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Chemistry

• EDITORIAL •

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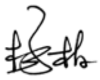
Preface

In Honor of the 80th Birthdays of Professors SHEN JiaCong, SHEN ZhiQuan and ZHUO RenXi

Professors SHEN JiaCong, SHEN ZhiQuan and ZHUO RenXi are famous chemists and educationists of China, and academicians of the Chinese Academy of Sciences. Although born in 1931 and approaching their 80th birthdays, these scientists are still very active in both research and education. Many of their students have become professors and leaders at universities in China, the US, and other countries. The three professors have made significant contributions to the promotion and growth of polymer science in China. To commemorate their 80th birthdays, the editorial board of *Science China Chemistry* has produced this special issue in Chinese and English Editions. We are honored to dedicate this issue to them. We thank the many professors who have contributed a great deal of time and effort to this special issue on writing and reviewing. We also thank the editorial staffs of *Science China Chemistry*, Dr ZHU XiaoWen, and Dr TIAN Ying for their work on the design, organization, editing and production of this issue.



YANG Bai GAO ChangYou ZHANG XianZheng

January 17, 2011

YANG Bai received his Ph.D. in Polymer Chemistry and Physics (1991) from the Chemistry Department at Jilin University. During this time, he investigated the design and synthesis of high performance optical polymers. Later he studied the preparation of polymer nanocomposites and hybrids with high refractive indices and photo-electro functionalities. In 1992, he was appointed as an associate professor and then promoted to full professor in 1994. In 1999, he received the National Science Fund for Distinguished Young Scholars of China and the honor of Cheung Kong Scholar from the Ministry of Education of China. His current research is focused on studies of the synthesis and properties of quantum dots (QDs) in polymers, high index optical hybrid materials, and fabrication of ordered polymeric microstructures with photonic properties by modified soft lithography. Since 2008, he has been a member of the editorial board of *Science China Chemistry*.

GAO ChangYou received his Ph.D. (1996) in Polymer Chemistry and Physics from Jilin University under the supervision of Profs. SHEN JiaCong and YANG Bai. He worked in the Department of Polymer Science and Engineering at Zhejiang University as a postdoctoral fellow from 1996 to 1998, before joining the faculty as an associate professor from 1998 to 2001. He was promoted to full professor in 2002. Prof. GAO was a principal investigator for the National Science Fund for Distinguished Young Scholars of China (2004), and was appointed as a Cheung Kong Scholar from the Ministry of Education (2007). His research focuses on biomedical materials for tissue engineering and regenerative medicine. Since 2008, he has been a member of the editorial board of *Science China Chemistry*.

ZHANG XianZheng received his Ph.D. in Polymer Science from Wuhan University in 2000 under the supervision of Prof. ZHUO RenXi. He worked in the Institute of Materials Research and Engineering in Singapore as a research associate from 2000 to 2001. From 2001 to 2004, he worked as a postdoctoral associate at Cornell University. He was appointed as a professor at Wuhan University in 2004. He is a member of the editorial board of the *Journal of Bioactive and Compatible Polymers* and the *Journal of Clinical Rehabilitative Tissue Engineering Research* (in Chinese). He is involved in several national research projects such as the National Basic Research Program of China (the 973 Program) and the project from National Natural Science Foundation of China. His research focuses on design and synthesis of biomedical polymers and their applications in the biomedical and biotechnological fields, such as controlled drug release, tissue engineering, and gene delivery.

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SHEN JiaCong

Professor SHEN JiaCong

SHEN JiaCong was born in Zhejiang, China, in October 1931. He is a polymer chemist and pioneer of supramolecular chemistry in China. In 1991, he was elected Academician of the Chinese Academy of Sciences. Prof. Shen has been working at Jilin University (formerly Northeast Renmin University) since his graduation from the Department of Chemistry, Zhejiang University, in 1952. In the 1960s, he studied organic chemistry and polymer chemistry under Prof. TAO WeiSun, and polymer reaction statistical theory and micro kinetics under Prof. TANG AoQing. During this time, he studied the relationships between molecular weight distribution and polymer reaction mechanisms and polymer chain structure/distribution using statistical theory construction through modeling and probability function. He also used the paramagnetic resonance method to trace radical reactivity changes in bulk polymerization system, and reveal microenvironment and diffusion images of active radicals. Furthermore, he developed optical resin with a high refractive index. Since the late 1980s, Prof. Shen's research focuses mainly on supramolecular chemistry and self-assembly techniques.

