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Fine Particles Science and Technology

From Micro to Nanoparticles

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PREFACE

The NATO Advanced Research Workshop on *Fine Particles Science and Technology. From Micro to Nanoparticles* was held at the Hotel Villa del Mare, Acquafredda di Maratea, Italy, on July 15-21, 1995. It was extremely stimulating, with the participation of 56 speakers and 40 researchers, including world-wide leading scientists in the field from academia, research institutes and industries.

The so-called monodisperse microparticle originally attracted the interest of researchers essentially for quantitative interpretation of surface interactions as a function of morphology and size. In the recent years significant progress has been made in the preparation of a large number of inorganic colloids consisting of particles of different chemical composition, shape and modal size, especially by precipitation. These materials have then been used in attempts to elucidate some crucial aspects of surface science such as heterocoagulation, particle adhesion, corrosion to name a few.

Presently, the importance of well-defined fine particles has been recognized in numerous applications, as ceramics, catalysis, pigments, recording materials, medical diagnostic and many others. For example, the role of fine particles in various ceramic applications has become evident since the quality and reproducibility can be more readily achieved by starting with a well-defined powder. Processing (e.g. compaction, sintering, etc.) can in many cases be done more efficiently and at a lower temperature if uniform particles are used. Different properties of matter will be needed when dealing with electro-optical, capacitor, piezoelectric, magnetic composite, superconducting or other ceramic materials. Similar aspects are present in the request of pigments and inks for high-speed printing and the diagnostic and novel disease treatments in medicine.

Semiconductor particles in the nanometer size have also been prepared and investigated in the last decade. Surface boundary processes such as photocatalytic reactions on semiconductors are not largely understood and nanometer particles can be used to elucidate these mechanisms. The

particles are so small that the colloidal solutions are completely transparent, so stationary and time-resolved optical spectroscopy can be employed to study the reaction processes. The use of colloidal particles both in solution and in thin layers for solar energy conversion, synthesis of organic compounds and destruction of contaminants have attracted large interest.

An important aspect is the influence of the particle dimension and surface properties on the energies of the electronic levels and on the reactivity and kinetics of the charge carriers. In the range of nanometer size, a gradual transition from solid state to molecular structure occurs as the size decrease. Consequently, a splitting of the energy bands into quantized levels occurs. Particles that exhibit this phenomenon are called "Q-particles". The optical, electronic and catalytic properties of this quantized material drastically differ from those of the corresponding macrocrystalline substances or micrometer particles. Q-particles of many materials have been recently prepared in form of colloidal solutions or embedded in porous matrices and are stable over a long period of time. In sandwich colloids, in which Q-particles of different materials are coupled as well as in porous semiconductor electrodes containing Q-particles in the pores, very efficient primary charge separation is observed. Enhanced photocatalytic activity and electrodes with high photocurrents can be achieved.

The purposes of the workshop were to bring together two communities that are traditionally isolated, the colloidal chemistry and the nanoparticles, quantum-size effect, community and to cover issues ranging from very fundamental physics and chemistry to technologically applied problems.

Five intensive days were planned for this NATO ARW covering the major areas of interest including: i) the understanding of the formation mechanism of uniform fine particles and the search of new processes, besides precipitation, for the generation of well-defined colloids; ii) the elucidation of the formation mechanism of fine particles by precipitation (actually the most used technique) which requires the knowledge of the relationship between the complex chemistry of solutions in which the solid is formed, and the composition, structure and other characteristics of the resulting products; iii) the sequence of events leading to the formation of monodisperse colloids.

Significant fundamental advances related to nanoparticles were presented at the workshop, and many open questions have been highlighted. Among these issues are: i) factors determining the rate of

electron transfer from solution or adsorbed species to the particles or among the particles themselves. Data were presented showing that the reorganization energy for electron transfer is mostly due to the reorganization of the medium, implying very small reorganization energy in the solid; ii) strategies to induce new crystallographic structures in nanoparticles; iii) spectroscopic properties of nanoparticles. Size dependent dielectric function could account for same observation in metallic clusters and small particles.

It was reported that the majority of uniform particles are internally composite (i.e. built of much smaller sub-units). At present, it is not understood why a huge number of primary particles can aggregate to much larger identical colloids. This evidence naturally leads to the much discussed possibility that some of the quantum size properties should be retained in the larger particles. It turns out that even the frontier systems of nanoparticles are fast moving toward possible applications.

At the interface between micro and nanoparticles is the growth mechanism in constrained systems (e.g. inverted micelles, cavities of clays or zeolites, Langmuir-Blodgett films and similar microreactors). Observations were presented that the microreactor does control the growth and limits the size of the resultant particles. However, the particles often grow to sizes much larger than the ones dictated by the size of the microenvironment.

In the book the following topics: microparticles, nanoparticles, applications to materials preparation, synthesis, and properties, applications to environment and other areas are sequentially presented. The hope is that this book will stimulate the research in the fundamental and applied aspects in the micro to nanometer sized particles.

I would like to express here my gratitude to the co-director of the NATO ARW, Prof. Jerzy Szczypa, who contributed considerably to the success of the workshop. Furthermore, I would also like to express my sincere tanks to the members of the Scientific Advisory Committee, who helped in the difficult task of selecting the topics and the lecturers. My special tanks must also be addressed to the Local Organizing Committee, who contribute with enthusiasm to the success of the meeting.

The workshop would not have been the same without the dedicated help of the staff of the Hotel Villa del Mare, to whom we owe the creation of a very warm and pleasant atmosphere, conducive to scientific and social interactions among the participants.

Finally, I wish to thank the NATO Scientific Affairs Division who supported financially this Conference. As well, I would also like to gratefully acknowledge the financial contribution of Center for Advanced Materials Processing (Potsdam, USA), Italian National Research Council (CNR, Italy), IACIS, and Regione Basilicata.

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