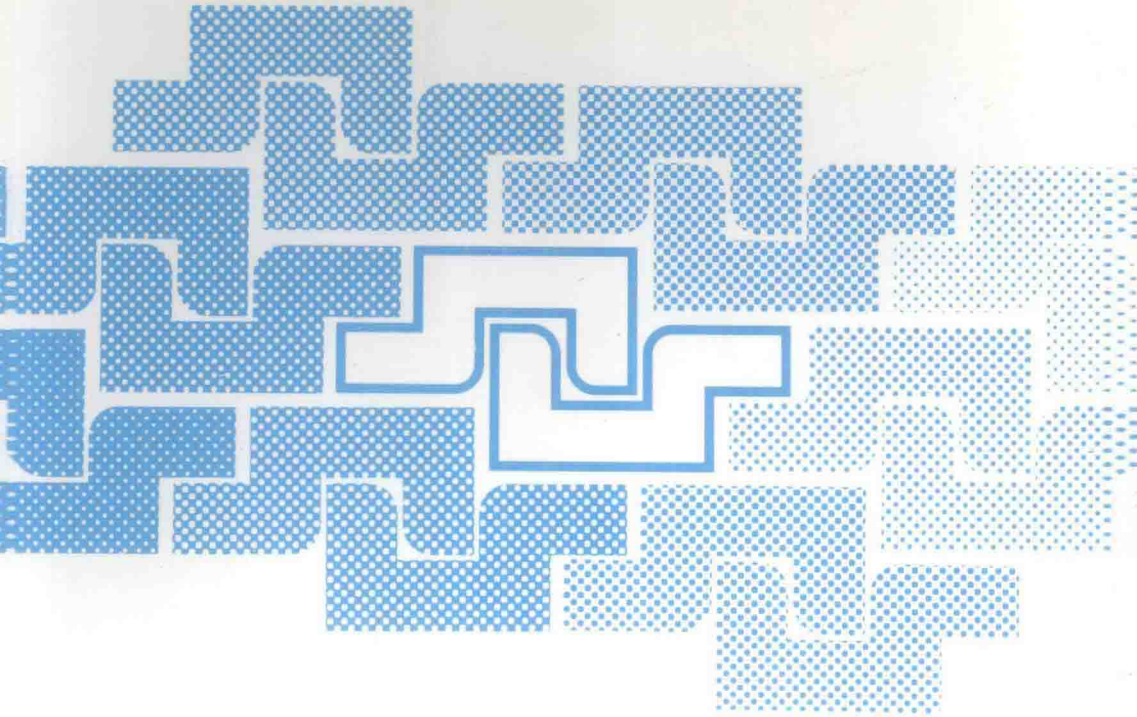

# Hydrogen Materials Science and Chemistry of Carbon Nanomaterials

Edited by

A. Nejat Veziroglu, Svetlana Yu. Zaginaichenko, Dmitry V. Schur, B. Baranowski, Anatoliy P. Shpak and Valeriy V. Skorokhod

II. Mathematics, Physics and Chemistry – Vol. 172

# Hydrogen Materials Science and Chemistry of Carbon Nanomaterials

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# Preface

The 2003 International Conference "Hydrogen Materials Science and Chemistry of Carbon Nanomaterials" (ICHMS'2003) was held in September 14-20, 2003 in the picturesque town Sudak (Crimea, Ukraine) known for its sea beaches. In the tradition of the earlier ICHMS conferences, this 8$^{th}$ ICHMS'2003 meeting served as an interdisciplinary forum for the presentation and discussion of the most recent research on transition to hydrogen-based energy systems, technologies for hydrogen production, storage, utilization, materials, energy and environmental problems. The aim of ICHMS'2003 was to provide an overview of the latest scientific results on research and development in the different topics cited above. The representatives from industry, public laboratories, universities and governmental agencies could meet, discuss and present the most recent advances in hydrogen concepts, processes and systems, to evaluate current progress in these areas of investigations and to identify promising research directions for the future.

The ICHMS'2003 was the conference, where a related new important topic of considerable current interest on fullerene-related materials as hydrogen storage was included into the conference program. This meeting covered synthesis, structure, properties and applications of diverse carbon materials ranging from nanotubes and fullerenes to carbon fiber composites and sorbents. Thus, the ICHMS'2003 conference was unique in bringing together hydrogen and carbon materials researchers and engineers from developed countries of Europe and America, new independent states of FSU and other countries for discussions in advanced materials development and applications.

The ICHMS'2003 format consisted of invited lectures, oral and poster contributions and also the conference representatives took part in the exhibition of new materials and equipment.
This book with ICHMS'2003 Proceedings brings together the research

papers that were presented. We hope that they will serve as both a useful reference and resource material for all the participants and for those whose interest in the subject matter may develop after the event.