Prof. Shen entered the field of supramolecular chemistry by developing interfacial self-assembly methods for the fabrication of various composite films. By conducting multiple electrostatic self-assembly at liquid/solid interface using building blocks with mesogen groups, his group successfully fabricated a large variety of organic-organic, organic-inorganic, organic-polymeric and inorganic nanoparticle-oligomer multilayer films. The introduction of mesogen groups greatly enhances the stability of the multilayers and is proven to be useful to fabricate multilayer films with clear interfaces. This work pioneered a novel way to fabricate ultrathin organic functional composite films and inorganic-organic hybrid materials which can integrate multiple functions. By sequential assembly of enzymes and oppositely charged partner species in aqueous solutions, multilayer films of enzymes were fabricated in a mild condition which is key important to keep the activity of the enzymes in the films. This concept of enzyme assembly provides a facile way for the immobilization of highly efficient enzyme in porous carriers. Prof. Shen noticed that, compared with ultrathin films, the micrometer-thick films can load more drugs and realize the sustainable release of drugs, and meanwhile are easier to control the micro-/nanostructured morphologies. Then, he and coworkers developed several strategies of rapid layer-by-layer assembly for the fabrication of micrometer-thick films with high loading capacity and easily tailored hierarchical micro-/nanostructures. With the layer-by-layer assembled thick films in hands, they can peel the films from substrates to obtain free-standing films with the functionalities not restricted by the underlying substrates. They can also fabricate films with self-healing ability to produce endurable materials for a long term of usage. Besides the layer-by-layer assembled films based on electrostatic interactions, his team established the layer-by-layer assembly methods based on hydrogen bonding and coordination bonding as driving forces, which enables multilayer fabrication in non-aqueous solutions. Prof. Shen took advantage of the self-organization in the layer-by-layer assembly process to fabricate ordered thin films. For example, the self-organization of star polymers with polymerizable double bonds and well-tailored wettability in aqueous solution produce duckweed and reversed duckweed monolayers, which can be transferred to substrates to produce thin films with crystal-like structures. Systematic spectroscopic investigations were conducted to clarify the structures of the assemblies and to understand the structure-dependent self-organization/assembly behaviors of the star polymers. The above achievements won him the Second Prize of National Natural Science in 2004. Based on the research results of his team, he and his colleagues wrote a book *Layered Supramolecular Structures – Assemblies and Functions*, which was published by Science Press in 2004 and was recognized as an authoritative reference in the field of interfacial assembly and composite film fabrication.

With the development of supramolecular chemistry, more attention has been paid to understand the intrinsic relationship between life science and supramolecular science. Prof. Shen realized in early 1990s that biological supramolecular systems would be the source of new thinking and new ideas for supramolecular chemistry. He regarded that enzymes are high efficient catalysts in nature and the simulation of enzymes are helpful for designing high efficient supramolecular catalysts. Therefore, the simulation of the antioxidative glutathione peroxidase (GPx), one of the natural seleno-enzymes, has been his main research topic. To design artificial enzymes with catalytic efficiencies and specificities equivalent to or superior than natural enzymes, he and co-workers modified and reconstructed the active sites on naturally existing protein scaffolds for the preparation of artificial enzymes based on the concepts of supramolecular recognition. They further put forward the concept of substrate-recognition and catalysis synergy for designing of high efficient artificial enzymes. They obtained a large variety of artificial seleno-enzymes, spanning from small host molecules, imprinted polymers, natural enzymes, antibodies to nano-enzymes by combining multidisciplinary strategies, including chemical synthesis, genetic engineering, molecular imprinting, monoclonal antibody technology, supramolecular self-assembly and nanotechnology. Most of the artificial seleno-enzymes have extraordinarily high activities comparable to natural ones, providing a novel concept to designing supramolecular catalysts. The achievements in artificial enzymes won him the First Prize of Advanced Scientific and Technology Award of Jilin Province in 2009.

