sets a standard for how chemical processes on surfaces can be studied and elucidated.

Concluding remarks



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Through a series of imaginative studies (Behm et al,1983; Cox et al. 1985; Imbihl et al. 1985; Imbihl et al. 1986; Eiswirth et al 1989;Jakubith et al. 1990; Kim et al. 2001; Beta et al. 2004) Ertl could establish the microscopic causes of the observed non-linear behavior. Again, Ertl demonstrated how the full spectrum of methods of surface physics and surface chemistry could be combined to yield comprehensive understanding of important and complex catalytic processes. High pressure *in-situ* methods include work function measurements that can be used to study changes in adsorbate coverage, FTIR that gives information on adsorbate-surface interaction and X-ray diffraction that yields information on the state of the catalyst itself. These methods are generally much less precise than high vacuum techniques, but they yield invaluable corroborating information to help close the pressure gap. In the study of sensitive oscillatory reactions on surfaces, the energy input must be controlled and minimized, and this is a further constraint. The use of AES that proved such a powerful tool in the studies of the Haber-Bosch process is, for example, not feasible. Instead, low energy methods must be employed, such as LEED that directly monitors structural changes and PEEM that that monitors the local work function with high spatial resolution.

Concluding Remarks

Ertl has developed a general methodology that can be applied to the important problems in molecular surface science. He has applied the methodology to some of the most central previously unanswered questions concerning molecules on surfaces. The investigations have been carried out with the greatest elegance in the experimental approach. His work is characterized by the ambition to always use the method best suited to solve the problem at hand. Ertl is never satisfied with an isolated interesting observation. Instead the studies are brought to their logical conclusions. Through his accurate studies he has provided a firm basis for our thinking about molecular processes at surfaces.