GIANT MOLECULES: THE MARRIAGE OF THE UNIVERSITY WITH THE COMMUNITY

WHAT IS POLYMER SCIENCE?

Small molecules, which constitute, in increasing size, gases, liquids, oils and greases soon leave the field of general chemistry as they become giant molecules. These giant molecules or macromolecules are called polymers by the industry and form a class of materials which we can touch, feel, see and shape to produce objects and use daily.

There is a fine line of differentiation between the giant molecules of nature and those prepared synthetically, and the linkages are becoming ever closer. Our own DNA, which defines who we are, needs merely 20 building blocks to be created. Yet, the infinite variety of structures, which these 20 building blocks can create, creates the diversity of individuals and the diversity of nations. As the DNA structures are simplified, the animal and plant kingdoms are created.

Chemistry gives us millions of new building blocks to use synthetically and the only limitation we have is the cost of producing them, their toxicity and environmental concerns.

Over a very short time, basically since the Second World War, the polymer industry has grown to be 44% of the chemical-based manufacturing industry. It has further extended its growth into the automobile, cable and electronic industries, amongst others.

As a major employer, each facet of the industry is diversified. For instance, there are more than 250 decorative paint companies in South Africa, ranging from small to large. A similar situation exists in the areas of adhesives, injection-moulded plastic parts, extruded plastic parts, fibreglass structures and even fibres and clothes.

Without all these active polymer producers and converters, we would be without most of our clothes, our combs and brushes, toothbrushes, comfortable mattresses, blankets, carpets, painted walls, resin-protected wooden doors and windows, our fridges, computers, photocopying machines, high-grade writing paper, inks, photographic film, stiffies and CDs and, more important, our health.

As far as our health is concerned, I refer to the following: the bag filters which filter the air which we breathe, after it leaves power stations and other electrical generating industries and the clean water we drink, which has been clarified by polyelectrolytes or, in the case of rural communities or industrial wastes, filtered by polymeric membranes. The use of polymers in synthetic heart valves, coronary artery replacement, lenses, etc. is a growing development area.

Much of the current groundbreaking work in polymer science is now in the fields of microbiology and biosystems. Techniques are being used to biosynthesize exotic new fluoro-containing polypeptides for their own specific bioproperties.

STRUCTURES OF POLYMER SCIENCE INSTITUTIONS AT OVERSEAS UNIVERSITIES

Let us look at two of the internationally strongest polymer departments as examples: my alma mater, the Institute for Polymer Science at the University of Akron, and the Department of Polymer Science at the University of Eindhoven in Holland.

The Polymer Institute at Akron University, when I attented it in 1966, had six professors and about 36 postgraduate students. Presently the academic staff in Polymer Science numbers 25 and there are 118 MSc and PhD students. There is now a second department, linked to the first, for polymer engineering with its own staff and students. The Polymer Science department staff comprises chemists, polymer scientists, chemical engineers, mechanical engineers and biopolymer scientists.

This holistic approach allows a problem area to be addressed from several sides. This multidisciplinary structure has led to enormous international recognition and acclaim. A few years back the concept of the polymer valley was instituted around Akron and presently boasts 149 new companies that moved into the area and are showing remarkable growth.

The Eindhoven Polymer Laboratories, Holland,

includes the Department of Polymer Chemistry and Technology with their 13 academic professors and seven technical staff, who are linked to the Department of Organic Chemistry and the Department of Mechanical Engineering. This brings the collaborating academic staff to the interdisciplinary staffing, and includes chemists, polymer scientists and chemical engineers in the Polymer Department and specialist chemists and mechanical engineers in the other two departments. This holistic approach has made them one of the best recognized centres in Europe. They enjoy strong student and industrial support.

HISTORY OF POLYMER SCIENCE AT THE UNIVERSITY OF STELLENBOSCH

In 1970 the teaching of Polymer Science was introduced at Stellenbosch, and I was appointed as a senior lecturer in the Department of Chemistry to offer a service course in Polymer Science to the Department of Chemical Engineering and, a short time later, to provide postgraduate courses in the Department of Mechanical Engineering.

Research into membrane systems for water supply and advanced binders for rocket fuels led in 1977 to the creation of the Institute for Polymer Science. This is also the time when the first technological transfer of membrane technology was made to the Paarl company, Bakke Industries. Their membrane division later became Membratek, still later De Beers Desalination/Membratek and now the company Envig.

