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"State of the development of Membranes Science and Technology in Korea"

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SUMMARY:
In the present report the current state of development of Membrane Science and Technology in Korea has been analysed. In particular the membrane research status and application of membrane science and operations in Korea were analysed. This report includes a list of Korean companies manufacturing and supplying membranes and membrane devices, mainly in the field of water treatment. A significant part of reported information about membrane research and applications have been obtained from Korean reports. The main part of information about the membrane market development has been achieved by the web.

KEYWORDS:
Membrane science, membrane operations, membrane devices.

Document history and validation

When	Who	Comments
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Partners acronym list

During the NanoMemPro project, the different organisations will be represented by the following acronyms:

CNRS	Centre National de la Recherche Scientifique	F
Imperial	Imperial College of Science, Technology and Medicine	UK
IBET	Instituto de Biologia Experimentale Tecnológica	P
GKSS	GKSS Forschungszentrum Geesthacht GmbH	D
FORTH/ICE-HT	Institute of Chemical Engineering and High Temperature Chemical Processes - Foundation for Research and Technology Hellas	GR
Vito	Flemish Institute for Technological Research	B
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology	N
UTwente	University of Twente	NL
UNIZAR	Universidad de Zaragoza	SP
LUT	Lappeenranta University of Technology	FI
ITM-CNR	Istituto per la Tecnologia delle Membrane	I
ICTP	Institute of Chemical Technology in Prague	CZ
DTU	Technical University of Denmark	DK

Table of Contents

1 State of the development of Science and Technology of Membranes in Korea

1.1 History of membrane technology in Korea

A brief history of membrane technology development in Korea is here outlined. The membrane industries and their market have been expended rapidly for the last decades, since micro filtration was first introduced to Korea for the membrane filtration and sterilization in the microbiology laboratories and the pharmaceutical industries in 1960's.

The development of membrane technology was among the major areas of interest in the Korean governments' first long term (1992-1996) R&D program for energy conservation technology. Poor in mineral and energy resources, and heavily dependent on atomic energy for power supply, Korea should exert particular efforts on New and Renewable Sources of Energy (NRSE) development and conservation technologies. This stimulates the Korean government to initiate the energy saving membrane technologies program in academia, government and industrial R&D centres starting from the year 1993.

The market size of membrane modules was estimated to be about US$ 100 million (2000), excluding hemodialysis modules, with the high annual growth rate of more than 20%. However, the economic crisis caused the decrease of its annual growth of 1998 by 8%. Major area of the current membrane market includes production of potable water for home usage and process water, production of ultrapure water for semiconductor industries,. Also membrane market for environmental application including gas separation and organic separation is expected to grow so fast. The large membrane market provoked the membrane R&D as well as the efforts in membrane productions. The membrane R&D has been very active since 1980s and resulted in production of ultrafiltration and reverse osmosis membranes. In fact, with an increase of membrane market, the membrane production and the number of membrane companies are also increasing (*see section Korean membrane companies*), but the large portion of membrane modules have been imported until now.

The membrane studies were started at some universities in Korea in 1970's. The research area was limited to the membranes for reverse osmosis. At the same time, flat sheet membrane hemodialyzer was applied to the medical area for the treatment of kidney patients. In 1974, an electrodialysis plant, the first industrial application of membrane technology was built in Ulsan petrochemical complex to produce annual capacity of 150,000 tons of table salts.

Since 1980's the membrane research has become active due to the national R&D program launched by the government. The Ministry of Science and Technology (MOST) started to support the membrane projects on gas and liquid separation carried out by the national research laboratories.

In 1985, Monsanto Prism separator for the recovery of hydrogen gas was introduced. However, membrane processes have not drawn general interest from industry until 1987 when a reverse osmosis plant for the production of processes water with a capacity of 10,000 m^3/day was built by Kugdong Petroleum Co.

Consumption of ultrapure water is increasing sharply in recent years mainly due to the rapid expansion of semiconductor industry and the introduction of ultra high pressure boilers for plants. In the meantime, reverse osmosis and ultrafiltration processes were applied to small scale treatment of water, such as, ultrapure for laboratories, hospitals and semiconductor plants.

Ultrafiltration was introduced to one of the Kia Motor Co. for treating wastewater from electropainting. The largest plants have been built at the west coast of Korean peninsula for desalination of reclaimed land water with the capacity of 10,000 ton/day and 80,000 ton/day.

As the government regulations on pollution are getting tighter and heading to the total discharge policy instead of present concentration control, membrane processes have been accepted as a major environmental sound and sustainable technology. A waste water treatment plant of large industrial scale with a daily capacity of 10,000 m3/day using NF and RO was constructed at Hansol paper manufacturing plant. Posco started a series of 25 million US$ pilot tests for the installation of membrane processes to treat effluents of waste water treatment plant for water reuse. Posco plants to increase its budget up to 1 billion US$, should the project proves to be successful in the future. Among various membrane related technologies, treatment of leachate from landfill sites is presently attracting particular commercial interests.

In 1990's new membrane research project were initiated and supported by MOST and other ministries. The Highly Advanced National Project (HAN Project, so called G-7 project) was a large scale and long-term R&D program frame work. This project aimed at developing strategic industrial technology in order to make Korea more self-reliant in S&T. Several membrane project in the category of advanced materials and environmental technology supported by MOST and the Ministry of Environment (MOE) under this frame work were carried out by national research laboratories, universities and industries (Table 1).

Table 1 - Highly Advanced National (HAN) Projects

Project Title	Research Institute	Funding	Period
Membrane Technology for Water Treatment	KIST	MOST / Jinro	1992 ~1998
Polymeric Membranes for Gas Separation	KIST	MOST / Kolon	1992 ~1998
Composite Membranes and their Separation Characteristics	KRICT	MOST / Hyosung T&C	1992 ~2001
Separation of Carbon Dioxide	KRICT	MOE / SsangYong Cement	1992 ~1998

Another national project for membrane technology for energy saving were supported by the Ministry of Commerce, Industry and Energy (MOCIE) from 1992, and this is the first long term (1993-1998) membrane research program for energy conservation technology. A total of US$ 5 million was allocated for 12 membrane research projects during this period. More additional membrane projects were funded by this program after 1998. Korea-Australia joint project on Submerged Membrane Bioreactor (SMBR) started from Hanyang University and University of New South Wales for two years in 1999-2000.

