VOL 55 NO 18 30 SEPTEMBER 2005

RRL-Bhopal signs MoU with ICCT, Krasnoyarsk Russia for Research on Utilization of Solid Industrial Wastes

A joint research project is being implemented between Regional Research Laboratory (RRL), Bhopal, and Institute of Chemistry and Chemical Technology, Krasnoyarsk, Russia, under the ILTP programme of cooperation between India and Russia, implemented through Department of Science and Technology, New Delhi, and the Russian Academy of Sciences, Russia. Under this project, research is being carried out on utilization of solid industrial wastes such as silicious Zn-Pb cake, deactivated catalysts and ash-slag (fly ash for making value added products such as frit/glaze materials), inorganic pigments, ceramic tile bodies etc. Dr V. G. Samoylov, Vice Director, and Prof. A. G. Anshits, Vice Director, ICCT visited RRL-Bhopal under this programme. An MoU was signed with visiting scientists for enlarging the scope of collaboration through submission of new joint projects.

Signing of MoU between RRL-Bhopal and ICCT, Krasnoyarsk, Russia, for research on utilization of solid industrial wastes

IICT develops Process for Biopesticide Formulations

THE Indian Institute of Chemical Technology (IICT), Hyderabad, has developed a process for biopesticide formulation (10,000 ppm) from the seeds of custard apple and karanja and recently transferred the technology to a small-scale industry unit, M/s Sri Biotech, Hyderabad. The formulations prepared from the extract of the seeds of custard apple and karanja are effective in controlling the insect pests of several crops and are not phytotoxic. These biopesticides are eco-friendly, safe and biodegradable.

Biopesticide formulation developed by IICT, being shown to client — M/s Sri Biotech, Hyderabad.The project team is seen with the client

IICT has demonstrated the process on 1 kg batch of feed stock of seeds of custard apple and karanja. The process technology is available for other interested entrepreneurs for transfer and could be implemented at small scale industry level where seeds of custard apple and karanja are available locally.

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Flame Retardance and Smoke Suppression of Poly (vinyl chloride) using Multicomponent Systems

THE above paper, by Sunil K. Sharma, Scientist, Fire Research Division, Central Building Research Institute (CBRI), Roorkee, published in Fire Technology, has won Director's best paper award. Abridged version of the paper is given below:

Metal-based organic complexes (MBO) are a class of FRSS (flame retardant smoke suppressant) additives that comprise a transition metal and an organic ligand that cleaves at an elevated temperature thereby releasing the metal in a reactive state. They help in the formation of char and thus act as an effective smoke suppressant. Use of MBO complexes as flame retardant smoke suppressants, phosphate ester as a flame retardant and active filler as endothermic material is reported here as multicomponent FRSS systems. MBOs used in the present study are the chelates of pentanediono. They were used alone as well as in combination with aluminium trihydrate (ATH) as filler were used to impart flame retardancy and smoke suppression to poly vinyl chloride. Their performance was measured in terms of flammability, smoke generation, char formation and evolution of combustion gases. MBOs of molybdenum and chromium were found to be very efficient flame retardant smoke suppressants.

Flame retardants make a very significant contribution in reducing the likelihood of ignition and also in limiting the growth and spread of fire, even though they are not so effective in fully developed fires. Smoke development from PVC has long been considered to be one of its weakest characteristics. The improvements in smoke suppression have played a vital role in acceptance of new PVC materials for various applications. Flame retardancy and smoke suppression in polymeric materials are usually achieved by incorporation of suitable additives. Perhaps the most critical smoke suppression has come from use of multi additive formulations comprising phosphate ester plasticizers in combination with metal based additives and hydrated oxides, large-scale studies on several lining materials including PVC modified by multi component systems have been reported. Of the large number of suppressants reported in the literature, it is the reactive additives that form the most widely applicable and diverse group that includes oxides and other compounds of transition metals. These additives act both in the vapour and the condensed phase processes that include promotion of the protective char layer formation, soot oxidation or production of such species, that inhibit the chain reactions in the vapour phase. Polymer combustion involves thermal degradation of the solid matrix to the liquid and the gaseous components. The zone corresponding to the formation of volatile decomposition products from the semi decomposed substrate is the interphase where most of the initial reactions take place, particularly the action of additives such as flame retardants and smoke suppressants.

PVC decomposes by a chain stripping mechanism to leave a polyene backbone. It is this polyene structure that gives off abundant soot via the production of cyclic (mainly aromatic) hydrocarbons. In case of plasticised PVC formulations, degradation of plasticizer and formation of HCl play an important role in the formation of smoke during thermal degradation. In the presence of transition metal complexes, nearly all polyenes formed are catalytically converted to trans isomers, which in turn are converted to carbonaceous char.

Although several flame-retardant systems have been developed for use in polymers, many of these are known to increase the amount of smoke and toxic gases generated by them. Use of silica gel in combination with potassium carbonate for a wide variety of polymers such as PP, PMMA, PVA, Cellulose, Nylone, PS SAN etc. have been reported. Flame retardancy without any adverse effect on smoke and CO generation was observed. Metal-based complexes have certain detrimental effects associated with them. Molybdenum compounds destabilize the colour of PVC and under certain circumstances even hurt the dynamic heat stability. Zinc as borates, oxides or stannates can also reduce the thermal stability. Aluminium and magnesium containing compounds can reduce processability and affect physical properties at normal levels required for FRSS. One way to reduce the detrimental effects of the individual elements and capitalize on the fire, smoke and synergistic attributes is by the formation of complexes that have extremely good dispersion characteristics in the polymer. Metal-based organic complexes are one such class of transition metal-based chelates that have good uniform dispersion in the polymer matrix. Their use in combination with other additives (multi component system) is all the more advantageous.