In 1981, with industrial funding, a second academic post was introduced and Polymer Science was introduced as an honours, MSc and PhD level programme in the science faculty, while housed in and administrated from within the Department of Chemistry.

These courses put the University of Stellenbosch on a par, all be it in a very minor way, with the international university trends in the USA, Europe and Japan, concerning the teaching of polymeric materials.

For many years this Polymer Science Institute stood as the sole structure in polymer-related tertiary education and, as a consequence, student numbers grew. Within the last few years, this subject has been introduced at other universities and at three technikons, of which two are highly successful.

During this period, we moved from a small laboratory to a larger one at inorganic chemistry, to the entire bottom floor at inorganic chemistry, to a building that is now the central parking lot off De Beers Street to half of the present polymer institute building plus the building in the parking lot. Following a disastrous fire, the present building was modified for use between 1983 and 1986. A couple of years later the Polymer Engineering Annexe in Banhoek Road was purchased and over the past few years a new organic laboratory and extended floor, a new store room, two new laboratories and two new offices have been added to the existing Polymer Science building in the central campus.

This trend is ever continuing as industrial needs for personnel continue to escalate.

Research has been carried out in numerous and various fields. Relative to the wine industry, the coatings for cement tanks for wine production and storage, waxes for grafting, and wound protection against dry rot during pruning were researched and the results applied.

The track record of research success at Stellenbosch is excellent, even when internationally judged. New membranes and membrane systems for industrial waste cleanup and the supply of drinking water were investigated. In short, results of research and development at Stellenbosch University have led to the creation of the technology for the establishment of companies, such as Envig (Paarl), who have supplied desalting plants to the towns of Bitterfontein and Nuwerust to provide them with drinking water, and have created the water treatment plants, for instance at Sasol (R100 million), Mondi and Eskom.

Polymer Science at Stellenbosch University was established and grew by an arduous but most rewarding learning curve. Difficulties have resulted in a number of unique features which are represented in the present teaching of Polymer Science at the University.

CREATION OF THE PRESENT STRUCTURE AT THE INSTITUTE FOR POLYMER SCIENCE

The present Polymer Science staff consists of two members: a professor and a senior lecturer, with *ad hoc* financial support from the faculty for visiting lecturers, and a technical assistant. The 1997 student enrolment figures comprise one

postdoctoral-fellow, 15 PhD, 19 MSc and 17 honours students (a further seven students from other departments are associated). This latter number includes students of the Chemical Engineering Department, with whom we often interact, and who work partly in the polymer research laboratories.

The present research structure takes the form of a partnership between industry and the government, through the THRIP programme.

Prior to support via the THRIP programme, Polymer Science was under-equipped to meet certain acceptable standards (which are ever increasing). With the industrial THRIP link to the University of Stellenbosch, a marriage of industrial and academic needs occurred.

In the past some success was achieved by accepting small amounts of industrial funding and training students in industrially desired programme areas. None of this led, however, to entrepreneurial or major industrial expansion. Recent contracts under the Water Research Commission insisted that products should be deliverable. This led to an interdisciplinary scheme in which salaries for chemists, polymer scientists, chemical engineers and mechanical engineers were funded. It was in this way that membrane technology grew at this university in competition with more stereotyped attempts at a northern technikon, the CSIR and later the Atomic Energy Corporation. Both industry and local and international marketing developed.

The idea underlying the creation of the Technopark at Stellenbosch was that of bringing industry closer to the universities, but this did not succeed in the field of Polymer Science. What has succeeded is the approach similar to that of the University of Akron, namely that the research staff of corporate research laboratories are housed within the structure and milieu of a university teaching and research entity.

This year the Polymer Institute has been awarded a UNESCO internationally accepted centre at Stellenbosch University.

THE ROLE OF THRIP SUPPORT

Three years ago I sat on a Steering Committee Meeting for the THRIP programme with the founder/proposer, Dr A Geertsema (Sastech), amongst others. One of the points discussed was the need to create centres of excellence, first on a national basis and thereafter to create a centre that could compete internationally. It was said that such a centre would reach critical mass, acquire the correct facilities and attract both industrial funding and the top students. Properly trained manpower could then be created in South Africa, in research areas which correlate with industrial cluster plans for the short and medium term.

The Foundation for Research and Development core research programme would also provide parallel funding to ensure that, within such a THRIP programme, the long-term development goals could be met. This is often and correctly regarded as basic research, but is also the cornerstone of a successful growing industry, especially if there is a link between this long-term research and the short-term THRIP programmes.

