

Catalysis for energy*

New findings and developments in the science and technology of catalysis can provide new methodology to energy industry, explore new products and new processes in fuel production and other energy-related areas such as fuel cells, utilization of biomass and hydrogen energy. To take stock of the major challenges and evolve future strategies for research and development in the usage of catalysis for energy production, the Catalysis Society of India organized a national workshop at Varanasi. The event was attended by more than a hundred participants and it spanned research themes such as upgradation of petroleum feed stocks, biomass conversion, coal hydrogenation and gasification, solar and hydrogen energy and natural gas processing.

Inaugurating the workshop M. M. Sharma (University Institute of Chemical Technology, Mumbai) spoke about the importance of catalysis in the refining industry, energy production, etc. He also referred to several challenges that lie ahead such as optimization of Fischer–Tropsch technology for better selectivity, catalytic combustion to increase combustion efficiency, electro-catalysis for fuel cell applications and conversion of methane for energy production. On this occasion, the Principal N. N. Godbole Memorial Lecture–2006 was delivered by M. S. Ananth (IIT, Chennai), who spoke about the engineering aspect of salt effects in solution with mechanistic details.

The first keynote speaker B. Viswanathan (IIT, Chennai) outlined various possibilities and challenges in the production and storage of hydrogen. He discussed the limitations in commercializing the technology of photo-electrochemical splitting of water and presented possible alternate sources and routes for hydrogen generation. He also examined the current status and the way out of the current tangle with respect to the choice of materials for hydrogen storage. In another talk,

Haridwar Singh (Armament Research and Development Establishment, Pune) provided an overview of different types of propellants such as cryogenic, liquid, solid and hybrid propellants for propulsion of missiles and space vehicles. The lecture addressed the chemistry and working mechanism of homogeneous and heterogeneous catalysed solid propellants. These propellants offer numerous advantages over conventional ones. He felt the need for initiating bigger R&D projects in a tropical country like India where rocket motors are used at extreme temperature conditions.

In another lecture, a journey into the amazing world of nano-science and its relation with catalysis was provided by S. Narayanan (Indian Institute of Chemical Technology (IICT), Hyderabad) who explained the significance of particle size factor in understanding catalytic phenomena. The electronic properties of nanoparticles, important in any catalytic process, can be tuned by adjusting the particle size which could form the basis of catalysts with enhanced activity and selectivity. R. P. Verma (Indian Oil Corporation Limited, Faridabad) gave an overview of various R&D efforts towards indigenous development of petroleum refining catalysts. Explaining the role of catalysts in national economy he presented several case studies in major secondary refining processes such as hydro-processing, isomerization and fluid catalytic cracking while describing the approach of his own organization in development and commercialization of these catalysts.

The first plenary lecture by M. Lakshmi Kantam (IICT, Hyderabad) dealt with recent progress in the synthesis of novel materials for energy-efficient organic transformations. She showed how reactive nano-crystalline metal oxides such as MgO, ZnO and CuO can be utilized as efficient heterogeneous catalysts in the synthesis of chiral epoxy ketones via Claisen–Schmidt condensation asymmetric epoxidation reactions as well as in the asymmetric Henry and Michael reactions. S. N. Mukhopadhyay (IIT, Delhi) spoke on the use of newer enzymes and cellular catalytic systems for value added materials and energy production. He informed

that specific features of these systems can be utilized in production of hydrolysed protein-based biodegradable polymers using tannery waste. Photo-catalysis is a cost-effective technology where sunlight can be utilized as a sustainable energy source for hydrogen production. R. P. Viswanath (IIT, Chennai) provided an overview of preparation, characterization and photo-catalytic activity of cadmium sulphide nano-particles in various shapes like nano-rods, porous powders and nanotubes. A. Datta [Indian Institute of Petroleum (IIP), Dehra Dun] briefly described the role of surface science and application of elegant surface-sensitive techniques such as X-ray photoelectron spectroscopy, low energy electron diffraction, high resolution electron energy loss spectroscopy along with scanning, tunneling and atomic force microscopy in developing and monitoring activity of catalysts. The technology for catalytic conversion of natural gas to fuels and energy was the subject matter of two presentations. While A. V. Ramaswamy (University of Pune, Pune) addressed the problems and solutions of converting natural gas to synthesis gas and then to liquid hydrocarbons through Fischer–Tropsch catalysis, S. C. Roy [Central Fuel Research Institute (CFRI), Dhanbad] presented a state-of-the-art status and feasibility report of this technology in the Indian context. L. D. Sharma (IIP) reviewed the current status and emerging trends of reforming technology in petroleum industry. This is one of the important secondary refining processes to improve the quality of motor gasoline along with production of aromatics, high purity hydrogen and LPG.

Fuel cells in their assembly require hydrogen-rich gas stream at the anode, as fuel, which should be free of CO. Presence of CO deteriorates the Pt-based anodic catalyst with time and, therefore, CO has to be preferentially oxidized to CO₂ with minimum loss of H₂ in the gas stream. Two talks were devoted on this aspect. Rajiv Kumar (NCL, Pune) explored the plausibility of using nano-gold catalysts supported on reducible and non-reducible oxides for preferential oxidation of CO in H₂-rich reformats whereas K. M. Parida

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(Regional Research Laboratory, Bhubaneswar) presented results of his experiments on the effect of sulphate ion on the catalytic activity of gold catalyst promoted with titania for CO oxidation. In another lecture, V. Durga Kumari (IICT) talked about the results on the preparation, characterization and evaluation of nano Cu/ZnO/Al₂O₃ composites for steam reforming of methanol for fuel cell applications. In this study copper nano-particles were obtained using surfactant assisted co-precipitation method.