In early 1990s, photoelectric industry developed rapidly. The traditional inorganic semiconductor materials can not fully meet the demand for the rapid development of photoelectric industry. Prof. Shen recognized that the organic photoelectric materials would hold a great promise in photoelectric and related industry and started the research on photoelectric functional materials. In their research work, they emphasized innovation concepts in the design and development of novel photoelectric materials. They proposed and experimentally established the principles to enhance the efficiency of electroluminescent devices with the use of phosphorescent materials. They developed a class of new phosphorescent materials which have been proven to have the highest electroluminescent efficiency. They introduced the concept of supramolecular science to the design and synthesis of light-emitting materials. The weak intermolecular interactions and their guiding roles in the formation of aggregated structures of light-emitting molecules have been studied systematically. A molecular cross-stacking mode named X-aggregate, was proposed to be useful for the preparation of light-emitting molecules with highly enhanced efficiency. Experimental results confirmed that light-emitting molecules in the X-aggregate state show high luminous efficiency and chroma stability. This discovery solved the problem of aggregation quenching fluorescence, which is the puzzled problem in the field of luminescent materials. The above achievements won him the First Natural Science Prize of Scientific Research Achievements of the Ministry of Education of China in 2001 and the Second Prize of National Natural Science in 2009. The achievements of basic research also attracted a great deal of attention in the industry. A R&D and production base was established on the basis of Jilin University's technology of luminescent materials.

His academic achievements, such as Statistical Theory of Condensation & Addition Polymerization and Cross-Linking Reaction, Layer-by-Layer Assembly and Function of Organic Polymer System, New-Concept Organic Electroluminescent Materials, and Synthesis and Fabrication of Micro-/NanoStructured Polymer Optical Functional Composites, won him the National Natural Science Award (second class) in 1989, 2004, 2009, and 2010. He has coauthored books on *Statistical Theory of Polymer Reaction*, *Micro Reaction Kinetics of Addition Polymerization*, *Layered Supramolecular Structures – Assemblies and Functions*, along with more than 500 publications. More than 70 doctoral students graduated under the supervision of Prof. Shen since 1978. Some of these graduates hold key positions at local and international universities, institutions and high-tech enterprises.

Prof. Shen has worked at Jilin University for almost 60 years. After his graduation from Zhejiang University in September 1952, under the necessity of national reconstruction, he transferred with a large group of graduates to Shenyang by train. Prof. Shen has made great contributions to education and scientific research, and was also actively involved in administration work and devoted himself to the development of both the College of Chemistry and Jilin University. He was appointed the dean of the Chemistry Department from 1980 to 1985, and vice-president of Jilin University from 1985 to 1990. In 1992, Prof. Shen was entrusted by Prof. TANG AoQing as the director of the Open

Prof. Shen was working with his group members

Laboratory of the Molecular Spectrum & Structure at Jilin University. With a scientist's strategic foresight, Prof. Shen decided that supramolecular chemistry was the new and main research objective of the laboratory and thereafter established Key Laboratory of Supramolecular Structure and Materials. He emphasized the use of spectral methods to study the assembly and function of supramolecular systems. Prof. Shen made every attempt to update instruments and equipments of the laboratory. He always has an open mind in collaborating with young scientists. He encourages young scientists for their career achievements. His Two Bases Ideas attracted many young scientists to work hard in the laboratory. Under the leadership of Prof. Shen, the key laboratory is renowned both domestically and internationally because of its advanced equipments, nice academic reputation and rational promotion pathway for young scientists. On a purpose of cultivating excellent young scientists, he offered the director position to a young scientist in 1997. Ten years after this, in 2007, the laboratory was upgraded to a State Key Laboratory, and is recognized as an international research base. Overall, the laboratory's progress is linked to Prof. Shen's supervision, sense of responsibility, and disregard of personal gain.

In 1984, Prof. Shen was appointed as a guest professor at the University of Utah, USA, which broadened his knowledge of research methodology, and encouraged him to develop his research to an international level. He attended a number of international academic symposiums in the United States and other developed countries. By making full use of these opportunities, he established important international collaborations with world famous scientists, which have facilitated rapid development of supramolecular science in China. Prof. Shen has co-chaired the Xiangshan Scientific Symposium four times since 1994 with Jean-Marie Lehn (Nobel Laureate, founder of supramolecular chemistry, member of the French Academy of Sciences), Helmut Ringsdorf (member of the German Academy of Sciences), and George M. Whitesides (member of the United States National Academy of Sciences), which greatly impels the development of supramolecular chemistry in China.

Prof. Shen was giving a lecture

Prof. Shen is also concerned about the evolution of his Alma Mater – Zhejiang University. Concurrently to his position at Jilin University, he accepted a joint professor position in the Department of Polymer Science and Engineering in 1995, and the College of Material & Chemistry in Zhejiang University from 1999 to 2008. During this time at Zhejiang University, he investigated biomedical materials. A group of young scientists at the university were inspired by his creative thinking and strategic scientific planning, and evolved into an active group in this emerging interdisciplinary field. Prof. Shen established the Biomedical Macromolecular Institution at Zhejiang University in 2008.