Metal-based Organic omplexes

Metal-based organic complexes are a class of FRSS additives that comprise transition metal and an organic ligand that cleaves at an elevated temperature thereby releasing the metal in a reactive state. These additives limit the polyene length, thereby restricting intramolecular cyclization. Organometallic complexes are known to affect the initial stages of polymer degradation because they release the metal in reactive state for its action as a flame retardant smoke suppressant (FRSS) additive. They help in the formation of char and thus act as an effective smoke suppressant. This efficacy could be ascribed to their better miscibility with the polymer. Dicyclopentanedienyl Iron (Ferrocene) was the first MBO that was widely acknowledged as a flame retardant smoke suppressant for poly (vinyl chloride). Essentially all of the effective metal-based smoke suppressants appear to work in solid phase and interfere with the normal degradation pattern of PVC. Metal-based organic complexes cause incandescence of char residue left after dehydrochlorination in the temperature range of 350-450°C. This phenomenon parallels quantitative carbon monoxide and carbon dioxide formation whereas such products are normally formed at temperatures higher than 500°C for pure PVC.

Flame retardant smoke suppressant efficiency of MBOs is increased because they are spread much more evenly through the polymer system in a smaller amount. Pentanedione (acac) complexes (which have been found to be the most efficient FRSS additives for PVC) of molybdenum, vanadium, chromium and cobalt were synthesized using 2,4 pentanedione (acetylacetone). In each case the hydrogen of the hydroxyl group of the enol form of the 1,3-diketone was replaced by metal, resulting in the formation of a chelate ring. The general formula being: M^{+n} $(C_4H_7O_2)_n$ where 'M' represents the metal (Mo, V, Cr, Co) having a valency 'n'.

Multicomponent System

Multicomponent fire-retardant systems normally take advantage of several fire retardant mechanisms. One of the most important of these is the concept of what some call chemically combined water in a dry system. Well-known materials of this type are ATH and magnesium hydroxide. When raised above the decomposition temperature, the endothermic compounds with hydroxyl groups sacrificially break down; creating considerable absorption of heat that takes away from the heat available to decompose a polymer system into the low molecular weight fuel gases that support the combustion; thus retarding the polymer burning process. The by-products of decomposition are simply anhydrous oxides and water. Advances have been made in optimizing the leading low-smoke flame retardant chemistry for PVC by combining char-forming and endothermic mechanisms. Because the metal-based additive-induced type of char formation does not inhibit other fire retardant mechanisms, MBOs were used with other FR additives (like those active in gas phase and endothermic materials) to enhance their efficacy and reduce smoke. In the present communication, author has attempted the use of a flame retardant plasticizer, metal-based organic complexes and the endothermic filler ATH.

Conclusion

Based on his experimental work, author has concluded in his paper that multi component systems which comprise of more than one active ingredient, take advantage of more than one mechanism for achieving the end results. The presence of phosphate platicizer has been found to play a definite role in enhancing the efficiency of the additive that acts in the condensed phase. Generally speaking, pentanediono complexes are effective smoke suppressants in the presence of phosphate plasticizer. Tris(2,4 pentancdiono) cobalt (III) that revealed only a moderate improvement both in flame retardancy and smoke suppression when used with phthalate plasticizer was found to be very efficient smoke suppressant when phosphate plasticizer was used. As expected the use of multi component systems transformed an exothermic (fire propagating) system into an endothermic (fire retardant) one without any adverse consequences. Excellent smoke suppression (9Sl ~ 83) was achievable. ❐

NISTADS signs MoU with IPM

THE National Institute of Science, Technology and Development Studies (NISTADS), New Delhi and Institute of Policy and Management (IPM), Chinese Academy of Sciences (CAS), P. R. China desirous of promoting closer ties and greater understanding between India and China and recognizing the mutual benefits that may be derived from a programme of collaboration in science and technology policy research, have reached the following understanding and agree to collaborate in research on science, technology and development policy where this seems desirable and when the available resources permit. It may include activities resulting in joint output, research consultations and holding of seminars and meetings; to exchange information and researchers for short and long term periods where such exchange appears desirable and when resources permit; and to undertake other activities as agreed by both organizations. This collaboration will be for the period of three years, starting from 30 July 2005. This may be extended subject to review by both parties at the end of the period. ❐

New R&D Facilities at Central Electronics Engineering Research Institute (CEERI), Pilani

THE new R&D facilities at the Central Electronics Engineering Research Institute (CEERI), Pilani, in the recent past include:

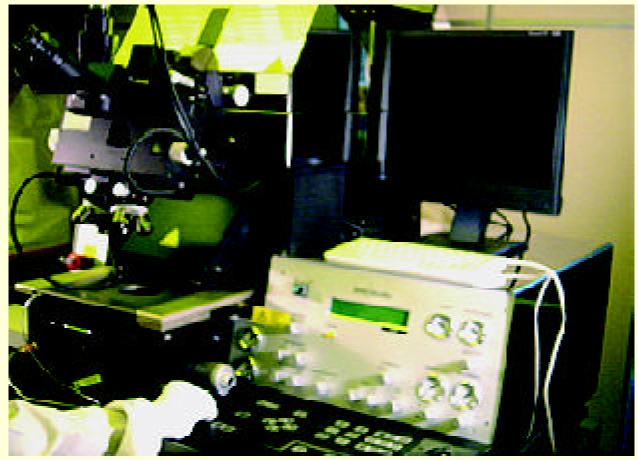
Mask Aligner

Suss MA6 Mask aligner has been procured from Suss Micro, Germany. It is useful for high-resolution optical lithography. It can handle wafers up to 6″ diameter for development and small volume production of MEM and Microsensors. It has 400 nm exposure wavelength optics and is capable of 0.6 mm resolution in vacuum contact. It is equipped with topside alignment with split field colour video microscope and front to back side alignment image storage technique for MEMS application. This mask aligner has a capability with 1 mm front to back side alignment accuracy.

LPCVD Reactor

A new facility for the deposition of LPCVD poly-silicon and silicon nitride on 4″ and 6″ diameter wafers was created. This LPCVD reactor was procured from SEMCO, France. The new facility is able to deposit low stress silicon nitride and poly-silicon films used in MEMS fabrication.