In 1995 the research projects for the cleaner production technology were also launched by MOCIE as an effort to change the domestic industrial structure to environment friendly structure. 13 membrane related projects for the cleaner production were supported by this program for 6 years.

The Creative Reaserch Initiative (CRI) program and the national research Laboratory (NRL) program were initiated by MOST for strengthening the basic and core technologies of 21st century.

The CRI program was launched in 1997. It aims to strengthen the national potential for technological competitiveness through creative basic research. Under CRI program one membrane project titled “Facilitated Transport Membranes” was established at KIST in 1998. This project will be funded up to for 9 years. This project focuses on exploring transport phenomena through facilitated membranes, developing new membranes and making technological breakthrough in the field of facilitated transport membranes.

The National Research Laboratories (NRL) program, launched in 1999, aims to explore and foster research centres of excellence, which will play a pivot role in improving technological competitiveness. The MOST will fund US$ 250,000 each laboratory up to 5 years with a special enphasis on strengthening core technology in its relevant fields. It has funded over 400 NRLs across the nation. Under the NRL framework 3 national research laboratories for membranes research (see section 2.2.1 National Research L) were established at Hanyang University, KRICT and GIST. The membrane projects of NRL program focus on the exploring the core technology in gas separation membranes (Hanyang University), membrane reactors (KRICT), ion exchange membranes (GIST).

From 2002 to 2010, US$ 1 billion will be invested by MIE to transfer and expand the core environmental technology development from HAN projects to industries. By this project called Eco-technopia 21 (see in

3. Application of membrane technology in Korea), the development of highly efficient membrane systems for drinking water and wastewater treatment will be funded.

From 2004 till 2011, Ministry of Environment launched a Eco-Star Project for Innovation and Integration for Water Treatment aiming to develop highly efficient and compact membrane system for water treatment with a total budget of US$ 100 million. As a result of the project, they have successfully demonstrated a large scale water production plant with the capacity of 50,000 m3/day where the membranes and modules are all produced by KOLON and H2L, both are domestic companies manufacturing SMBR and MF membranes, respectively.

From Dec 2006 till 2011, Ministry of Land, Transport and Maritime Affairs launched a seawater desalination project to convert large amount of salt water into fresh water for the quest of rapidly increasing potable water. Center for Seawater Desalination Plant is targeting to get the top SWRO technologies in the world and launched *Seawater Engineering & Architecture of High Efficiency Reverse Osmosis* (SEAHERO) R&D program.

Center for Seawater Desalination Plant pursues the RO membrane technique which meets 3L skills. 3L means the three main technical objectives including large scale, low energy, and low fouling for SWRO plants. 3L will be the key to open a doorway to world-leading SWRO technology. At first, large scale is to design and construct the largest unit SWRO train [6MIGD = 27,000 m^3/d] in the world. Second, low energy means to lower energy consumption of whole SWRO plant including intake, pretreatment, SWRO systems, and so on by 4kWh/m^3. At last, low fouling is to reduce fouling effect by 50% in terms of silt density index [SDI] and a new fouling parameter developed through CT1 project.

From 2002 to 2012, carbon dioxide reduction and sequestration R&D center (CDRS) (www.cdrs.re.kr) was established sponsored by MEST under the Frontier Project framework. Membrane related projects were included in this frame to capture carbon dioxide from postcombution resources. Thermally rearranged membranes were discovered and targeted to capture CO2 efficiently from coal-fired power plant and iron manufacturing companies (POSCO). Final target of the membrane project is to install the pilot scale module right after the combustion sources.

From 2008-2013, CO2 capture from precombustion sources has launched aiming at the CO2 capture during the IGCC process at 250 ^{o}C sponsored by Ministry of Knowledge Economy (MKE).

Starting from 2010, Ministry of Education and Science and Technology (MEST) is planning to support Global Frontier Framework which includes membranes as one of the important target for the green energy and global warming policy.

The future of membrane research in KOREA is very bright from the point of funding source, but the research activities need to expand to new applications such as clean energy and clean production technology from the traditional applications such as water treatment (MF, UF, RO).

1.2 Membrane market

The current membrane market is led by the membrane processes industries for the production of ultrapure and potable water as well as for processes-water treatment. The microfiltration market is approximately US$ 30 million per annum with an annual growth rate of 10%. This market growth comes only from its usage as a pre-treatment filter for pure water production. Currently, almost of the microfiltration membranes are imported from abroad.

The ultrafiltration membranes are used for preparation of ultrapure water in semiconductor industries (US$ 3 million) and for treatment of electro-deposition painting system in automobile industries (US$ 2.3 million). The rest of industrial applications including oil/water separation stands at US$ 5 million per annum. Water purification for home usage by using ultrafiltration membranes is getting more popular and its market is currently about US$ 5 million per annum.

The reverse osmosis membrane, mostly for water treatment, holds the biggest share in Korea membrane market. Its market size for membranes modules is about US$ 35 million per annum. Reverse osmosis membranes in industries have been used primarily for treatment of boiler feed water and process water, and production of ultrapure water. Recently, the market of water purifier for home usage has been expanded very rapidly and consumed almost 60% of reverse osmosis membranes. In the water purifier for home usage, ultrafiltration and reverse osmosis membranes compete each other. The pharmaceutical and biochemical industries have also used membrane process as a standard process.

The water treatment market is expected to continue to lead the domestic membrane market for the foreseeable future. Tighter environmental regulation will stimulate the application of membranes for improvement of air and water quality. For example, membranes for separation of volatile organic compounds will be commonly used in many painting and coating industries. The membrane applications in chemical and biochemical industries, in particular, are expected to grow rapidly in a near future, which constitutes almost 50% of the market in the development countries such as USA.

1.3 Membrane industries

Until recently all the membranes and membrane modules had been imported from abroad. Many domestic engineering companies have designed systems with the imported modules and applied them to water treatment until the last decade, and have urged polymer producers to develop cheap membrane modules. This marked has encouraged R&D for membranes, resulting in the production of reverse osmosis and ultrafiltration membranes. Nowadays, **KOLON**, **SK Chemical** and **HYOSUNG T&C** have produced ultrafiltration membranes from early 90's and **WOONGJIN CHEMICAL (formerly SAEHAN)** has started to produce reverse osmosis membranes from 1992. KOLON has produced ultrafiltration membranes for potable water production for home usage and is producing hollow fiber membranes for hemodialysis whereas SK Chemical has concentrated on industrial ultrafiltration membranes. WOONGJIN has produced reverse osmosis membranes for potable water and expanded its production to industrial applications. They started to produce reverse osmosis membranes for desalination. Aiming at the installation of RO plant near Busan area in collaboration with Doosan Heavy Industries, they are planning to install membranes for pilot test under the sponsorship of Ministry of Land and Sea. AIRRANE CO. was established in 2001 aiming at air separation. In general, the membrane industry in Korea has been developed for the last two decades, but it is expected to grow swiftly.