By wisely choosing the collaborating industrial research groups, we could address a number of problems facing the University.
These include

- availability of up-to-date analytical equipment;
- training of technicians to use this equipment;
- funding the maintenance of the equipment.

Furthermore, the research becomes pertinent and overseas expertise far more readily available.

THE INFLUENCE OF THRIP ON OUR PRESENT STRUCTURE

How does this marriage between industry and university affect student enrolment, graduate student jobs, job creation in South Africa, replacement of imports and the creation of products for export expansion?

The student enrolment in postgraduate study in Polymer Science has doubled over the past four years and is placing an unexpected strain on academic and technical staff allotment and laboratory bench space. The result of this marriage is indicated by the number of postgraduates: in 1994 – 23; in 1995 – 29 (first year of THRIP funding); in 1996 – 33, and in 1997 – 51 (first major THRIP funding).

Job opportunities available for graduates in Polymer Science have always been high. In Belgium it was recently revealed that there are five jobs for every available polymer scientist. In South Africa, most of the students are already assured of a future job whilst studying and an increasing number of bursaries are being made available. We receive numerous requests for personnel, and at present students can be adequately trained only at Stellenbosch.

RECENT THRIP FINANCED SUCCESSES

The brand named paints of Plascon are strengthening their leadership in the market, following improved binder formulations.

Concerning import replacement: the drive of the industrial THRIP programme at the University addresses the threat of an overseas company flooding the market in a marketing exercise. Such a case in point occurs with ISCOR building new coil coating lines. The overseas engineering group specified more environmental friendly coatings for application for the steel in this plant, stipulating the international brand names. Dekro Paints, who produces coatings for steel for the two existing ISCOR plants, was not included in these specifications. A new water-based product has been tested successfully and is even more environmentally friendly than the imported product. This not only protects Dekro against imported products, but will also allow them to convert their existing lines at the other ISCOR plants and their next challenge is exporting a quality product that is not available overseas. Sales of R60 million are expected in 1998.

Marmoran, a specialist coatings company with stone finishes and stone-like decorative finishes, has been part of the industrial THRIP programme for three years. From a 1994 turnover of about R3 million, they had last year alone a R32 million contract with Malaysia for the supply of special polymer-bound finishes.

LINKS

As is done at overseas institutions, it is necessary for us to gather expertise and create a team that can solve, in a holistic fashion, a problem presented to the University. This favours creating links with other departments who, for similar reasons, wish to create links with us. Within the University of Stellenbosch, links that concern student sharing or joint project supervision exist between Polymer Science and many parts of the Department of Chemistry, with three staff members at Chemical Engineering, with Biochemistry, Wood Science, Animal Science and Electrical Engineering.

Formal regional links include those with Peninsula Technikon, Cape Technikon, University of the Western Cape and the University of Cape Town.

Formal national links include those with Port Elizabeth Technikon, UNISA, ML Sultan Technikon and PU for CHE.

Formal international links exist with Max Planck and the University of Wupperthal in Germany, with the Universities of Eindhoven and Delft in Holland, Moscow University and Karpov Institute in Russia, and with the Universities of Illinois and Southern Mississippi in the USA. All these links ensure student and staff sharing, both in South Africa and in the respective countries.

WHAT RESEARCH LINKS STELLENBOSCH UNIVERSITY WITH ALL THE ABOVE INSTITUTIONS?

In the field of membranes our goal is the provision of clean water for rural and coastal communities. Here we have a multi-faceted approach: new membranes are designed and produced in-house. With the Department of Chemical Engineering, housing is designed; with ML Sultan Technikon in Durban, plants are designed. With the network of technikons, these plants are built and put into the field and run, providing community water, e.g. at the former University Conference Centre at Mon Villa. Also in the field of membranes, research into catalytic electro-membranes for the decoloration and sterilization of water is carried out in collaboration with the company Radical Waters, the heterogeneous catalysis group at Max Planck and Prof U Simon at the University of Essen, Germany.

Separation and electrochemical catalytic membranes appear to be very useful for the separation of Sasol fuel streams into valuable products for the polymer industry. The Fischer Tropsch process at Sasol produces a range of products with hydrocarbons of different lengths, a high percentage of which comprises olefins. This is the basis of Polifin, which produces polyethylene and polypropylene from the lower members of the hydrocarbon family. Many of the larger molecules are hydrogenated to make petrol, oils and waxes. Our separation processes will facilitate the purification of the larger olefins. This is most meaningful as they have a value that can be ten times in excess of their value as a fuel stock. We have achieved a fair amount of success in this regard and have obtained the necessary patent(s).