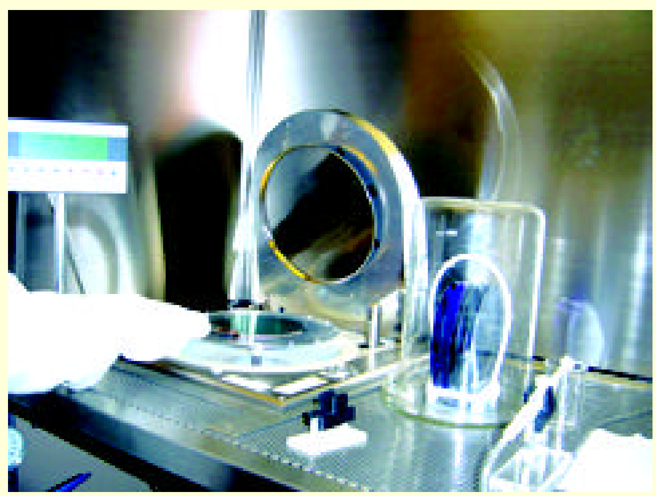
LPCVD Reactor



Mask Aligner

Spin Coater

Spin Coater Suss Delta 80BM has been procured from Suss Delta, Germany. It is capable of coating photoresist on both-sides of up to 6″ diameter silicon wafers. This

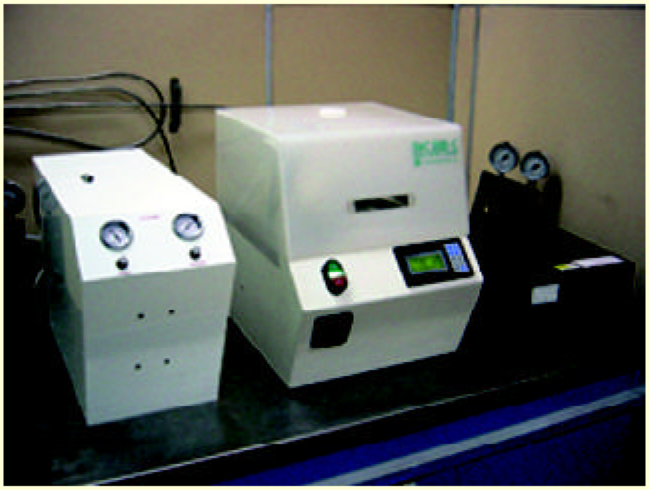


Spin Coater

semiautomatic coater has multi-step gyroset technology of coating photoresist thickness ranging from 1 µm to 100 µm used in MEMS and Microsensors. It is fitted in a class-10 clean air station in order to create particle-free photoresist films on silicon wafers.

Megasonic Cleaner: 1 MHz Spin Cleaning

For high-quality cleaning of processed wafers before bonding to glass, a megasonic cleaner has been procured from Nano Master, USA.



Megasonic Cleaner: 1 MHz Spin Cleaning

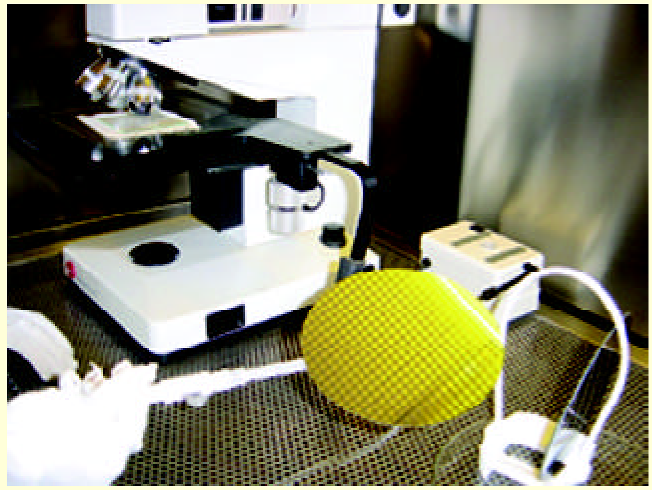
Photoresist Bake Ovens

A pair of Bake Ovens has been procured from M/s Despatch, USA. These photoresist bake ovens are class-10 compatible with internal air filtration system. The temperature accuracy inside the chamber is ± 1°C.

Photoresist Bake Ovens

Class 10 Clean Air Stations

The stainless steel vertical flow station gives class-10 clean air environment and is equipped with sound absorbing material. The main air filter is an ULPA-



Class 10 Clean Air Stations

filter absorbing 99.999% particle greater than 0.3 μm in diameter. These clean air stations are being used for spin coater, mask aligner and wafer inspection.

Mask Fabrication

Under the modernization programme of CSIR, CEERI has recently installed a sophisticated laser pattern generator, DWL 200 manufactured by Heidelberg Instruments Microtechnik, Germany. The system is capable of generating submicron feature size of different shapes and sizes directly on chrome blanks or semiconductor substrate normally required for VLSI, MEMS and integrated Optic Device development. The

Mask Fabrication

system is housed in class-100 clean room supported by 60 kVA separate power supply, an UPS system and environmental control. The main objective of setting up of this state-of-the-art facility at CEERI has been to cater to the needs of microelectronic community within the country in addition to in-house users. The system is fully commissioned and approximately 100 photomask-sets for in-house as well as outside users have already been fabricated for different devices.

Features:

Exposure Source	: Kr^+ Laser, 413 nm
Write Methodology	: Spot Beam Raster Scan
Input Design Data	: CIF, GDSII, GERBER, DXF, EMASK
Structures	: Wave guide, splitters, circles MEMS structures, multiplexers etc.