Prof. Shen's curriculum vitae present a series of breakthroughs ranging from polymer reaction micro kinetics to supramolecular chemistry, photoelectrical materials and biomedical materials. Prof. Shen's research achievements highlight his strategic vision and creative spirit, and have ensured his station in the progress of Chinese chemistry. His peers and students are strongly impressed by his indomitable attitude and diligence toward research, and his passion for encouraging young scientists.

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SHEN ZhiQuan

Professor SHEN ZhiQuan

SHEN ZhiQuan was born in Shanghai in 1931. She is a polymer chemist and scientist of rare earth coordination polymerization in China. In 1995, she was elected Academician of the Chinese Academy of Sciences. She received her Bachelor degree from the Department of Chemistry of Shanghai University in 1952. From 1952 to 1962 she worked at Suzhou University, and from 1962 to 1979 at the Changchun Institute of Applied Chemistry, Chinese Academy of Sciences. Since 1980 she has worked at Zhejiang University, where in 1984 she was promoted to professor. Other positions she has held include Chair of the Department of Chemistry, Head of the Polymer Chemistry Institute, Consultant Member of the Chinese Chemical Society, member of the State Council Degree Committee, member of the Evaluation Group of the National Natural Science Foundation, and Vice Chairman of the Zhejiang Association for Science and Technology. Currently, Prof. Shen is a doctoral advisor in the Department of Polymer Science and Engineering of Zhejiang University. She also works as a consultant for the *Science China Chemistry* and other ten more journals. She is the Committee Member of the State Key Laboratories of Polymer Materials Engineering and Polymer Chemistry and Physics.

Prof. Shen has long been engaged in basic polymer chemistry and materials science research, and has mainly focused on studies of transition metal and rare earth coordination polymerization. During the 1960s, she was the first in China to investigate the *cis*-polybutadiene rubber by trinary nickel catalytic system, and contributed substantially towards the establishment of the Chinese polybutadiene rubber industry. For this she was a major awardee of the Special Class Prize from the National Science and Technology Progress of China (1985). Her international contribution to the development of rare earth coordination polymerization for rubber has been outstanding. Between the 1960s and the 1970s, she conducted and led research on rare earth coordination polymerization and related rubber investigations, consequently, she was awarded the Second Class Prize of the National Natural Science Prizes of China in 1982. During the 1980s and the 1990s, Prof. Shen and her group conducted systematic studies on the polymerization of acetylene and its derivatives (terminal alkynes, phenyl acetylene), oxiranes (ethylene oxide, propylene oxide, epichlorohydrin), thiirane, octene, lactide, lactone, and acrylates. They have also researched rare earth catalysis of the copolymerization of CO_2-oxirane, styrene-maleic anhydride, styrene-acrylonitrile, oxirane-maleic anhydride and more. Based on innovations from this research, she was awarded the Third Class Prize of the National Natural Science Prizes of China in 1993, several prizes from the State Educational Commission and Zhejiang Province, First Prize of Guanghua Science and Technology in 1994, the Prize for Science and Technology Progress of Ho Leung Ho Lee Foundation in 2001, and the Prize of the Zhu KeZhen Foundation of Zhejiang University in 2002. She has instructed more than 40 PhD and master students. One of her students won the First National Excellent Doctoral Dissertation Award, many have become professors in universities in different countries all over the world, and some have become leaders in their research fields.

Prof. Shen has more than 400 academic publications and several patents. She has been recognized with the following awards: First Advanced Science and Technology Female Workers in Zhejiang Province (1988), National Advanced Women Worker (1993), Ten most Distinguished Ladies in Zhejiang Province (1995), Labour Model of National Education System (1995), People Teacher Award (1998), Ten Most Distinguished Ladies in China (1998), and National Ethics Advanced Individuals (2001).

During the economic and technological isolation of China in the early 1960s, Prof. Shen under the guidance of Professor OUYANG Jun (Director of The Polymer Synthesis Laboratory, Changchun Institute) studied the synthesis