1.4 Membrane R&D program for energy saving

Project accomplished under the sponsorship of RaCER under MOCIE constitute two main streams of membrane technology; liquid separation and gas separation. Not only the development of membrane materials but also the developments of energy-saving membrane processes have been focused. A total of 12 project are coordinated by the Cooperative Research Center. Total R&D budget for this project was about 5 million US$ for the years 1993-1998. CRS is also seeking for an international partner for the project to develop the materials, modules and the processes. Multi-national enterprises (SK Engineering and Memtec) have participated in this follow-up project along with Hanyang University and University of New South Wales to conduct the research on submerged membrane bioreactor.

2. Membrane research organization in Korea

2.1 Research Institutes

a) Korea Research Institute on chemical Technology (KRICT)
b) Korea Institute of Science and Technology (KIST)
c) Korea Institute of Energy Research (KIER)
d) Korea Institute of Industrial Technology

2.1.1 Korea Research Institute on Chemical Technology

The **Membrane and Separation Research Center**, KRICT in Daejeon was established as a Korea Research Institute of chemical Technology in 1990.

Recent research areas:

1. Hollow fiber membranes in water treatment
2. NF membranes in organic separation
3. PV/VP membranes in organic separation
4. Membrane contactors in degassing and CO_2 separation
5. Inorganic membranes in membrane reactors applications
6. Polymer Electrolyte Membranes for Fuel Cells

Staff:

Director (Kew-Ho Lee), 6 Senior Researchers, about 20 Researchers, Postdoctors and Graduate Students

Overview on activities:

- Development of Hydrogen Permselective membranes: *separation of H_2 by Pd-based composite membranes, preparation of Pd-alloy composite membranes, separation of H_2 by Silica Composite membranes, membrane fabrication via the soaking-rolling method, Pt-loaded silica membranes via the soaking-rolling method, permeation of the Pt-included silica composite membranes.*
- Membrane reactors for Hydrogen Production by steam reforming of MeOH/DME:

  PEMFC with membrane reactor system, DME Steam Reforming using a membrane reactor, Reaction efficiency by DME steam reforming, methanol Steam Reforming using a membrane reactor, experimental conditions for methanol reforming, comparison of methanol conversion, applications (high temperature H_2 separation and recovery, H_2 purification, H_2 genarator, catalytic membrane reactor for hydrogenation and dehydrogenation reactions, H_2 resource for PEMFC)

- Membrane contactors for CO_2 separation and degassing*: Mass transfer resistance model for the CO_2 absorption across the hollow fiber membrane was proposed and analyzed. Application of membrane contactors, carbon dioxide separation, morphology of PVDF hollow fiber membranes, hollow fiber membrane contactor module, membrane contactor, removal of dissolved oxygen in water, apparatus for hollow fiber spinning, pilot plant for CO_2 separation.*
- Pervaporation separation of organic mixtures through polymeric membranes: *pervaporation process, pervaporation equipment & module development , applications (dehydration of solvents and other organics, organics/organic separations), PV technologies & KRICT membranes (membranes: gradient cross-linked polyvinyl alcohol membrane, asymmetric type polyvinyl alcohol membrane, various ionomer membranes, polyelectolyte complex membranes, surface modified asymmetric membranes; technologies: on-line GC analysis-built pervaporation equipment, vapour permeation equipment, hollow & plate-type pervaporation module).*
- MF/NF membranes for WATER treatment: Membranes embedded with titania can be applied for the water treatment where membranes are fouled heavily. Recently, titania impregnated membranes are attracting much attention because of their unique characteristics such as high water flux, photo catalysis, and chemical resistance over other membrane materials.

  Removal of dissolved oxygen (DO) from process water is one of the primary concerns in various industries such as semiconductor manufacture, pharmaceuticals and biotechnology. The catalyst-doped membrane contactors with Pd-PVDF membranes were prepared, and the removal efficiency of dissolved oxygen from water was tested by catalytic reaction with these membranes and hydrogen. Other membranes for water treatment, such as high flux nanofiltration membranes, UF/MF metal/ inorganic membranes are also studied in KRICT.

Jeong-Hoon Kim

The development of fluoropolymer membranes for fuel cell; the development of pervaporation membranes for the separation of biobutanol broth; the development of ion exchange membrane and elecrodialysis process; development of hollow fiber membranes and process for the CO_2/CH_4 recovery from flue gases and landfill gases.

2.1.2 Korea Institute of Energy Research

Jung Hoon Park

Development of cermet membrane for H_2 separation

- Preparation of pure metal/ceramic cermet and analysis of its performance
- Preparation of alloy metal/ceramic cermet to endure hydrogen embrittlement and deterioration