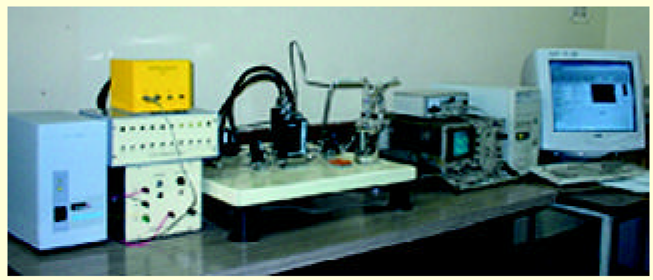
Specifications:

Minimum Feature Size	: Near Micron on chrome blanks
Accuracy	: 10% of minimum feature seize
Plate Size	: 2.5″ × 2.5″ to 8″ × 8″
Applications	: Direct write on semiconductor/ ceramic substrate photomask generation on chrome blanks

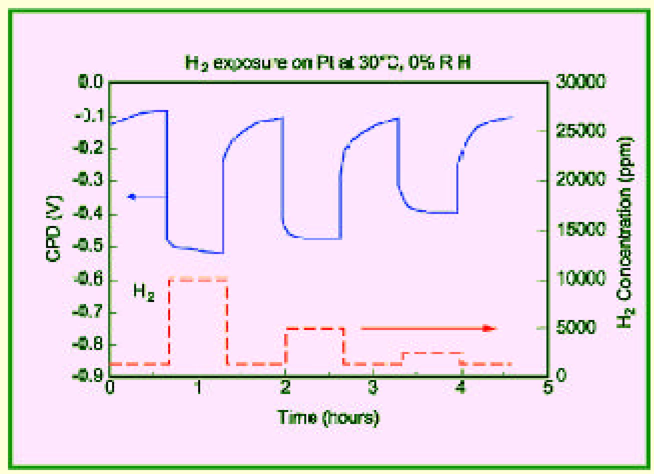
State-of-the Art Gas Sensor Characterization System

A state-of-the-art gas sensor characterization system has been developed at CEERI with the financial aid from DAAD-Bonn, Germany. The computer controlled characterization system is constructed on a LabView platform for automatic measurements. The system is capable of measuring the change in conductivity or the change in work function of a film on adsorption of gaseous species on its surface. The gas sensing properties of both the FET (field effect transistor) type or conductivity type materials and sensors can be measured accurately with the help of this system.

The work function change measurements are performed using a commercial Kelvin Probe. The computer controlled volumetric gas mixing is employed to expose the sensor or a gas sensitive film to a test gas of desired concentration. A humidifier and a heater are incorporated in the system to carry out measurements at variable humidity and temperature conditions. The gas sensing measurements can be performed manually or in auto mode. The following figures show the system and a typical response of a platinum film to hydrogen (work function change).



Gas Sensor Characterization System



Work Function Change

Salient Features

- Characterization of FET/conductivity type sensors
- Measurements of gas sensing properties of thin/thick film materials
- Kelvin Probe for CPD/work function measurements
- LabView measurement platform ❒

Seminar on Awareness of Recent Advances in Science &Technology

THE Regional Research Laboratory (RRL), Jorhat, recently organized a two-day national level seminar on the theme, 'Awareness of recent advances in science and technology' with a view to focussing on the recent advances in Science and Technology and exchange of views amongst scientists, engineers, academicians from diverse fields and institutions. Prof. P.C. Kesavan, Member RC and DAE-Homi Bhabha Chair & Distinguished Fellow of M.S. Swaminathan Research Foundation, Chennai, presided over the seminar. Dr G. Thyagarajan, Chairman, Research Council and former Director, RRL-Jorhat, formally inaugurated the seminar. Dr A.R. Balakrishnan, Member, Research Council, RRL- Jorhat and Professor of IIT, Madras, Chennai, spoke about the background of the seminar and its importance.

Earlier, Shri D.K. Dutta, Scientist and Area Coordinator of the Engineering Science welcomed the audience. In his inaugural speech Dr Thyagarajan underlined the fact that during the last three decades, the world has seen a great explosion of knowledge. There have been rapid advances in Science & Technology, particularly in the areas of Biotechnology, Communication and the Engineering sciences. The technologies involved in these areas are called critical technologies and innovation is the only *Mantra* now. Such is the speed with which these are evolving that it has become almost impossible to keep up even with the latest computers available. There has also been sudden development and ramification of nano-technologies. Seminars such as the one organized are therefore necessary to keep abreast with latest knowledge. This was a small effort but one with far reaching ambition behind it, he informed.

The seminar covered the two broad areas of Engineering Sciences and Biological Sciences. A good number of participants from all over India participated. Noteworthy among those who attended were Dr G. Thyagarajan, Prof P.C. Kesavan, Dr A. R. Balakrishnan, Prof G.D. Sharma, Vice Chancellor, Nagaland University; Prof O. N. Mohanty, IIT, Kharagpur; Prof G.D. Yadav, Dr **S**.S. De, IIT, Guwahati; Prof. G.K. Suraishkumar, IIT, Madras, Chennai; Prof Rajat K. Chaudhuri, Calcutta University, Dr S.N. Dube, Director, Defence Research Laboratory, Tezpur; Dr G.N. Hariharan, Principal Scientist, Lichen Ecology & Bioprospecting Laboratory, M.S. Swaminathan Research Foundation, Bangalore; Dr S.S. Malik, National Bureau of Plant Genetic Resources (NBPGR), New Delhi and Dr P.S.V.V. Khan, IBSD Imphal. Eminent experts delivered a total of nine lectures in the relevant fields. There were four lectures in Engineering Science section, viz. (I) Steel for New Millennium Auto Body by Prof. O. N. Mohanty, (ii) Exciting opportunities for Chemical Engineering in the 21st Century by Prof G. D. Yadav, (iii) Combustion Generated Air Toxics- their Monitoring and Abatement by Prof. D.S. De, (iv) The Culture in Bio-reactor by Prof G.K. Suraishkumar and five lectures in Biological Sciences, viz. (I) Unraveling of Human Genome : how it was done and its implication by Dr Amit Ghosh, former-Director, IMTECH, Chandigarh, (ii) Plant molecular biology revisited—30 years of development by Prof Rajat K. Chaudhuri (iii) Chemical Warfare by Dr S. N. Dube, (iv) Bioprospecting ecological and economic potentials of lichens by Dr G. N. Hariharan and (v) Biodiversity management of sustainable agriculture by Dr S. S. Malik.