Prof. Shen is in her office

of *cis*-polybutadiene rubber with various catalytic systems. A series of butadiene rubber compounds named Butadiene 1, Butadiene 2, Butadiene 3 and Butadiene 4 were successfully fabricated using catalytic systems containing titanium, cobalt, and cobalt with microlevel amounts of nickel, respectively. Inspired by the literature, Prof. Shen began to explore methods for preparing *cis*-polybutadiene rubber using the ternary nickel catalytic system nickel naphthenate-boron trifluoride diethyl etherate-trialkylaluminium in alkane solvent (Butadiene 5). After extensive exploration and modification, Butadiene 5 was successfully prepared. Synthetic rubber producers agreed to industrial production of Butadiene 5 by the Sixth Jinzhou Petroleum Factory, which is currently the PetroChina Jinzhou PetroChemical Company. After several years of research and collaboration, industrial production of Butadiene 5 began in China. Later on, five more 10000 ton butadiene rubber factories were constructed, including Beijing Yanshan Rubber Factory, Yueyang Synthetic Rubber Factory, Shandong Synthetic Rubber Factory and Shanghai Synthetic Rubber Factory. As a result, Changchun Institute of Applied Chemistry, the Sixth Jinzhou Petroleum Factory and some other institutes were awarded the Special Class Prize of National Science and Technology Progress of China (1985), of which Prof. Shen was one of the major awardees.

In 1962, Prof. Shen employed rare earth compounds to replace the traditional Ziegler-Natta catalyst in butadiene polymerization. She found this polymerization could be catalyzed by chloride and aluminum triethyl heterogeneous phase systems of nine anhydrous rare earth metals, including yttrium, lanthanum, cerium, praseodymium, neodymium, samarium, gadolinium, erbium and ytterbium. The ytterbium chloride–aluminum triethyl system had particularly high activity, and could be used to prepare 1,4-poly-utadiene rubber with more than 94% in the *cis* form and a molecular weight of 300000–600000 Da. The original research was published in 1964 in the *Chinese Science Bulletin*, a top academic journal in China. This was the first article in the world to report stereospecific polymerization of butadiene by rare earth catalysts. After this, Prof. Shen studied stereospecific polymerization of butadiene by β-diketone chelates, which were provided by YAO KeMin (Inorganic Chemistry Labortary, Changchun Institute of Applied Chemistry). These included benzoyl acetone, benzoyl trifluoroacetone and thenoyltrifluoroacetone chelate with different rare earths and in trialkylaluminum homogeneous systems. Surprisingly, it was discovered that the homogeneous system had higher catalytic activity than the heterogeneous system, and the system of praseodymium and neodymium produced 1,4-polybutadiene rubber with 96% in the *cis* form. This research was published by *Polymer Communication* in 1965, and was the first academic article in the world that covered the stereospecific polymerization of butadiene by rare earth chelates. In 1970, Professor WANG FoSong, who was elected Academician of the Chinese Academy of Sciences in 1991, successfully polymerized isoprene using rare earth compounds.

During 18 years of work in the Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Prof. Shen and her colleagues have conducted laboratory and industrial studies on nickel and rare earth catalysis of *cis*-polybutadiene rubber polymerization. Because of her hard work, Prof. Shen was awarded several national Prizes. In 1973, she participated in a Chinese Academy Polymer Delegation to Japan. When meeting with Japanese synthetic rubber experts and professors, she and her colleagues were complimented for having achieved the miracle to synthesize and industrialize more than one kind of rubber in one person "life". Prof. Shen was very pleased and felt honored that she had been involved in these significant events of the rubber industry of China.

With the support of Sinopec Beijing Yanshan Company, Prof. Shen and Professor ZHANG YiFeng *et al.* studied the gas-phase polymerization of butadiene in 1997. After comprehensive selection, combination and exploration of preparation methods, a supported rare earth catalyst for gas-phase polymerization of butadiene was successfully developed. Its high catalytic activity and high tacticity led to its approval for a China Invention Patent (No. ZL99101536.3, approved on May 8, 2002).

In 1981, Prof. Shen and YANG MuJie *et al.*, were the first to employ rare earth catalysts to prepare *cis*-polyacetylene film at room temperature with excellent thermo stability and antioxidant activity. Polyacetylene can be doped with either electron donor or acceptor impurities to form n- or p-type semiconductors, respectively. It can achieve the conductivity of metal, and is referred to as a synthetic metal. Around the same time, American, New Zealand, and Japanese scientists were attempting to develop plastic batteries made of polyacetylene. Because of their research into conductive polymers (like polyacetylene), scientists from these three countries were jointly awarded the Nobel Prize for Chemistry in 2000.