As these new olefins become available, we will work together with Sasol and Polifin in creating new products. Such a product is, for example, the polypropylene/polypentene copolymer. A minor change to a very standard polymer such as polypropylene imparts more clarity in film applications and better sealability, and would thus be advantageous in

packaging potato chips, for instance.

Polifin has recently donated R2 million, spread over five years, for this work to be continued. Their aim is to foster a centre of expertise in their field at Stellenbosch University which would attract suitable students and become a concerted interaction between the University and Polifin. The new developments within the inorganic division of the Chemistry Department all augur well for this Polifin incentive at the University of Stellenbosch. We are the only university selected for such funding. Two bursaries have also become available yearly at R32 000 each for students wishing to study polymerization catalysts, with inorganic chemistry as 30% of their programme and polymer synthesis for the other 70% of their programme.

In the area of polymer synthesis, expansion will be into the area of polyolefin products, e.g. for Polifin and for injection-moulding and extrusion companies. Other synthesis work concerns the decorative industry which encompasses mainly Plascon, but also Dekro Paints and Marmoran. 80% of the decorative properties of coatings stem from the polymeric binder used. Whereas historically fats and oils sufficed as binders, over the last couple of decades, acrylics have become the preferred choice as they are user-friendly, colour fast, are gloss or matt and resist dirt retention.

Core shell polymerisation for the manufacture of binders, being available in South Africa, essentially began at the University of Stellenbosch and Plascon, and is now the household word for new decorative coatings and constitutes success also with Marmoran's thick film decorative coatings.

Concerning the field of electrical conducting binders, there has been interaction with the Department of Electrical Engineering and the company AMS. A host of adsorptive materials for radar and microwave instruments have resulted, of which the most notable are the outdoor radar test site, now available at Aerotech in Pretoria (800 square metres) and the new absorbent materials for millimetre wave and portable blankets and foams for vehicles. This joint interaction has been very beneficial and the industrial THRIP programme has proved its worth.

One of the more exciting programme areas is the creation of medical prostheses in the heart research group at the University of Cape Town where two students of the University of Stellenbosch work under the co-guidance of Prof Zilla. One student works on improved replacement heart valves with anti-thrombic coatings, whereas the other student works on improved synthetic coronary arteries.

SERVICES TO COMMUNITY (Industry and all South Africans)

Benefits to the community are numerous. Firstly, over the last 15 years we have offered an analytical service to the public at large. This has now been improved by the company Roediger Agencies. This industrial THRIP interaction links small industry to the University through a number of technical assistants who solve industrial problems. Output from this interaction has been a support to small industries with technical problems. The University profits from an added equipment list and trained technicians who can operate and maintain certain analytical equipment for student use.

The most meaningful services to the community have been in the fields of the provision of potable water and the cleaning up of industrial effluents, as well as the development of techniques in the paint industry, especially paints for low-cost housing in South Africa and the expansion of South African paint products overseas. Many new jobs have been created around these technologies.

This year an International United Nations Education, Science and Cultural Organization Centre was established at the University of Stellenbosch. The goals of the centre include expanding the training available at Stellenbosch in materials science into the rural areas of South Africa and undeveloped areas of Africa, the Near and Far East, former Communist Bloc Countries and parts of South America. They wish us to approach this project by making distance education materials available as a service to factories, schools, technical colleges and universities. These materials are to consist of subject matter in the form of written, audio and visual and preferably also multi-media aids. Also required are inexpensive practical kits. As a structure emerges we are to propose additional UNESCO schools for macromolecules and materials at other chosen international centres to be under the umbrella of the Stellenbosch University UNESCO Centre.

In providing such a service, we are already collaborating with the Chemical Education Department of Witwatersrand University and the University of Illinois in the USA, but will in future attempt to link up more strongly with the language departments of our own University and special departments in Australia, the USA and Holland. IUPAC will help fund this endeavour.

The centre will also offer facilities for professors

from overseas to spend a couple of months to finalize their research projects on one of our instruments or to use library materials. We hope to offer a similar facility as a help to PhD students enrolled at African universities who might wish to accompany their professors for a short stay.

OUR FUTURE

Academically, a programme in applied science can be very beneficial to the University. This could be in the form of an undergraduate materials science programme and postgraduate polymer science and engineering programmes.

Already on the horizon is the need by the polymer industry for chemical engineering activities, such as process control and on-line monitoring, while plastic closures and corks are areas suggested for regional industrial growth linked to the soft wine-drink industries.