Finally, this conference was generously supported by the Scientific and Environmental Affairs Division of NATO as an Advanced Research Conference within the Physical and Engineering Science and Technology Area of the NATO Science Programme. Their contribution is gratefully acknowledged and the Organizing and all ARW participants want to overflow with effusive thanks to NATO Committee for the financial support of our 8th ICHMS'2003 Conference and to **Mr. Jean Fournet**, Assistant Secretary General, Chairman of NATO Science Committee, and **Mr. Fausto Pedrazzini**, Programme Director, NATO Scientific Affairs Division, for the displayed mutual understanding and the comprehension of significance of problems under discussions at the ICHMS'2003 conference.

**T. Nejat Veziroglu**
**Svetlana Yu. Zaginaichenko**
**Dmitry V. Schur**
**Anatoliy P. Shpak**
**Valeriy V. Skorokhod**

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# FIRST PRESIDENT OF UKRAINE

**Dear conference participants and guests !**

Allow me to greet all of you at this remarkable place of the Earth.

With great satisfaction I want to establish the fact that by the end of XX century Ukraine become at last the reality for the whole world. At the attainment of its position on political arena our country remains nevertheless the unknown practically from the viewpoint of contribution to the world science in spite of its vast scientific potential.

Virtually nothing strange is in that because Ukrainian scientists had no way to declare themselves over a long period of time for the well-known for all of us reasons.

The time has come to show for world community our scientific achievements and by every new fact and experiment, by every result to demonstrate ourselves and all world that Ukrainian science exists really.

The science in civilized world is cosmopolitical by its nature. And your ICHMS'2003 Conference confirms this generally known fact. The co-operation of scientists from different world countries has met here and chemists, physicists, production engineers and others are deeply involved in studying of such global problem as alternative power sources. All of you gather together in order to inform one another about new results, to discuss problems, to find the new approaches, to see something in smb's eyes and above all to create new knowledge in archimportant field of science as power engineering.

The power engineering is the most significant element of civilization life without which it is impossible to imagine both the present and the future of mankind. Everything that we use now in order to live, drink, eat, work, move in time and space is bound up in any case with energy. All's that exist owing to the realization of scientific knowledge gained tens and hundreds years ago is not enough to look ahead with confidence. The gas, oil and especially bituminous coal are inexhaustible power sources. The power engineering of the future is first of all the new ideas and ways of solar energy transformation and then the materials allowing the realization of ideas. All over the world thousands of peoples work in this area. Therefore the co-operation of scientists is important for solution of global problems for all mankind. Having such opportunity I want to wish all of you that these several days of ICHMS'2003 Conference in such beautiful site of Crimea will become useful for you and the new acquaintances and contacts will make the beginning for new programs and projects.

**First President of Ukraine**
**L.M. Kravchuk**

international association for hydrogen energy
POST OFFICE BOX 248266 • CORAL GABLES • FLORIDA 33124 • USA

# WELCOME TO THE PARTICIPANTS OF ICHMS'2003

At The Hydrogen Economy Miami Energy (THEME) Conference in March 1974, a handful of scientists from around the world proposed the Hydrogen Economy. Since then, over the first quarter of a century, the foundations for the Hydrogen Energy System have been established through the hard and ingenious work of researchers from many countries.

Conversion to the Hydrogen Energy System began early this century. The Toyota and Honda companies have started leasing hydrogen fuel cell cars in Los Angeles, Tokyo and Yokohama. General Motors is planning to test a hydrogen-fueled delivery van in the streets of Tokyo. Daimler-Chrysler has begun manufacturing hydrogen buses. Although, at the moment, they are more expensive than diesel buses, many large cities are buying these hydrogen-fueled buses in order to fight pollution in the city centers. The Siemens-Westinghouse Company is marketing hydrogen fuel cell power plants for electric utilities. Hydrogen hydride electric batteries have already been commercialized. The Airbus Company is working on hydrogen-fueled air transport.

Japan has earmarked four billion dollars in order to acquire all the hydrogen energy technologies by the year 2020. Europe has initiated a vigorous hydrogen energy program. They are going to spend five billion Euros during the next five years on Hydrogen Energy R & D. President Bush of the United States, in his State of the Union address, February 2003, referred to hydrogen as the 'freedom fuel,' which will free the world from dependence on petroleum. The U.S. Government has earmarked 1.7 billion dollars for commercializing hydrogen fuel cell vehicles, and 1.2 billion dollars for $CO_2$ free hydrogen production from coal.

International conferences, such as the ICHMS'2003, will help speed up this transformation. At the conference, recent research findings on hydrogen materials science and metal hydrides chemistry will be presented and discussed. The chemistry of metal hydrides and hydrogen materials science will play an important role in hastening the conversion to the Hydrogen Energy System. The research endeavors of the scientists and engineers participating in this conference will make significant contributions to facilitate this milestone conversion.