◦ Development of unit process for permeation test

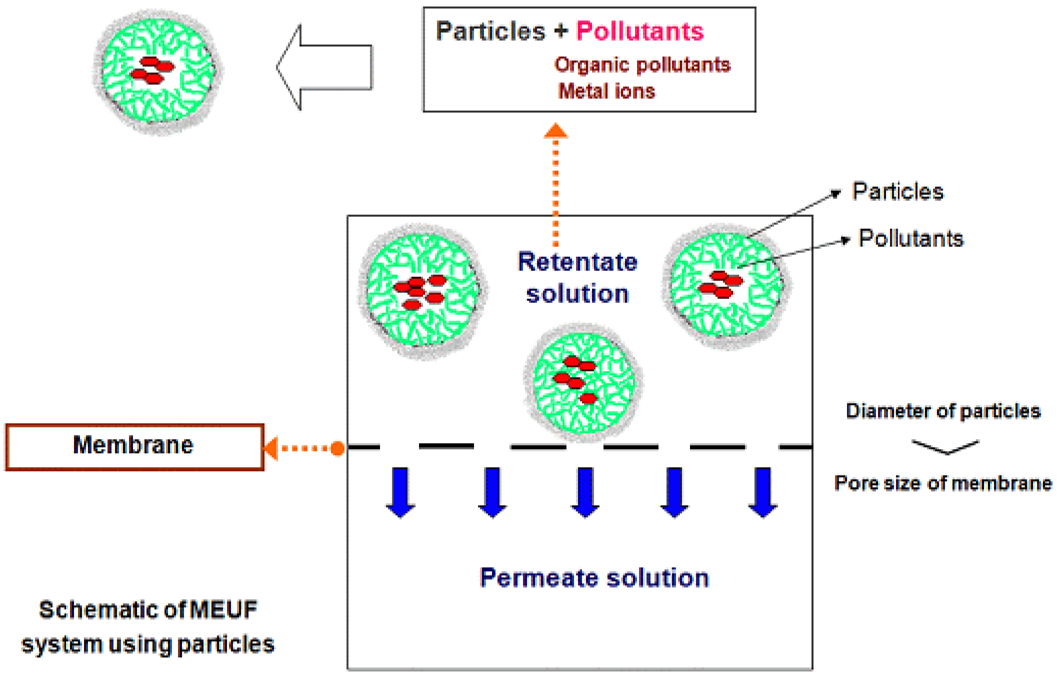
- Setup and operation of lab-scale test equipment
- Development of sealing material and technology for high temperature
- Development of membrane process for model gas permeation in high pressure
- Process optimization according to operation condition

2.1.3 Korea Institute of Industrial Technology

Jin Kie Shim

MEUF(micellar-enhanced ultrafiltration) System

To improve the performances of membrane separation, there has been a constantly increasing level of interest and research efforts in surfactant-based separation processes. The MEUF(micellar-enhanced ultrafiltration) was recently proposed to treat wastewater containing inorganic pollutants and toxic organic chemicals because of the synergetic effect of two techniques such as reverse osmosis and ultrafiltration which showed the high selectivity and flux, respectively.



Schematic of MEUF system using particles

However, the MEUF had the detrimental effects such as micelle breakage, loss of surfactant and ineffectiveness in the MEUF process when surfactant molecules were below the critical micellar concentration. Thus, to overcome the disadvantages of the MEUF, micelle-like ANPs(amphiphilic nano-sized polymers) were applied to the system, forming the nano-sized micelle at the low concentration. In addition, the ANPs enhanced their stability in the treatment of wastewater. The formed ANPs aggregated the pollutants and the increased size of the ANPs-pollutant complexes could not penetrate the membrane, in the results of the removal of the pollutants.

Our lab focused the study on the preparation of the various functional ANPs and the evaluation of the removal ratio of the pollutants as the functions of transmembrane pressure and concentrations of the NANPs in comparison with the normal surfactants.

Membrane surface modification

Membrane surface was modified using the graft of the functional chains to enhance the selectivity and the anti-fouling. In the study of surface modification of the our lab, various sources of energy was investigated such as UV, plasma, gamma ray and ion beam. The effective methods have been studied on the surface modification of the membranes. Surface modified membranes were used in the separation and purification of bio-active agents, the removal of the pollutant and the MBR.

Table 2 summarizes the research activities of membrane researchers at national research institutes in Korea.

Table 2. Investigators and research areas in national research institutes in Korea

Investigator	Affilation	Major areas	Minor areas
Kew-Ho Lee	KRICT (Korea Research Institute of Chemical Technology)	Pd membrane reactor for H_2 production	PVDF membrane contactor for CO2 separation
Jeong-Hoon Kim		Polymeric Gas separation, Polymer electrolytes membrane for fuel cell	Pervaporation based bio butanol separation, ion exchange membrane
Jong-geon Jegal		Reverse osmosis membranes Reinforced membranes for MBR	Pervaporation
You-In Park		Carbon-based gas separation	Membrane contactor for CO2
Beon-Sik Kim		Ion liquid membrane for CO2	Gas separation for PFCs
In-Chul Kim		Microfiltration	Nanofiltration
Seung-Eun Nam		Polymer fuel cell membrane	Pd membrane
Jung-Hoon Park	KIER (Korea Institute of Energy Research)	Ion transport membrane for oxygen separation Cermet membrane for hydrogen separation Membrane reactor for syngas	Membrane contactor CO_2 membrane
Gab-Jin Hwang		Ceramic hydrogen membrane Membrane reactor	Ion transport membrane Carbon membrane
Churl-Hee Cho		Ceramic CO2 membrane Bio-ethanol separation using zeolite membrane	Ceramic membrane for methane separation
Hyung-Keun Lee		Polymer membrane contactor Hollow fiber membrane	Hollow fiber membrane for SF6 separation
Jong-Soo Park		Hydrogen purification using Pd type membrane	Environmental application of membrane

2.2 Universities:

a) Hanyang *University*
b) Yonsei University
c) Seoul National University
d) Chung-nam National University
e) Korea Advanced Institute of Science Technology
f) Seoul National Polytechnic University
g) Dong-guk University
h) Kyung-hee University
i) Kyung Il University
j) Hannam University
k) Hanbat University
l) Chungbuk National University
m) Gwangju Institute of Science Technology
n) Gyungsang National University
o) Kyungbook National University
p) Dongeui University

2.2.1 National Research Laboratory - NRL

Korea government delivered a National Research Laboratory (NRL) program aiming to explore and foster research centres of excellence, which will play a role in improving technological competitiveness (MOST). Each Laboratory is funded up to 5 years with 250,000 US$. Over than 400 NRL across the nation and 3 NRL for membranes were established:

1. NRL for gas separation membranes (Hanyang University**)**
2. NRL for functional membranes (KRICT)
3. NRL for cleaner separation (GIST)

Mainly involved respectively in:

- Development of molecular sieve membranes and gas separation systems (Hanyang University)
- High efficient membranes for separation and reaction (KRICT)
- Electrochemical technologies using ion-exchange membrane for cleaner separation process (GIST)

2.2.2 Hanyang University:

Young Moo Lee, Ho Bum Park

School of Chemical Engineering

College of Engineering, Hanyang University

Seoul 133-791, Korea

(http://mbl.hanyang.ac.kr/), (http://leer.hanyang.ac.kr/)

Young Moo Lee: National Research Laboratory for Membrane (NRLM) has started studies on polymer synthesis and its application to membranes. It has performed various works on liquid and gas separation, drug delivery system, polymer electrolyte membranes for fuel cell. Its research topics were one of the most important areas in recent development toward advanced materials. In Membrane Research Laboratory, there have been active research activities about the synthesis of novel polymer materials and their applications. As a result of vigorous research, over 240 original papers in international SCI journals were published. 30 students received their Ph. D. degrees and 80 students obtained their M.S. degrees during this period.