In the panel discussion for Engineering Sciences section, tremendous concern was expressed about the growing use of thermosetting plastics in automobiles as these might turn out to be a major source of pollution. Similarly, the extensive use of cell phones has the potential to lead to pollution due to exhausted batteries. Likewise, excessive water used by the textile industries, which is the largest foreign currency earner, is a source of major pollutants in terms of toxic and hazardous chemicals. There was concern for the Brahmaputra with municipality drainage through the Bharalu stream in Guwahati. Suggestions for the use of plants as filters for the removal of organic pollutants were received. Emphasis on green chemistry for reducing pollution at source was also stressed together with the use of membrane adsorption and catalytic chemistry. It is indeed a formidable engineering and technological challenge to develop techniques deliverable and acceptable to the people.

In the panel discussion for Biological sciences it was opined that since the North East India is one of the major biodiversity hotspots of the world there is need to convert this biodiversity into economic ventures. In the process there would be the scope of emerging new sciences also. It was suggested that Genome Literacy Clubs need to be organized to protect the biodiversity of the region and its flora and fauna should be properly documented. It was felt that the research infrastructure in the existing universities and R&D institutions of the region are inadequate and thus not able to take care of the rich but threatened bio-resources of the region. There are rules for protection of biodiversity, but these are not strictly implemented. ❐

Training for trainers and master craft-persons

A seven-day training programme for trainers and master craft-persons of Assam was recently organized at the Regional Research Laboratory (RRL), Jorhat. The Development Commissioner (Handicrafts), Ministry of Handloom and Textiles, Government of India, Guwahati, sponsored the programme. A total of 22 master craft-persons from various parts of the state participated in the training. The training, consisting of 13 lecture schedules and five practical demonstration classes was conducted by resource persons drawn from Institutes such as the Indian Institute of Entrepreneurship (IIE), Guwahati; Small Industries Service Institute (SISI), Guwahati; Life Insurance Corporation of India (LICI), Development Commissioner (Handicraft), Cooperative Sectors Bank, NABARD, CAPART, MSEC, besides the scientists from RRL-Jorhat. Training was imparted on all aspects of handicrafts such as skill development, entrepreneurship, industrial support, marketing procedures, setting up of industries and export promotion, etc. Participants were also given practical training by experts. Dr P.G. Rao, Director, RRL–Jorhat, inaugurated the training programme in the presence of Shri Faizur Rahman, President, NESSIA, Jorhat. The trainees were familiarized with the activities of the laboratory, especially with those related to engineering and design. Highlights of the programme were summarized by the faculty members of different organizations with audiovisual presentation of the scope of Computer Aided Design (CAD) in the handicrafts sector. The participants displayed their creations at a mini exhibition-cum-sale counter opened within the laboratory premises for public view. It generated interest among the visitors and helped the trainees to search for prospective market for their products. Dr R.K. Sharma, Dr P.R. Bhattacharyya and Dr R.K. Adhikary, senior scientists of RRL-Jorhat, and Shri P. Thakur and Shri B. Mushahary, Development Commissioner (H), Jorhat conducted the programme. ❐

Master craft persons of Assam being imparted training by RRL Scientists

Training Programme on Industrial Offshore Surveys for Naval Officers

THE National Institute of Oceanography (NIO), Goa, recently conducted a Hydrography Specialization Course on Industrial Offshore Surveys for eight Naval Officers from India, one each from Bangladesh and Nigeria and two from Sri Lanka. The institute has been conducting this course for naval officers since 1997 at the behest of the National Hydrographic School (NHS), Vasco-da-Gama.

The Navy personnel explore the sea-bottom and sub-bottom features of the seas using contemporary geo-scientific methods. Consider-ing their requirement, a course comprising of a series of lectures by scientific and technical staff of NIO on geological and geophysical surveying and mapping techniques followed by tutorials was conducted. Field work onboard Coastal Research Vessel Sagar Shukti was also organized in order to provide practical training to the participants. Dr A.K. Chaubey, Scientist, was the course coordinator.

A participant, Cdr. Michael O.A. Odebode (Nigerian Navy) receiving Certificate from Dr Satish R. Shetye, Director, NIO. Dr A.K. Chaubey, Course Coordinator is seen on mike

On completion of the course, a valedictory function was organized. Cdr. P.1. Mathews, Officer-in-Charge, NHS, was the Chief Guest. Speaking on the occasion, Cdr. Mathews appreciated the efforts of NIO for imparting state of the art training on Industrial Offshore Surveys – Long Hydrography Course to the naval officers. The trainee officers received certificates at the hands of Dr Satish R. Shetye, Director, NIO. Dr Rajiv Nigam, Scientist, NIO proposed vote of thanks.

So far, 75 naval officers have undergone this course at NIO, 51 officers from the Indian Navy and 24 from Malaysia, Indonesia, Myanmar, Nigeria, Vietnam, Sri Lanka and Bangladesh. ❒

Dr Y. Nayudamma Memorial Award (2004) presented to Shri Madhavan Nair, Chairman, ISRO

THE Dr Y. Nayudamma Memorial Award (2004) was presented to Shri G. Madhavan Nair, Chairman, Indian Space Research Organisation and Secretary, Department of Space, Government of India for his outstanding contributions to India's space science and satellite development programmes, at a glittering function held at Tenali. Dr N. Jayaprakash Narayan, National Co-ordinator, Loksatta, presented the Award and Citation to Shri Nair. Shri Nair delivered the 13th Shri Y. Nayudamma Memorial Lecture entitled 'Development of Rocket Technology,' which is reproduced below:

Development of Rocket Technology

"I am extremely happy to be here amidst all of you and feel proud to have the opportunity to deliver the 13th Nayudamma Memorial Lecture organized in memory of Dr Nayudamma. It is indeed an honour for me to have received the Dr Nayudamma Memorial Award. I am aware that eminent personalities have delivered lectures earlier, in his memory. Dr Nayudamma was a great visionary who has contributed immensely to the field of scientific research. During his tenure as Director, CLRI, the institute emerged as one of the leading centres for leather research. His contributions towards indigenization of Leather technology in the country are really remarkable. He strongly believed in merging the modern and traditional practices towards developing an 'alternate technology'. He felt the need for a strong R&D base in the country to meet the challenges of industries and the present day CSIR is the result of this. It was during his period that the idea of industrial research and their applications took shape. Dr Nayudamma with his creative mind, extraordinary brilliance, great managerial qualities and above all excellent human qualities has been an ideal scientist for many of us to emulate.