I take this opportunity to congratulate the organizers of this important series of International Conferences on Hydrogen Materials Science and Chemistry of Carbon Nanomaterials, and wish all of the participants a very productive conference and pleasant days in the beautiful Crimea.

**T. Nejat Veziroglu**
**Honorary Chairman, ICHMS'2003**
**President, International Association for Hydrogen Energy**

**NATIONAL ACADEMY**

**OF SCIENCE OF UKRAINE**

*54 Volodymyrs'ka str,. Kyiv, 01601 Ukraine,*
*Tel: 380-44-226-2347, Fax: 380-44-228-5522*

**Dear colleagues!**
**Delegates of ICHMS'2003!**

Allow me to greet the ICHMS'2003 Conference on behalf of National Academy of Sciences of Ukraine.

The conference subjects testify about the scale and importance of problems to be considered at this scientific forum. The carbon nanotubes as well as compositions based on hydrideforming alloys and carbon nanostructures are perspective materials with high hydrogen capacity. These materials and their properties inspire hydrogen scientists with certain optimism because application of carbon nanomaterials in energetics and automotive transport helps in handling the important problems and first of all energy and ecological problems. The materials science subject will receive the attention it deserves, the decision of these questions requires the wide application of energetic installations based on fuel cells both for large-scale generation of energy and for autonomous power supply of separate objects and transport.

I do not want to minimize the importance of a valuable contribution of all world association, but I should like to remind that Ukrainian Academy of Sciences does not stand aside of investigations in this field.

At present time much attention is being given within the framework of Academy to the study and development both of hydrideforming materials and of various carbon nanostructures. Leading Institutes of National Academy of Sciences of Ukraine make the considerable contribution for solving the problems of hydrogen materials science and chemistry of carbon nanomaterials.

Thus, it is no coincidence that Ukraine become the country where scientists from many countries come for exchange of experience and knowledge in this prospective science field for the second tens years.

Take this opportunity I want to wish You the successful scientific work and further creative initiative. Let such conferences, as ICHMS'2003, unite scientists eliminating the geographical and language barriers.

I wish You the fruitful scientific work, every success and the fine rest in the bright Crimean sun.

**B.E. Paton**
**President**
**of National Academy of Sciences of Ukraine**

# Russian Academy of Science

Российская Академия Наук

The twenty-first century will be known as the century during which the Hydrogen Energy System replaces the present fossil fuels system. Hydrogen is going to be the permanent answer to the twin global problems: (1) the rapid depletion of fossil fuels, and (2) the environmental problems caused by their utilization, such as the greenhouse effect, climate change, acid rains, ozone layer depletion, pollution and oil spills.

Hydrogen is already making inroads into the fossil fuel realm in every direction. Especially over the past two years, there has been an increase in activities. Siemens-Westinghouse announced that they will have a 1 MW $H_2$ power plant available for sale soon, having a 70% efficiency. There are hydrogen fueled bus demonstration projects in several cities of the world. A $H_2$ fueled Mercedes bus will be on the market in two years' time. All of the major car companies have announced that they will offer $H_2$ fueled cars to the public by the year 2004. Hydrogen hydride electric batteries are already available for lap-top computers and electric cars. The Airbus Company is developing a $H_2$ fueled air transport. The United States and Japan are working on $H_2$ fueled hypersonic passenger planes. The Shell Oil company has established a Hydrogen Division. No doubt the other petroleum companies will follow suit.

In the tradition of the earlier conferences, the 8th ICHMS'2003 Conference is providing an international forum for the presentation and discussion of the latest R&D results in field of hydrogen materials science and carbon nanomaterials, covering hydrogen production, storage, distribution, i.e. engines, fuel cells, catalytic combustion, hydride applications, aerospace applications, hydrogen fuelled appliances, environmental impact and economies. I am sure that proceedings of this conference will bring together research papers and they will serve as a useful reference and resource material for all the participants.

On behalf of Russian Academy of Sciences I would like to extend my deepest appreciation to all delegates and participants who come from many different countries to make this conference a success.

**Academician**
**Yu.A. Ossipyan**

HOLDER OF NATIONS FRIENDSHIP'S ORDER

**ACADEMY OF SCENCES,**
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**Dear colleagues!**

I am honoured to welcome all of you on the behalf of the Presidium of the Academy of Sciences of the Republic of Tajikistan.

Every year hydrogen power engineering takes more and more important role in the life of society and in the life of each state. This problem is especially actual for Tajikistan, which has not gas and oil resources.

Investigations in the filed of power-intensive substances and hydride chemistry are being successfully carried out in Tajikistan since 1968. Needs of promptly developing new techniques and technology for substances with such properties considerably promoted the development of a number of new fields of chemistry, including hydrogen materials science and chemistry of carbon nanomaterials.