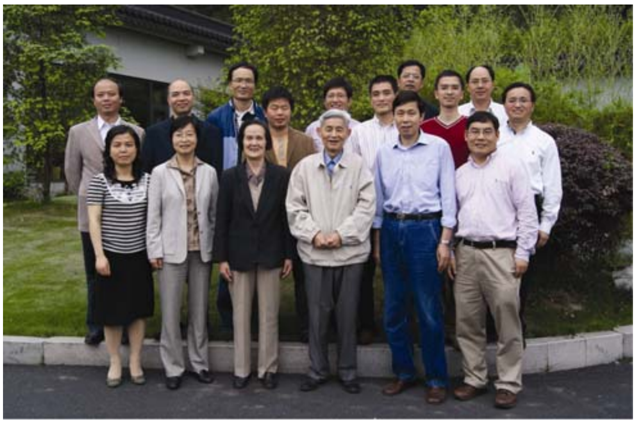
With the rare earth catalytic system, ring-opening polymerization of ethleneoxide could be achieved. Under certain conditions, poly(ethylene oxide) could be prepared with molecular weights of 500000 Da and with more than 80% conversion. Prof. Shen further discovered that the rare earth acetylacetonate–triisobutylaluminum–water system was a good catalyst for the ring-opening polymerization of epichlorohydrin (ECH). This system produces rapid polymerization and the molecular weight of polyepichlorohydrin can reach up to 1000000 Da with a crystallinity of 10–20, which is lower than with other catalytic systems. These characteristics are ideal for a synthetic rubber.

Prof. Shen has also been involved in important research on how to fix carbon dioxide, which is a key problem for the utilization of natural resources and protection of environment. In 1980, Prof. Shen and Prof. ZHANG YiFeng *et al.* first found that a novel catalyst, which was composed of rare earth phosphonate [$Ln(P_{204})_3$], triisobutylaluminum (TIBA) and glycerine, could copolymerize carbon dioxide and propylene. Most importantly, the activity of the $Y(P_{204})_3$-TIBA-glycerine system was the highest, and could be used to prepare polycarbonate with a molecular weight as high as 470000 Da. Furthermore, the thermal decomposition temperature of the produced polycarbonate was more than 300 °C, which indicates it has excellent thermo stability.

Prof. Shen and colleagues have also systematically studied the use of various catalysts composed of different rare earths, coordinating groups and trialkylaluminums to the ring-opening polymerization of lactide to prepare polylactide. The product has stable and controllable molecular weight, and a narrow poly-distribution under mild reaction conditions.

Since 2001, Prof. Shen's group has continued their investigation of the synthesis of rare earth catalysts and their corresponding polymerization properties, resulting in a number of innovations. They continued to produce excellent results in the expansion of applications for traditional multi-component rare earth catalysts in the synthesis of polymers, studies of the rare earth catalyzed homopolymerization and copolymerization of novel monomers such as isocyanates and allene. Rare earth catalysts were creatively employed to catalyze degradable aliphatic copolyesters by condensation polymerization. They also researched and prepared rare earth complexes with new structures, identified the crystal structures of more than ten of these complexes, and investigated their applications as one-component catalysts in the controllable ring-opening polymerization. Additionally, they conducted quantum computational and other computer simulation studies of the mechanism of the ring-opening polymerization catalyzed by rare earth catalysts, which had not been investigated thoroughly either in China or abroad. Furthermore, they combined rare earth catalysts and new polymerization approaches, for example ATRP and click chemistry, to synthesize classes of polymers with novel topological structures. These included calixarene- or cyclodextrin-core amphiphilic multiarm or heteroarm star-shaped polymers, allene-backbone graft copolymers, and amphiphilic block copolymers. They studied the micellization of these polymers and investigated applications for them in many fields including sustained drug release and nano-metal preparation. The group's academic achievements greatly advanced the research of rare earth catalyzed synthetic polymers.

Prof. Shen has diligently served her country and people for more than fifty years, and has dedicated her life's work to the promotion of education and science promotion in China. Her indomitable and enterprising spirit, hard work, sincere humility, generosity and helpfulness have impressed everyone coming into contact with her. Her self-discipline, tolerance of others, and enthusiasm when tutoring the younger generation mean she is held in deep esteem by students and colleagues in the field of chemistry.



Prof. Shen's group members

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ZHUO RenXi


Professor ZHUO RenXi

ZHUO RenXi was born on Gulangyu Island, Xiamen, Fujian Province in 1931. Prof. Zhuo has been recognized for his research in biomedical polymers. In 1997, he was elected Academician of the Chinese Academy of Sciences. Since graduating from the Department of Chemistry at Fudan University in 1953, Prof. Zhuo has taught in the Department of Chemistry at Wuhan University. He has more than 570 publications and has received many honors in recognition of his research achievements. Prof. Zhuo has been presented with a number of national awards including the National Natural Science Award (1991 and 1999), the Science and Technology Progress Award from the Ministry of Education (1991 and 1999), the National Invention Award for Science and Technology from the Ministry of Science and Technology (1983), and the National Science Congress Award (1978).