The NRLM research interests are divided into two parts: development of materials for membrane separation and technology and biomaterials. Membrane processes have been known to be energy saving and used for new and efficient separation processes, especially in the separation of organic mixtures, gas separation, VOC removal, fuel cell membranes and submerged membrane bioreactors. NRLM spinned off two venture companies in previous years : Biorane Co., Ltd. and Airrane Co., Ltd. Conducting businesses related with biomaterials and air separation membranes, respectively, NRLM hope these venture will provide both domestically and internationally more business opportunities for NRML alumni, scientists and engineers in the field.

NRLM recently discovered the thermally rearranged (TR) polymer membranes from soluble precursor made of functional group containing polyimide will be converted into stable polybenzoxazoles which showed an extraordinary gas permeation performance as reported in Science in 2007. These types of TR polymer membranes far exceeded the trade-off limit of gas separation as reported by L. Robeson in 1991 and 2008. could be shaped into hollow fiber and could be used in real application for CO2 removal from natural gas and air separation and even hydrogen recovery as well as postcombustion purpose. This report briefly introduces the performance of TR membranes.

Yong Soo Kang:

Facilitated transport membranes

Facilitated olefin transport membranes can be an excellent energy-saving replacement candidate for olefin/paraffin separation process. Membrane process in ethylene and propylene preparation and purification can substitute the conventional distillation process with enormously reduced cost and space (100trays, 50m x 2).

Silver nanoparticles as a new carrier

As new carrier materials, the polarized silver nanoparticle by electron acceptors can reversibly react with olefin molecules, resulting in the facilitated olefin transport. By the increased activity in silver?olefin complexation, the interactions between $BF4^-$ ions (from the ionic liquid $BMIM^+BF4^-$) and the surfaces of silver nanoparticles caused the Ag surfaces to be partially positively charged. The surface positive charge and consequent enhancement in olefin complexation ability were exploited through the use of silver nanoparticles as a new type of olefin carrier for facilitated transport. As a result, membranes containing $BMIM+BF4^-$/Ag nanoparticles demonstrated a mixed-gas selectivity of 17 for a 50/50 (vol %) propylene/propane mixture and showed stable performance for 100 h.

2.2.3 Yonsei University

Byung Ryul Min, Soo Hong Roh and Jong Hak Kim

Byung Ryul Min

Antifouling nanofiltration membranes

The water treatment process employing a separation membrane with the advantage of energy saving has gained a highly growing attention. In this research we are working on thin film composite (TFC) nanofiltration membrane to increase antibiofouling functions by applying silver, titanium dioxide (TiO2) nanoparticles, which have of antibiofouling function, in order to reduce the contaminants decreasing the efficiency of membranes and to characterize the surface of the membrane.

Polyelectrolyte membrane fuel cell

The most commonly used proton exchange membranes are perfluorinated copolymers with a pendant sulfonic acid group, there has been a strong effort over the last few years to find an alternative sulfonated polymeric material. In this project we have employed partially fluorinated polymer electrolyte membranes due to easy synthesis with low cost but comparable electrochemical properties to perfluorinated membranes.

Biohydrogeneration

Biohydrogen generation is one of the emerging area for the generation of hydrogen from microorganism. In this project we employ a novel bioreactor composed of composite membrane from naturally abundant chitosane with silicone coating. Immobilized anaerobic microorganisms on the membrane are deeped into the feed to generate hydrogen.

Facilitated transport

Facilitated transport is one of the important process for propylene/propane mixtures separation. In this project membranes comprising silver salts physically dispersed in poly(dimethyl siloxane) for the separation of olefin/paraffin. Inert composite membranes, in which silver salts are physically dispersed in rubbery poly(di-Me siloxane) (PDMS), were prepd. and tested for the sepn. of propylene/propane mixts.

Jong Hak Kim,

Prof. Jong Hak Kim is devoted to the study of polymeric materials, particularly self-organizing and nanostructured polymer systems, for applications including fuel cells, solar cells, rechargeable batteries and separation membranes. The "grafting from" technology to prepare the well-defined microphase-separated structure of polymeric materials using atom transfer radical polymerization (ATRP) is currently used. Various amphiphilic comb-like copolymers are synthesized through this approach. Graft copolymers incorporating proton conducting groups are being explored as polymer electrolyte membranes for fuel cells. The structure of proton transport channels has been controlled and fixed by crosslinking the hydrophobic domains, which also provides the greater mechanical properties of membranes. These materials can also serve as the structure-directing agents for nanocomposites. We are also investigating supramolecular polymers containing multiple secondary bonding sites and their uses as polymer electrolytes for dye sensitized solar cells.

2.2.4 Gwangjoo Institute of Science and Technology (GIST)

Seung Hyun Moon

Prof. Seung-Hyeon Moon has been working on synthesis, characterization, and process application of electromembranes in Department of Environmental Science and Engineering at Gwangju Institute of Science and Technology. In the area of environmental applications, the membranes studies are focused on clean technologies and industrial wastewater treatment. From 2000 to 2005, he had led the National Research Laboratory (NRL) on electromembranes processes for cleaner environments where electrodialysis had been applied for various chemical, biochemical, and environmental processes. Also the Basic Atomic Energy Research Institute (BAERI) on water chemistry in nuclear power plants had been operated from 1999 to 2005 for purification of cooling water using electrodeionization process. Further fuel cell membranes and polymer electrolytes for solar cell are being developed in this laboratory. Electrochemical properties of ion exchange membranes and transport characteristic of ions through the membranes are investigated. Selected recent research topics are following:

- A preparation of a single-layered enzyme membrane using asymmetric pBPPO base film for development of a pesticide detecting biosensor
- Analysis of Fouling in the electrodialysis process in the presence of an anionic surfactant fo ulant
- In-situ polymerization: a novel route for thermally-stable proton conductive membranes
- A covalent organic/inorganic hybrid proton-conducting membrane with semi-interpenetratin g polymer network
- Sulfonated polystyrene/polyvinyl chloride composite membranes for PEMFC applications
- An electrical impedance spectroscopic (EIS) study on transport characteristics of ion-excha nge membrane systems