Creation of the ecologically clean transport by the way of application of different non-traditional fuels, including hydrogen, is the general direction of air basin protection.

Hydrogen is one of the perspective fuels for transport. Many properties of hydrogen give him the first place in future expectations. The last stage of ecologically safe hydrogen cycle is water. Consequently, the source f hydrogen on the Earth is practically inexhaustible.

Today's hydrogen power engineering is very broad notion.

It is pleasant that we discuss many aspects of hydrogen and carbon chemistry.

Our conference is traditional one owing to the great efforts of Organizing Committee and I would like to thank them heartily for their great job on conference organization.

I hope that the ICHMS'2003 Conference will allow us to work fruitfully, to learn a lot of useful information and will give the opportunity to establish joint projects.

I heartily greet the participants of the Conference and wish them enjoyable and fruitful time in Crimea.

**U.M. Mirsaidov**

**President**
**of Academy of Sciences**
**of the Republic of Tajikistan**
**Chairman of the Commission**
**of Majlisi Milli (the Parliament)**
**of the Republic of Tajikistan**

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**Dear participants of ICHMS'2003 !**

The Science and Technology Center in Ukraine (STCU) welcome in my person the participants of the VIII$^{th}$ International Conference "Hydrogen Materials Science and Chemistry of Carbon Nanomaterials".

I am glad that a lot of world scientists and investigators want to take part in this conference in Ukraine and present the papers in many aspects of hydrogen in metals, alloys, carbon nanomaterials from fundamental to applications. Hydrogen sorbing properties of newly discovered carbon nanostructural materials inspire hydrogen scientists with certain optimism. In the development of all new energy options, hydrogen necessarily will play an important role because of its ability to supplement any energy stream and to be applied to any load. Given the significance of energy in the environmental problems of our world, it is urgently necessary that the leaders in civic and industrial societies have a more thorough understanding and appreciation of the existing states of energy systems and their related technologies.

The search of alternative power sources is the most actual theme of today. I hope that your work will accelerate the substitution of existing power systems which use fossilized fuels for inexhaustible and ecologically clear Hydrogen Systems. The creation and development of such systems will give an opportunity to harmonize the pragmatic human's treatment of nature.

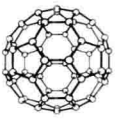
I very hope that Ukrainian science, as well as in the developed countries, in spite of all difficulties and problems, will have its future and will develop including such an important and considerable fields as hydrogen materials science and carbon nanomaterials.

STCU provide financial support to carry out of projects and to hold a number of conferences devoted to consideration of environmental and energy problems, among which is ICHMS conference.

On behalf of STCU let me wish you the fruitful work and every success in discussing vital important problems for all humanity.

**B.A. Atamanenko**
**Senior Deputy of**
**Executive Director of STCU**


# VIII INTERNATIONAL CONFERENCE
## *"Hydrogen Materials Science & Chemistry of Carbon Nanomaterials"*



Sudak, Crimea, UKRAINE, September 14 – 20, 2003

## Dear Colleagues, guests, ladies and gentlemen!

The ICHMS'2003 Organizing Committee is glad to welcome you in Sudak and we consider it an honour that a lot of outstanding scientists and investigators from every corner of the world want to take part in this conference in Crimea. Our best wishes to all participants and visitors of ICHMS'2003.

We are especially obliged to our sponsors, as NATO Science Committee, Science and Technology Center in Ukraine, Columbian Chemicals Company and others that provide us the means to carry out this representative forum.

Two years have passed since our last meeting in Alushta. Certainly, this is a short space of time but we are filled with expectation of new discoveries and excellent results. We are sure that new substantial scientific results will be presented here and they will permit us to extend our's knowledge mainly in the strategically important field for the future, as hydrogen energy and in directly connected with it fields of hydrogen materials science and nanostructural carbon.

Our conference demonstrates the present-day state of affairs in 4 conference topics, which are perspective and quickly developed directions of modern materials science with a view to stimulate the new ideas, to support and ensure their realization.

The fact that scientists of various schools, directions and tendencies get together in Crimea two tens of years will favour the active discussions, fruitful contacts and new knowledge gaining. We hope that both the beauty of Crimean nature and fine weather will inspire scientists on the active work and deserved rest after ICHMS'2003.

We very hope to hear the qualitatively new results that will permit us to move from the pure scientific investigations to their wide practical implementation. This is not only our wish but also our scientific duty, result of work, which many of us devote all their efforts.

We would like to wish all scientists success and good luck.

**Organizing Committee of ICHMS'2003**

**A.P. Shpak, V.V. Skorokhod,**

**B.P. Tarasov, S.Yu. Zaginaichenko,**

**D.V. Schur, Yu.M. Shulga**

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