It is a matter of privilege for me to be delivering this memorial lecture on the topic ' Development of Rocket Technology,' to pay my humble tribute to this great visionary scientist of India.

Hon'ble Dr N. Jayaprakash Narayan, National Co-ordinator, Loksatta, presenting the Dr Y. Nayudamma Memorial Award to Shri G. Madhavan Nair, Chairman, ISRO. Also seen in photograph are: Shri P. Vishnu Murthy, Founder & Managing Trustee and Shri Ratheish Y. Nayudamma, Chairman of the Trust

Introduction

The Indian space efforts had a modest beginning nearly four decades ago, with a vision to explore the possibility of utilizing this emerging new technology for national development. It was Dr Vikram Sarabhai, the founding father of our space programme, who initiated the space research in the country through the sounding rocket experiments in the southern tip of India, Thumba near Thiruvananthapuram. These experiments were for investigation of the upper atmospheric and ionospheric phenomena associated with electro jet over the geomagnetic equator. He also formulated a vision statement that:

'We shall be second to none in the application of advanced technologies to the real problems of man and society.'

The translation of this vision into reality has been through a systematic process of evolution. This vision evolved into missions and projects, developing cutting edge technologies, creation of centres of excellence, harnessing of human resources and development of institutional framework. Present day ISRO is the result of all these.

Indian Space Programme – An outline

Since inception, the Indian Space Programme has undergone enormous expansion. It is unique and largest of its kind providing end-to-end solution towards meeting our national requirements. The Indian National Satellite system, INSAT is one of the largest domestic communication satellite systems with a present complement of 7 satellites providing services through nearly 150 transponders. While INSAT system continues to provide regular services in the areas of telecommunications, business communication, broadcasting and meteorological services, several initiatives have been taken to expand the application of INSAT to newer areas like Tele-medicine, and Tele-education. Use of INSAT for e-governance and developmental communication is also fast expanding. The INSAT system has extended the outreach to less accessible areas like North-East and the islands.

The Indian Remote Sensing Satellite system, IRS has the largest civilian constellation of remote sensing satellites today providing data in variety of spatial resolutions and spectral bands. The data is used for various applications in the fields of agriculture, forestry, ground and surface water, drought assessment and monitoring, flood mapping, land use and coastal studies.

Initial launches of IRS and all the INSAT launches so far have been carried out using procured launchers. Considering the need for achieving self-reliance in accessing space, ISRO has initiated a programme for development of rocket systems. Such technologies were not available from any quarter and thus it demanded setting up of laboratories and developing multidisciplinary systems in disciplines such as solid propellant and liquid propellant rockets, control, guidance and navigation systems, avionics, mission management, the launch complex systems, telemetry & tracking systems etc. Today, we have totally realized them and have two operational launchers, PSLV and GSLV, towards meeting the launch requirements of remote sensing satellites in low earth orbit and communication satellites of 2 tonne class into geo-synchronous transfer orbit.

Early Days of Rocketry

The story of rocketry dates back to several centuries. Around 1230 AD, the Chinese were the first to use rockets as weapon, which was termed as 'Arrows of flying fire'. It was just an ordinary arrow attached with a tube filled with a gunpowder mixture consisting of charcoal, sulphur and potassium nitrate. This was used to fight against the Mongolian enemies.

In the 18th Century, the troops of Hyder Ali and Tipu Sultan used rockets to fight against the British army during the Mysore war. This rocket consisted of an iron tube, about 3.8 cm in diameter and 20.5 cm long, filled with gunpowder and tied to a long bamboo pole. Likewise, all through the 13th to the 18th century, there were reports of many rocket experiments in Europe and England. For centuries rockets remained smaller in size, and their use was confined principally to weaponry and fireworks display. It was in the late 19th century, a Russian scientist, Konstantin Tsiolkovsky, most popularly called the father of modern astronautics, proposed the idea of space exploration. He suggested the use of liquid propellants for rockets in order to achieve greater range. Later in the early part of the 20th century, an American scientist, Robert H. Goddard conducted practical experiments in rocketry. Goddard's earliest experiments were with solid-propellant rockets. It was only during this time period that the development of modern rocketry began. A clear understanding of the principles of rockets emerged and only then did the technology of large rockets started to evolve.

During the World War II, in 1940, V2 rockets, the first successful long range ballistic missiles, were employed by the Germans. With the fall of Germany, many German rocket scientists ended up in United States and Soviet Union. Both the United States and the Soviet Union soon realized the potential of rocketry as a military weapon and also initiated a variety of experimental programmes towards exploration of outer space.

On October 4, 1957, the first Earth-orbiting artificial satellite Sputnik I was launched by the Soviet Union. With this a race for space between the two-superpower nations started. A few months after the first Sputnik launch, the United States followed the Soviet Union with a satellite of its own, Explorer I, launched by the U.S. Army on January 31, 1958.

Today's rockets are remarkable combinations of human ingenuity that have their roots in the science and technology of the past. The evolution of the rocket systems has paved the way for the exploitation of outer space and addressing the global issues of planet earth to improve the quality of life on our planet.

Beginning of Rocketry in India

The beginning of a new era in space research and rocketry in India started in 1963 in Thumba Equatorial Rocket Launching Station (TERLS). Though the sounding rocket program began with the launching of foreign Nike-Apache and Centaur rockets with international participants under the aegis of the United Nations; parallely our inquisitive young teams under healthy competitive environment took up the challenge of developing the indigenous sounding rockets. This effort culminated into the successful launching of our own pencil like rocket (compared to present PSLV or GSLV) Rohini –75 (RH-75) during 1967. This single stage rocket of 1.0 m length weighed 6.9 kg and carried 1.5 kg payload to an altitude of 6.8 km. Since then we have come a long way and today we have a range of sounding rockets from 75 mm to 560 mm diameter with capability to lift 10 to 100 kg payloads to an altitude up to 550 km. Till date, more than 4000 sounding rockets have been launched including those from US, the erstwhile Soviet Union, France along with indigenous Rohini rockets.