2.2.5 Chungnam National University

Yong Taek Lee

Pervaporation with a membrane is one of the economic technologies for separation of liquid mixtures including organic/water mixtures. Water could be separated from water/ethanol mixtures by pervaporation using the NaA and the NaY zeolite membranes synthesized in our laboratory. The effects of a concentration of ethanol at the feed side and a temperature were studied on the permeation flux and the separation factor of water with respect to ethanol. The separation factor obtained with the NaA zeolite membrane was found to be 1,000 times larger than those obtained with the NaY zeolite membrane. However, the water flux through the NaA zeolite membrane was observed to be lower than 1/2 through the NaY zeolite membrane. The water flux significantly increased as the temperature increased for both the NaA and the NaY zeolite membrane. The ethanol flux was not so much changed through the NaA zeolite membrane at below 0.8 mole fraction of ethanol in the feed solution as the temperature increased. On the other hand, the ethanol flux through the NaY zeolite membrane rapidly increased even at below 0.8 mole fraction of ethanol as the temperature increased. The NaA zeolite membrane was synthesized on the surface of a porous α-alumina support with the mother solution composed of 1Si : 1Na : 4Na : $6H_2O$. The pervaporation through the synthesized hydrophilic zeolite membrane could be applicable for the different aqueous solutions which might contain ethanol, iso-propyl alcohol(IPA), butanol, 2,2,2-trifluoroethyl alcohol(TFEA)

A novel technology for homogeneous deposition of zeolite particles on a porous support was developed so that those particles played a seeding role for the growth of zeolite crystals. After the particles were dispersed in water, the aqueous solution was fed through the bore of a porous tubular support. By keeping the other side of the support in a vacuum, the aqueous solution passed through the pores of the support, leading the particles to be homogeneously deposited on the support. The amount of the deposited particles was investigated by changing the following operating parameters: a particle concentration in the solution, a time for deposition, and the feeding rate of the solution. The amount of the deposited particles was found to be changed with the given operating condition.

2.2.6 Kyungbook National University

Kwang Ho Choo

Prof. Choo has been working on water engineering and chemistry for more than 18 years, with a strong bond with membrane technology, aiming for advanced water treatment and reuse. During his early research period, he investigated membrane bioreactors for the anaerobic and/or aerobic degradation of organic matter in industrial and municipal wastewater. His research focus was to illuminate fouling behaviors and mechanisms in membrane bioreactors and thereby to control fouling by means of either optimizing the membrane operation or integrating physicochemical methods. He reported several key findings related to membrane fouling in anaerobic membrane reactors, such as the formation of inorganic precipitates (struvite) and the significance of fine biocolloids and their dynamics in the membrane reactor. He is still interested in membrane bioreactors in regards to the interactions of biosolids and organics with pore structures and materials. Recently he has been focusing more on the integration of membranes with various physicochemical methods, such as iron oxide adsorption, polymeric chelation/complexation, and photocatalysis, for the hybridization of separation, degradation, and fouling prevention. His recent research has demonstrated that the marriage of porous membranes with active particulate media, such as iron oxide adsorbents or photocatalysts, is an attractive and viable option that can resolve the two inherent issues of membrane processes, such as the disposal of residuals and the fouling phenomena of membranes. Therefore, catalytic membrane reactors have been receiving more attention in environmental applications. His research activities are being further extended to membrane pretreatment for seawater reverse osmosis filtration, electrodialysis for wastewater reclamation, and membrane separation of micropollutants in water and wastewater. More recently, novel approaches, such as solar-powered electrochemistry and photochemistry, in combination with reactive membranes are the areas of his great interest in order to decompose water contaminants as well as to produce hydrogen fuel via water splitting. He is currently keen to pursue solutions to sustain water and energy simultaneously, using membranes in conjunction with cutting-edge technologies.

Dr. Choo is the author of more than 50 peer-reviewed papers and holds three patents on membrane technologies for water treatment applications. He has been recently appointed and serving as an editor (Environmental Section) of the *Korean Journal of Chemical Engineering* published by Springer. And he has been involved as an editorial board member for the *Membrane Journal* and the *Journal of Korean Society on Water Quality.* He has been also serving as an executive board member of the Membrane Society of Korea since 2004 and actively involved in several professional societies, such as the International Water Association (including Membrane Technology Specialty Group), the Korean Society on Water Quality, the Korean Society of Environmental Engineers, the Korean Society of Industrial and Engineering Chemistry, and the Korean Institute of Chemical Engineers.

2.2.7 Kyung Il University

Ho-Sang Choi

Inorganic membrane with the high permselectivity of hydrogen at high temperature has attracted much interest in the gas separation field due to the importance of hydrogen as an industrial feedstock for the production of fuels and many chemicals. The silica membrane research has been investigated and prepared by the chemical vapor (CVD) method. Along with silica membrane, the silica-zirconia membrane preparation for hydrogen separation and organic-inorganic composite membrane for PFC control have been investigated.

The electrical and chemical characteristics of electrolyte membrane for high temperature steam electrolysis (HTSE) applications have been analyzed with respect to preparation methods. The electrolyte membranes were prepared using dry and wet processes, and the membrane characteristics on the ionic conducting properties carry out to investigate and analyze. Researches on the inorganic or organic membrane for water electrolysis are carrying out at an instant. Hydrogen production system of high capacity for water electrolysis is developing with the research institute of industry.

Applications on UF and MF polymer membrane processes to treat the portable and the waste water carry out in the half of it. The membrane process for high concentration of the industrial waste water is developing with a research institute concerned with the industries.

2.2.8 Gyungsang National University

Sang Yong Nam

Gas separation membranes are used in a number of industrial processes such as the enrichment of O_2 and N_2 from air, separation of CO_2 and H_2O from natural gas, purification of H_2, and recovery of vapors from vent gases. Both asymmetric membranes and microporous composite membranes have been used in these commercial membrane-separation technologies. High performance air separation membranes which has thin skin layer containing minimum defects were prepared by phase inversion methods in our lab. Their O_2/N_2 separation properties were tested for air separation from lab-scale system. The possibility of CO_2 separation from N_2 based mixture gas using the membranes were evaluated to find commercially available membranes that can reduce membrane cost from inexpensive polymer materials. In addition, glassy fluoro polymers on a porous hollow fiber membrane support were prepared and tested for hydrocarbon separation.