Prof. Zhuo's academic career began in the 1950s as a young faculty member at Wuhan University. From 1957 to 1959, he conducted elementary organic chemistry research in the Department of Chemistry at Nankai University under the supervision of a professor from the Former Soviet Union. He mainly concentrated on the chemistry of organosilicon compounds. This research focus continued into the 1960s and early 1970s, when Prof. Zhuo's conducted fundamental studies on organosilicon compounds and silicon-based polymers, such as investigating Darzens reactions of organosilicon compounds, and the reactions between carbene and silicon-containing compounds. These organosilicon compounds and polymers were widely used for civil and military purposes. In 1972, the Office of Research at Wuhan University assigned a research project on Anti-fog Optical Glasses to Prof. Zhuo's group. Prof. Zhuo and his coworkers found that erosion of the optical glass surface led to the fogging that unfavorably affected the glass transparency. To overcome this issue, they designed and synthesized a silicon coating for the glass that contained a long alkyl chain. This coating could form a thin and transparent layer on the glass surface, and successfully maintained the high transparency of the optical glass. This coating could also be used in many optical devices. Later on, this technology was used on the crystal coffin of Chairman MAO ZeDong. The success of this research was honored with the National Science Congress Award (1978) and the National Invention Award for Science and Technology (1983). Prof. Zhuo's another organosilicon research project began in 1975 after a factory that manufactured magnetic tapes encountered technological difficulties. When the magnetic tapes were played image trailing occurred, and data were lost when the magnetic tapes were used for storage of computer data. These issues were caused by the detachment of magnetic particles from the tapes and the uneven distribution of the magnetic particles on the tapes. Prof. Zhuo and two colleagues visited the factory, and after carefully checking the production process, they found the performance of the two-component copolymer the factory used was not satisfactory. They suggested to replace the two-component copolymer with a slightly hydrophilic three-component copolymer, and added an organosilicon compound to improve adhesion between the magnetic particles and the copolymer. This resulted in the better adhesion between the magnetic particles and the copolymer, which led to the good dispersion of the magnetic particles on the tapes. After taking Prof. Zhuo's suggestion, the factory successfully solved this technological problem. This research was awarded the National Science Congress Award (1978).

In the 1970s, Wuhan University began to enrol students in its BS and MS programs in Polymer Chemistry and Physics. Because the research areas of these programs were not well defined at this time, Prof. Zhuo took this as an opportunity to review his own research focus. After thorough investigation of the research conducted at other universities and institutes and the international research frontiers of polymer science, his research focus turned to biomedical polymers in the late 1970s.

From the early 1980s, Prof. Zhuo's research has concentrated on molecular design, synthesis and characterization of biodegradable polymers, especially those with good biocompatibility. He has investigated polylactide, poly(β-hydroxybutyrate), polyphosphates, poly(amino acids), polycarbonates, polyanhydrides, and their functional derivatives and copolymers. A representative work was the systematic study on the enzymatic ring-opening polymerization of cyclic phosphates, carbonates and other cyclic monomers. As a new approach for synthesis of biodegradable polymers, enzymatic catalysis could eliminate the potential toxicity from metal-containing catalysts. Prof. Zhuo's group studied the catalysis by enzymes such as free lipases and immobilized enzymes on silica and TiO_2 nanoparticles. The immobilized enzymes were highly efficient catalysts for the ring-opening polymerizations of cyclic carbonates and cyclic phosphates. In contrast to the limited molecular weight products obtained from conventional enzymatic polymerizations initiated by free lipases, the polymerizations catalyzed by the immobilized enzymes produced polymers with high molecular weights.

Prof. Zhuo (left 2) attended the 27th IUPAC Polymer International Conference in 1981

Biomaterials are essential to meet the health needs of China's large population. One of the most important applications of polymeric biomaterials is drug delivery. Drug delivery systems aim to provide the controlled, systematic or site-specific drug release over an extended period of time. These systems have many advantages compared to conventional therapeutic systems, including the prolonged drug release, reduced side effects, improved drug bioactivity, and the enhanced therapeutic efficiency. Biodegradable polymers are important as the matrices for drug delivery systems. Prof. Zhuo's research in this field includes synthesis and characterization of novel biodegradable polymers with adjustable physicochemical and biological properties. The biodegradable polymers investigated include polycarbonates, polyesters, polyphosphates and polyphosphoesters with different functional groups. The incorporation of functional groups on the polymers could modulate the physicochemical properties such as degradability and hydrophilicity, and facilitate further modifications.