In the early phase of development of sounding rockets, there were a few failures associated with motor explosion, non-ignition of motor at higher altitudes, stage non-separation etc. But all this provided us with a learning ground to better understand the intricacies associated with use of solid rocket propellants and its interfaces, understanding of aerodynamic stability and controllability of rocket systems, provision of design margins for robustness etc. In addition to all this, it has helped us in improving our inspection, safety and quality procedures, which were later found useful during the development of satellite launch vehicles.

Launch Vehicle Programme - Evolution

The lessons learnt from the sounding rocket programme gave us the necessary confidence in taking up the development of India's first multi stage Satellite Launch Vehicle (SLV-3). It had the capability of lifting 40 kg in low earth orbit. SLV-3 programme resulted in significant developments in multiple disciplines of rocketry and provided us with necessary expertise to take up projects of much greater complexities. The intricacies of launch vehicle technology were learnt through three successful launches of SLV-3 during 1980-83. Though the very first flight conducted in the year 1979 was not successful the next three flights were successful thus establishing our confidence in satellite launching. These missions carried small Rohini satellites to prove technologies and some scientific instruments.

Considering the need for higher payload capability for scientific experiments and to achieve such a mission within the shortest possible time, a configuration of Augmented Satellite Launch Vehicle (ASLV) was evolved. It served as the low cost flying test bed for new technologies. Despite two failures, the extensive analysis brought out improvements in the better characterization of vehicle, new technologies and simulations. With two consecutive successful launches of ASLV, all the objectives of this programme were achieved. The major contribution of ASLV experience was that it enabled a better understanding of the difficult atmospheric regime of flight, issues related to control-structure interaction, implementation of on-board real-time based decision-making for event management, closed loop guidance for better tolerance in injection conditions.

Even while the development of ASLV was going on in 1982, ISRO took the challenging task of developing the Polar Satellite Launch Vehicle (PSLV) for launching the 1 tonne class operational remote sensing satellites into Polar Sun-Synchronous Orbit (SSO). Aiming at a performance increase by a factor of 20 times over its predecessor, ASLV and employing new technologies like liquid propulsion and three-axes guided injection, the gigantic PSLV required development efforts, generation of facilities and industrial support of much larger proportion. PSLV for the first time adopted liquid stages in addition to solid rockets. All the PSLV systems functioned well in the first flight conducted in 1993 but still the mission could not succeed in injecting the satellite into orbit due to a software implementation error. This led to strengthening further the ground simulations, additional testing of the vehicle hardware and software systems to its fullest capabilities prior to flight.

The major technological achievements during the PSLV realization phase were related to the development of 140 tonne solid propellant core booster, which is one of the largest operational boosters in the world. It uses the indigenously developed state-of-the-art high energetic HTPB propellant with high fuel value and solid loading capability. The development of super alloy M 250 grade maraging steel, which has a characteristics of high strength coupled with excellent toughness was successfully carried out for use in solid booster casing. All these were the result of one of the most successful indigenization efforts in the country.

In the area of liquid propulsion systems, realization of earth storable bipropellant system for second stage of PSLV was a major technological achievement. Mastering of fabrication and welding technology for high strength materials for use in liquid propellant tankages and high-pressure gas bottles were achieved during this period. In the area of on-board systems, use of redundant strap-down inertial navigation systems using dry tuned gyros and servo accelerometers, on-board computers for flight management functions of navigation, guidance, digital autopilot and vehicle sequencing etc were successfully mastered during this period.

Eight launches of PSLV have been taken up so far. The last seven missions conducted during 1994-2004 provided a string of successes. Starting with a payload capability of 800 kg in its first developmental flight, the capability of PSLV has been systematically improved to 1400 kg in its eighth mission. These improvements have been made possible by incorporating improved propellant loading for solid as well as liquid stages, improved efficiency of the upper stages, overall inert mass reduction by adopting composite structures wherever feasible, optimization in strap-on firing sequence, miniaturization of avionics packages etc. PSLV is under production to launch all national remote-sensing satellites and to respond to potential commercial opportunities. The capability of PSLV to carry 1000 kg to Geo-synchronous Transfer Orbit (GTO) has also been established with the launch of KALPANA –1.

In order to utilize the spare capacity whenever available, various payload accommodation strategies have been evolved over the years. These include provision for carrying up to two micro satellites on the vehicle equipment bay, or two spacecrafts of around 500 –600 kg using the dual launch adaptor or a possible mix of micro & mini satellites. The first one has been accomplished in the fifth mission of PSLV wherein it carried two micro satellites in a piggyback mode- KITSAT- 3 of Korea and TUBSAT of Germany. In the subsequent mission, when the micro satellites PROBA for Belgium and BIRD for Germany were launched along with the primary spacecrafts, the multiple orbit capability of PSLV was also demonstrated when PROBA was injected into elliptical SSO.

The 2 tonne GTO Launcher Geo-synchronous Satellite Launch Vehicle (GSLV) a three-stage vehicle employs solid, liquid and cryogenic propulsion modules for its stages. Keeping pedigree of already developed stages and in order to reduce the overall developmental cost and schedule, the PSLV modules were maximally utilized for the first two stages of GSLV. A procured cryogenic stage from Russia was used for the upper stage. Cryogenic propulsion is selected as it delivers more energetics measured in terms of specific impulse, which is almost 1.5 times that of liquid and about 1.75 times that of solid propellants. Especially when used as the upper stage, the payload capability of the launcher improves by 15 kg for every 1 s increase in specific impulse, which speaks, of its necessity for GTO launchers. GSLV has successfully completed 2 developmental and 1 operational flight during 2001 - 2004. Though the cryogenic stage was procured from Russia, total avionics system for cryogenic stage was realized by ISRO. Definition of the mechanical, electrical, thermal interfaces with ISRO subsystems and qualifying them through a series of joint hardware tests and software checks posed a major challenge. A number of interface checks were done at the level of engine, and through a series of cold and hot tests of stage using ISRO electronics. The realization of the cryogenic umbilical arms for feeding the propellants and the safe retraction of these just prior to take off was a critical development.