In terms of the industrial THRIP programme, the structure is very much in place, as are the interdepartmental and faculty links. New academic appointees need to include at least one chemical engineer and one chemist in the fields of polymer engineering and catalysis/polymer synthesis respectively. Polymer engineering, in some form or other, needs to be introduced to the University in collaboration with either chemical or mechanical engineering or in the short term through visiting professors.

Stellenbosch has been and is still considered as an internationally strong contender in various areas of Polymer Science. The recent award of the International UNESCO Centre confirms this.

If we can follow the trend of international successes, then the University should consider the establishment of academically structured institutes as separate entities, on a par with departments, but differing in having a multidisciplinary and formalized joint staff who interface between faculties. This opens teaching and research as well as student acceptance into the bio-engineering and engineering fields.

The Institute for Polymer Science at the University of Stellenbosch could follow this lead and grow not only into a plus point for the University, but also blossom and grow into the main player in South African Tertiary Education in polymers.

CONCLUSIONS

Advances in Polymer Science will continue to enhance our lives in an ever-increasing manner. The high growth over the past 25 years will continue to be above general industrial growth rates. The use of polymeric materials, especially in improved packaging, electronics, ecology and medical products are areas of major growth.

ACKNOWLEDGEMENTS

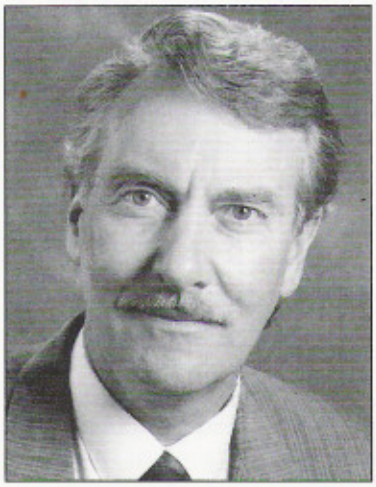
The following are most sincerely thanked for their support, in many and varied ways:

- The Rector
- The Dean of the Science Faculty
- The Research Development Division
- The Head of the Department of Chemistry
- Colleagues and University staff, past and present
- Institute for Polymer Science staff and students, past and present
- Sponsors (WRC, FRD/DTI, various industries)
- Erinda Cooper and Aneli Fourie for the presentation.

Designed and printed by US Printers, Stellenbosch

ISBN 0 7972 0666 3

INTRODUCTION



Prof Ron Sanderson obtained his BScHons degree from the University of Cape Town and his PhD (Polymer Science) from the University of Akron, USA. On his return, in 1970, he was appointed as a senior lecturer in the Department of Chemistry at the University of Stellenbosch.

During the mid-1970s he developed a special interest in polymeric membranes, particularly for water treatment. In April 1978 the Institute for Polymer Science was established, and soon thereafter a full Polymer Science Honours course was introduced. From then, until now, he has been the director of the Institute. Research and development is currently being done in the areas of decorative, active and passive polymeric films. This has attracted many postgraduate students, many of whom are from previously disadvantaged areas, and several from other countries. At present more than 50 postgraduate students (22 PhD, 24 MSc and 10 Honours) are registered for Polymer Science. Prof Sanderson has also actively promoted the idea of 'campus companies' within the Institute.

In 1997 he was awarded the associated UNESCO Centre for Macromolecules and Materials, the only UNESCO centre in this discipline.

Prof Sanderson is on the editorial board of the journal *Macromolecular Reports* and on the review board of *Journal of Membrane Science*. He himself has been author or co-author of at least 80 publications, 8 chapters in books, 88 international conference papers, 23 South African patents and 9 international patents. He has been promoter of co-promoter of at least 48 completed MSc degrees and 15 completed PhD degrees. He has served as a committee member of the following professional societies or associations: African Union of Pure and Applied Chemistry; International Association of Water Quality, Membrane Division; Water Institute, SA, both the MTD and the IUPAC Macromolecular Division. He is also a member of numerous other societies.

He has been honoured with the following awards: Centre of Expertise for Membrane Studies, 1988 (Water Research Commission); the William Sage Award of the Plastic and Rubber Institute, 1989, SA Division, and the Chemical Manufacturers' Association Award (shared with Dr EP Jacobs) for the best academic contribution to SA industry during 1992.

His main professional and research interests currently include postgraduate training in the field of Polymer Science, international co-operation in the field of membranes and thin-film research, the development of membrane hardware and reactors, and technology transfer.