The pervaporation of organic mixtures through polymeric membranes have been investigated for reuse in chemical industries. The dehydration of water from each ethanol, isopropanol and ethylene glycol mixtures were carried out using chitosan family membranes after specific modifications. Furthermore, the efficiency of pervaporation separation of methanol/MTBE (methyl-t-butyl ether) mixture was also evaluated through chitosan composite membrane modified with sulfuric acid and surfactants. Effects of feed concentration, temperature, crosslinking degree etc. were studied.

2.2.9 Kyung Hee University

Yong Taek Lee and Sungsoo Kim

1. Development of water treatment system for membrane technology.
   - RO membrane for desalination, MF, UF membrane for drinking water and sewage treatment.

2. Modification of polyamide membrane for chlorine resistance and fouling resistance improvement.
3. Preparation of nano-porous ceramic membranes using CVD process with high efficiency hydrogen manufacture.
4. Concentration of bio-butanol using PVDF/PDMS composite membrane by Pervaporation
5. Improvement of Polymer Electrolyte Membrane Fuel Cell humidity system with membrane Humidifier

2.2.10 Dongeui University

Kwang Hyun Lee

Dr Lee's present works are as follows: Application in ultrafiltration and reverse osmosis module set with acrylic wastewater; Advanced treatment of sewage wastewater using submerged membrane system; Application in membrane hybrid system with non-decomposing or hard-decomposing materials by biological treatment.

2.2.11 Other university Laboratories

Seoul National University

Tae Moon Tak

Chung Hak Lee

Table 3 summarizes the recent research activities of researchers at Korean universities.

Table 3. Typical research areas carried out in universities in Korea

Investigator	Affilation	Major areas	Minor areas
Byong Ryul Min	Yonsei Univ.	Ultrafiltration membrane and membrane for H2 production	Gas separation membrane
Soo Hong Roh	Yonsei Univ.	Membrane module and process development for water treatment	Restoration of contaminated ground water
Jong Hak Kim	Yonsei Univ.	Polymer electrolytes for fuel cells and solar cells	Faciliated transport membranes
Yong Soo Kang	Hanyang Univ.	Polymer electrolytes for facilitated transport and solar cells	Polymer electrolytes for fuel cells
Yong Moo Lee	Hanyang Univ.	Gas separation, Polymer electrolytes for fuel cells	Water Purification
Seungkwan Hong	Korea Univ.	Reverse osmosis and nanofiltration for biofouling	Water Purification
Jongok Won	Sejong Univ.	Polymer electrolyte membranes for fuel cells	Gas separation membrane
Kun Yong Chung	Seoul National Univ. of Technology	Process study for membrane performance enhancement	Gas separation, water purification membrane
Yong Take Lee	Kyunghee Univ.	Process study for membrane performance enhancement	Gas separation, water purification membrane
Sung Soo Kim	Kyunghee Univ.	RO membrane for desalination, MF, UF membrane for drinking water and sewage treatment	Nano-porous ceramic membranes using CVD process
Hyungsoo Kim	Sungkyunkwan University	Microfiltration and ultrafiltration	Wastewater treatment
Yongtake Lee	Chungnam National Univ.	Preparation of ceramic/zeolite membrane and its application	Modeling the membrane module and design of membrane process
Hongsik Byun	Keimyung Univ.	Fuel cell membrane	Gas separation
Jin Yong Park	Hanrim Univ.	Hybrid process of ceramic microfiltration and activated carbon adsorption	Micellar enhanced ceramic membranes
Ho Sang Choi	GIST	Ion exchange membrane, fuel cell membranes	Reverse osmosis
Ho-Won Lee	Jeju National Univ.	Water purification and membrane bioreactor (MBR)	Desalination

2.3 Private research Laboratories

- KOLON
- SKI
- HYOSUNG T&C
- SAEHAN

2.4 The Membrane Society of Korea

Membrane Society of Korea (www.membrane.or.kr), which has started as the Membrane Research Institute of Korea in 1987, now has over 20 years of history and that the Society became the home for 600 members of the Society with stable fund and office owned by the Society. The Membrane Society of Korea is a professional society, showing a rapid increase through academic achievements of the professionals related to the membrane, and internal and external activities of the Society.

The Membrane Society of Korea is now faced with the task of international take-off and internal and external diffusion of technology. AMS (Aseanian Membrane Society), which was held in 2004 and ICOM (International Congress of Membranes and Membrane Processes), which was held in 2005, could be burdensome to a small-scaled society like the Membrane Society of Korea, but all the works related to the conferences stated above was well arranged by the fewer people of superior ability, together with the solidarity and devotion of all the members of the Society.

As the government of Korea announced, Korea, as a country for the scarcity of water, has been carrying out many effective projects such as re-use and non-discharge system of water and altitude control system of clearing water. Re-use of water through the membrane is now becoming a big project in a scale of hundred million metric ton. Accordingly, the Membrane Society of Korea, with close cooperation with the government organizations such as the Ministry of Environment and the Ministry of Knowledge Economy, will actively participate in scientific symposium and education for those concerned, localization of membrane and its technology so as to diffuse and fix the technology of separating membrane.

The Membrane Society of Korea believes that the future of nation depends on the international competitiveness through scientific technology and technology based on industry in the 21st century. The Membrane Society of Korea is entrusted with the role of strengthening the technology based on industry through assurance of professional technology of separating membrane and the localization of separated membrane. Potential strength of the Membrane Society of Korea will remain long in history internally and externally when the localization of separated membrane increases its market share in the domestic market and is highlighted in the overseas market.

3. Application of membrane technology in Korea

There are about ten membrane manufacturers in Korea producing a variety of membranes ranging from liquid separation membranes (RO, NF, MF) to gas separation membranes. Table 4 summarizes the membranes producers currently active in production of membranes.