For the initial launches of GSLV the bought out cryogenic stages from Russia will be used. In the mean time, efforts are on to develop indigenous cryogenic stages. A cryogenic engine of indigenous design using liquid oxygen and liquid hydrogen has been fully qualified through a series of ground tests. Efforts are also on to complete the development of cryogenic stages for GSLV within a year.

Let me make mention here that, right through the evolution of launch vehicle programme, our thrust has been towards maximum utilization of the technical expertise and resources available in the academic institutions and Indian industries. This approach has made possible the timely implementation of our programme. As of now, more than 500 industries are participating towards realization of space systems, with their contribution as high as 70% of the product value.

Challenges in Launch Vehicle Design

The major steps involved during the course of design are sizing of the vehicle in terms of external configuration, number of stages, size of each stage, design of nominal flight sequence, consideration of aerodynamic and propulsion parameters, atmospheric conditions etc. These are used for carrying out the optimal trajectory design. The design during the atmospheric phase is more critical as the vehicle has to withstand the severe aerodynamic loads thereby making the structural integrity the prime concern. However, during the exo-atmospheric phase, the steering of the vehicle using closed loop guidance to the intended target is of prime importance. In addition to this, the overall mission design is very closely interlinked with other broader problems associated with aerodynamics, structure, thermal, navigation, guidance, control, propulsion etc.

Aerodynamic design of a launch vehicle is a complex activity that requires a synthesis of experimental aerodynamics (wind tunnel tests), use of available aerodynamic data banks, analytical and empirical methods, and increasingly use of CFD tools.

Vehicle electronics, another important component of launch vehicle caters to Navigation Guidance and Control system (NGC), which is equivalent to the brain of a launch vehicle. It enables to steer the launch vehicle towards the desired path and deliver the payload in the intended orbit. The other is the Telemetry Tracking and Command (TTC) system, which enables monitoring of health and performance of launch vehicle systems.

The validation of NGC system for varying vehicle environments is a time consuming task. This calls for the realization of simulation test beds with multiple computers and real-time operating software. Around thousand simulations are carried out in various environments of mission before the software gets validated for use in flight.

Advanced Missions of ISRO - Technological Challenges

The currently available expendable launch vehicles PSLV and GSLV are catering towards launching of 1t class remote sensing and 2t class communication satellites for meeting our national needs. Similarly, GSLV-MkIII, the new heavier lift launcher, which is under development, will meet the 4t class communication satellite requirements. With this the country will be totally self-reliant in launching satellites with indigenous launch vehicles.

Further, if we look at the cost per kg of these expendable launchers, they are in the range of 12,000 – 15,000 $/ kg. To provide the 'low cost access to space', the cost needs to be further brought down to something like 500 –1000 $ / kg. To achieve this, there is a need to make these systems recoverable and reusable and adopt advanced propulsion concepts like air-breathing propulsion. We have taken up initiatives in the newer propulsion technologies such as supersonic combustion required in the design of air-breathing propulsion. These are being experimented in the sub-scale programme. Satellite Recovery Experiment planned in the coming year will provide inputs towards achieving reentry/recovery objectives required for realizing a reusable launch vehicle. As a step further, a demonstrator for developing newer technologies for the Reusable Launch Vehicle is conceived. This is in its initial phase of design and will make use of concurrent engineering practices and inter-disciplinary design approach.

Another important mission planned towards planetary exploration is the Chandrayaan mission. This mission will form one major stepping stone in the efforts of ISRO and the nation as a whole towards launching a probe into a 100 km polar orbit around the moon in about four years from now using PSLV. This mission could provide an opportunity to explore the lunar surface and throw light on some of the aspects related to the origin of earth and kindle scientific temperament in the younger generation.

Some of the major R&D efforts in the coming years will be in the area of high specific impulse propellants, high strength materials like Al-Li alloy, metal matrix composites, smart structures, supersonic and hypersonic aerodynamics, CFD tools for internal and external flow field analysis, smart actuation system, robotics, fault tolerant on-board computers and advanced navigation sensors.

With the untiring and concerted efforts of ISRO scientists, India has achieved self-reliance in multistage rocket systems for launching its satellites for earth observation, scientific mission and communication. Futuristic need of low cost access to space requires innovative technologies and advanced materials to realize recoverable and reusable launch vehicle systems.

To meet these ambitious programmes, ISRO looks forward to seeing specific Centres of Excellence to carry out space related research in the universities, academic institutions and extended participation from the industries. The challenging demands of the future and our desire to make Indian space programme contemporary and competitive with other space faring nations, will put enormous responsibility on the shoulders of the technologists of our country. With the experience so far and the envisaged application and technology growth, a roadmap for the next 25 years has been conceived.”

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CSIR – Automobile Industry Get-together on Advanced Manufacturing Technologies

THE Structural Engineering Research Centre (SERC), Chennai, and the Central Mechanical Engineering Research Institurte (CMERI), Durgapur, are jointly organizing ‘CSIR–Automobile Industry Get-together on Advanced Manufacturing Technologies’, at Vigyan Auditorium, SERC, Chennai, During 17 December 2005.

The Get-together is aimed at bringing about a strong interaction between research/academic institutions and related industries/organizations in the country to work out strategies for making use of indigenous expertise to face the challenging problems of the industry and provide cost effective and reliable solutions.

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Dr P. R. Viswanath honoured

DR P. R. Viswanath, Head, Experimental Aerodynamics Division, of the National Aerospace Laboratories (NAL) Bangalore, has been elected a Fellow of the Society for Shock Wave Research at the Indian Institute of Science.

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