Harnessing hydrogen is critically dependent on its storage. The storage, cutting across the production, distribution, safety and applications, is considered to be crucial for bringing in hydrogen economy. O. N. Srivastava (BHU) showed applicability of complex sodium alanate (NaAlH₄) and carbon nano-tube-based materials as promising candidates for their high hydrogen storage capacity. G. V. S. Sastry (BHU) spoke about applicability of quasi-crystalline materials as catalysts. Comparing the catalytic behaviour of these materials with their crystalline counterparts, he presented detailed results on systems consisting of Al-Pd and Al-Ni-Co and showed that quasi-crystalline catalysts are found to have enhanced activity and lower reaction temperature.

The contributory papers covered diverse areas. G. Ganga Rao (IIT, Chennai) discussed important aspects of ceria-based materials and their application as catalysts, catalytic supports, solid state ionic conductors and as electrolytes and anodic materials for low temperature solid oxide fuel cells. In another paper on this subject, B. M. Reddy *et al.* (IICT) reported the synthesis and characterization of several nano-sized ceria-based oxide catalysts having composition Ce_xZr_{1-x}O₂ for their possible applications in removal of soot from diesel engine exhaust. Shailendra Tripathi (IIP) while highlighting the importance of gas-to-liquid technology in the wake of rising crude oil prices, discussed the results of several highly active Fischer-Tropsch catalysts (Co/Al₂O₃ promoted with Pt) for conversion of synthesis gas to liquid fuels. V. Siva Kumar (IICT) described a novel approach for the synthesis of methanol over Cu-ZnO-Al₂O₃ catalyst with and without promoter using cyclohexanol as the source of hy-

drogen. P. Siva Sankar Reddy (IICT) had studied the direct decomposition of NO (auto-exhaust) over Pd-La bimetallic catalysts supported on alumina.

With regard to the application of mesoporous materials and modified zeolites as catalysts, four presentations were made from NCL, Pune. The activity of TiO₂-supported mesoporous alumina for photo-degradation of methylene blue was discussed by S. V. Awate. Use of silico-aluminophosphate (SAPO-35) molecular sieve in selective conversion of methanol to olefin was presented by N Venkatathri. Application of commercially available synthetic zeolites with mordenite and faujasite structures in degradation of plastic waste was shown by V. R. Chumbale, whereas experimental results on the synthesis and characterization of novel mesoporous carbon was presented by P. Karandikar. These carbons have high surface area, large pore volume and chemical inertness which make them potential candidates for their use as catalytic supports and capacitors for energy storage. S. Navaladian (IIT, Chennai) reported the feasibility of carbon supported Pt-Au nano-wires as anodic material for use in direct methanol fuel cell. Modifications in the electronic structure of TiO₂ by doping it with N atom for enhanced photo-catalytic activity was discussed by M. Sathish (IIT, Chennai). Data on the synthesis and characterization of platinum catalysts alloyed with Cr and Co for use in polymer electrolyte fuel cell were presented by N. Lakshmi (Centre for Fuel Cell Technology, Chennai) who showed that catalyst based on Pt₃Cr can improve the performance and reduce the overall cost of technology. L. Dixit (IIP) explained the atomic level meaning of acid functions of zeolites and their role in catalysis. In another presentation, S. K. Roy (CFRI) gave an insight into the oxidative coupling of methane to C₂ hydrocarbons over aerogel catalysts such as La₂O₃/MgO, La₂O₃/MgO-CaO and La₂O₃/MgO-Al₂O₃/NiO.

The work by V. Sevavathi (Chennai Petroleum Corporation Limited, Chennai) was aimed at understanding the mechanism of desulphurization pathways for various refractory sulphur compounds present in the diesel fuel. N. Nagaraju (St. Joseph's College, Bangalore) discussed the catalytic activity of aluminium

hydroxide-supported molybdenum, chromium and vanadium oxo species in the conversion of benzyl alcohol into its dehydrated/oxidized products in liquid phase. K. J. Sudharshana (University of Petroleum and Energy Studies, Dehra Dun) reviewed the status of integrated coal gasification combined cycle (IGCC) as a viable technology for electricity generation. Rajeew Mehta (Thapar Institute of Engineering and Technology, Patiala) in his work investigated the kinetic rate constants for ring-opening polymerization of poly (lactic acid) using the concepts of molecular modeling. Ch Sailu (Osmania University, Hyderabad) had studied the vapour phase hydrogenation of phenol to cyclohexanone over Pd/silicagel carrier in presence of alkali metal promoters. The presentation by V. Durga Kumari (IICT) on hydrogen production by thermo-catalytic decomposition of methane was a topic of current interest for its approach to the practice of sustainable development. She presented the experimental data on the activity of different catalyst formulations based on metals, zeolites and carbons for production of CO_x free hydrogen.

A considerable part of the workshop was dedicated to poster presentations and discussions. In all, 52 posters were displayed in two different sessions. Many of these were contributed by young researchers.

The programme concluded with a valedictory lecture by S. N. Upadhyay (Institute of Technology, BHU) who stated that with the gradual depletion of fossil fuel reserves, the price of oil will continue to rise, therefore, other energy forms including renewables (wind, solar, water and biomass) and ultimately hydrogen will become the only option. However, many barriers would need to be overcome to realize hydrogen's promise. Catalytic technologies have to play a major role in this direction, he said.

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