To enhance the bioavailability of therapeutics and to deliver therapeutic agents to aimed tissues and cells, drug carriers should ideally be responsive to stimuli and be targetable. Due to the small size and the relatively large surface area, which facilitate the functionalization of the nanoparticles, nanoparticulate drug delivery systems have unique advantages to realize stimuli tailored drug delivery and to achieve active targeting compared with other drug formulations. Prof. Zhuo's group designed and prepared various nanoparticle-based drug delivery systems with the stimuli responsiveness to pH, temperature, redox potential, light and magnetic fields. To achieve enhanced synergy effects,, nanoparticle systems with double/multiple stimuli responsiveness were developed recently. Compared to the systems that respond to single stimuli, these multi-response systems could achieve more functions and could be modulated through different parameters. To further endow the nanoparticles with active targeting property, numerous studies in his group have been carried out on the incorporation of various targeting ligands to nanoparticle drug delivery systems through covalent bonds and biotin-avidin interaction.

In addition to drug delivery systems, novel vaccine adjuvants are also investigated in Prof. Zhuo's group. They found that polyphosphate derivatives with tyrosine dipeptide units could be used as vaccine adjuvants, which exhibited comparable capacity to stimulate immune responses as compared with Freund's complete adjuvant (FCA).

Besides the drug delivery systems for therapeutic purposes, Prof. Zhuo's group also works on diagnostic agents. In the 1990s, Prof. Zhuo began research on organ targeted magnetic resonance imaging (MRI) contrast agents composed of gadolinium complexes conjugated with different ligands such as DTPA, DOTA, amino acids and polymers.

The human genome project paved the way for a greater understanding of genetic diseases. It is now theoretically possible to treat diseases of genetic origin by administering healthy copies of genes with disease mutations or to promote a protective immune response by administering genes encoding specific antigens. However, the greatest hurdle to the realization of gene therapies is the development of efficacious delivery systems. Although viral vectors are efficient at mediating gene expression, safety issues seriously limit their application. Despite their comparatively low efficiency, non-viral vectors have many advantages over viral vectors in terms of safety and ease of manufacture. Most efforts of Prof. Zhuo's group have been focused on novel gene vectors including modified polyethyleneimines, linear, branched and dendritic polyamidoamines, polyphosphoramidates, and functional polycarbonates incorporated with

Prof. Zhuo and his group members

various targeting ligands including peptides, carbohydrates such as galactose for hepatocyte targeting, and vitamins such as folate, which exhibit improved gene transfection efficiencies with low toxicities.

Prof. Zhuo's pioneering work in the development of various biomedical polymers led to the establishment of the Key Laboratory of Biomedical Polymers by the Ministry of Education at Wuhan University in 1993. Throughout his scientific career, Prof. Zhuo has been inspired by the major national needs in biomedical materials. This brought him not only to the highest levels of scientific achievements, but also the recognition of many awards, including the National Natural Science Award (1999 and 1991), the Science and Technology Progress Award (1999 and 1991) from the Ministry of Education, the Natural Science Award of Hubei Province (2006), and the Natural Science Award from the Ministry of Education (2010).

As a senior scientist, Prof. Zhuo is still active in scientific research and keeps up-to-date with developments in polymeric biomaterials. Currently, he is a fellow of the International Union of Societies for Biomaterials Science and Engineering, and the vice chairman of the Chinese Committee for Biomaterials. He is also Associate Editor of *Polymer International*, Associate Editor-in-Chief of the *Chinese Journal of Polymer Science*, a member of the editorial board of *Acta Polymerica Sinica*, and a member of the advisory editorial board of the *Chemical Journal of Chinese Universities* and *Chemical Research in Chinese Universities*.

In addition to research, Prof. Zhuo also active in teaching. In 1960s, his undertook teaching activities including editing a text book on chemistry of organosilicon compounds, giving lectures, and supervising graduate students as an assistant of renowned Prof. ZENG ZhaoLun. Since the late 1970s, Prof. Zhuo has been actively involved in supervising graduate students and encouraging young students to pursue a career in science. Seventy-eight PhD students and 48 MS students have graduated under his supervision. Some of these students have become academic leaders in their respective fields, conducting research in the frontier of polymer science.