Table 4 List of membrane production Korean companies

Company	Membrane material	Configurations	Processes
Woongjin Chemical	Polyamide (PA) Polysulfone (Psf) Polyvinylidenefluoride (PVDF) Polytetrafluoroethylene (PTFE) Polypropylene (PP)	Spiral wound Pleated type	Reverse osmosis Nanofiltration Ultrafiltration Microfiltration
STX	Polyvinylidene fluoride (PVDF)	Spiral wound	Microfiltration Reverse osmosis
KMS	Polyethylene (PE)	Hollow fiber	Membrane bio-reactor
Pure-Envitech	Polytetrafluoroethylene (PTFE) Chlorinated polyvinyl chloride (CPVC)	Flat sheet	Membrane bio-reactor
H2L	Polyvinylidene fluoride (PVDF)	Hollow fiber	Membrane bio-reactor
Woongjin coway	Polyamide (PA) Polysulfone	Spiral wound	Reverse osmosis Nanofiltration Ultrafiltration
Airrane	Polysulfone (Psf) Polyimide(PI)	Hollow fiber	Gas separation
Chemicore	Polyacryronitrile (PAN) Polysulfone (Psf)	Hollow fiber	Ultrafiltration Gas separation

3.1 Potable water for home usage

In September 2004 started the *Eco-STAR Project* (Daewoo group) for "Innovation and Integration for Water Treatment Technology" including the **membrane based operation** as innovative technology. The objective of the project is to develop the high efficiency, low energy, less footprint compact system which can compete in a global market. This project includes membrane technology driven advanced drinking water treatment system, advanced domestic & industrial wastewater treatment system and water distribution maintenance system development.

In particular, the main tasks are:

- The development of advanced membrane materials for water/wastewater treatment processes.
- The development and commercialization of membrane processes for water treatment.

3.2 Waste water treatment

Advancement of technology is crucial to promote the increase of the use of reclaimed water. The technology should be feasible, economical, and sustainable for public acceptance.

Water Reuse is one of the key agenda for the 21st century regarding water usage of human mankind. Use of recycled water gives two of the most important advantages to us. First, it gives significant reduction of pollutants loading to the nature (even as zero emission). Second, it provides a new source of valuable product as usable water.

It is defined as the whole process of getting fresh water, after getting rid of salt solved in the sea water. The produced water is used as various purposes of water. The process of desalination can be classified into Evaporation Method and Membrane Filtering Method. The 97.5% of total amount of water in the earth is saltwater. Therefore, the desalination of seawater, which is handy to obtain, is one of potential alternatives to prepare the water shortage.

Nowadays the water shortage is getting worse throughout the world, so the Desalination System is on the rise as an alternative. The reason is that the seawater exists infinitely, and that it can be used without shortage even under a severe drought. As the areas of water shortage have been expanded due to population growth, improvement of life style, and an unusual change in the global climate since 1960s, it is notable that the demand of seawater desalination system and its applications has been increased. And also, in Korea, it is driven to induce the desalination system for the islands showing a chronical water shortage, as a measure for supplying water permanently. Theses areas have difficulties in securing water resources due to their topographical features and drought characteristics. However, in Korea, though we can regard desalination system as an alternative water resources to prepare water shortage in the future, the degree of development cannot be prior to and not be equal to the development plan of freshwater resources. To address the potential water shortage, it is necessary to secure a sufficient amount of the surface water and make a rational use of water.

The submerged type membranes have been commercially available from 2002 for sewage treatment system. There are more than 1,800 SMBR sewage treatment plants are available now with the treatment capacity varying from 100 m3/day to 30,000 m3/day. Membrane materials includes polyethylene, PVDF, cPVC. Typical plants are listed in Table 5. As a result of the Eco-Star project, they have successfully demonstrated a large scale water production plant with the capacity of 50,000 m3/day where the membranes and modules are all produced by KOLON and H2L, both are domestic companies manufacturing SMBR and MF membranes, respectively.

Table 5. Location of drinking water plant

Site	Capacity (m^3/day)	Material	Type	Constructor
Yidong DWP Pocheon-si Gyeonggi-do	1,500	PAN	UF(Hollow-fiber)	Taeyoung Construction
Yidong DWP YangPyeong-gun Gyeonggi-do	1,000	CA	UF(Hollow-fiber)	Samsung Engineering
Geochang-gun Wicheon DWP Gyeongsangnam-do	800	PVDF	MF(submerged)	DI
Siheung-si DWP Gyeonggi-do	3,600	PAN	UF(Hollow-fiber)	Hanwha Construction
Gimcheon, Jirye DWP Gyeongsangbuk-do	300	PAN	UF(Hollow-fiber)	Biryoung Engineering
Gongju-si DWP Chungcheongnam-do	30,000	PVDF	MF(Hollow-fiber)	Kumho Construction
Yeongdeungpo DWP	25,000 (submerged)	PVDF	MF(Hollow-fiber)	Hanwha Construction
Yeongdeungpo DWP	25,000 (pressurized)	PVDF	MF(Hollow-fiber)	Daewoo Construction
Mauna Ocean Resort	500	PVDF	MF(Hollow-fiber)	Kolon Engineering & Construction

Korea Water Resources Corporation (Kwater) installed a drinking water pant utilizing UF membranes with a capacity of 3,600 m3/day near suburban Seoul and one near Daejon with a capacilty of 30,000 m3/day. Table 6 summarizes the recent installation of membranes of both UF and MF.

Table 6. Location of wastewater treatment plant

Site	Capacity (m^3/day)	Manufacture	Material	Type	Constructor
Cheonan-si Chungcheongnam-do	30,000	Mitsubishi Rayon	PE	MF(Hollow-fiber)	Hyundai Engineering
Gimhae-si Chinyoung-eup Gyeongsangnam-do	14,000	Mitsubishi Rayon	PE	MF(Hollow-fiber)	Hyundai Engineering
Yangpeong-gun Gyeonggi-do	13,000	Mitsubishi Rayon	PE	MF(Hollow-fiber)	Hyundai Engineering
Dalseong-gun Daegu-si	25,000	KMS	PE	MF(Hollow-fiber)	Ssangyong Construction
Okchon-gun Chungchoungbuk-do	18,000	KMS	PE	MF(Hollow-fiber)	Ssangyong Construction
Gapyeong-gun Gyeonggi-do	900	KMS	PE	MF(Hollow-fiber)	Ssangyong Construction
Naju-si Jeollanam-do Jungheung Gold Spa	1,000	KMS	PE	MF(Hollow-fiber)	KMS
Namhe-gun Gyeongsangnam-do	500	KMS	PE	MF(Hollow-fiber)	KMS
Jinbu-myeon Pyengchang-gun Gangwon-do	4,100	Yuasa Membrane	cPVC	MF(Plate)	Taeyoung Construction
Daehwa-myeon Pyeongchang-gun Gangwon-do	1,000	Yuasa Membrane	cPVC	MF(Plate)	Taeyoung Construction
Cheongbuk-myeon Pyeongtaek-si Gyeonggi-do	8,200	Pure Envitech	cPVC	MF(Plate)	
Sungkyunkwan Univ. Natural Sciences Campus	1,200	Pure Envitech	PTFE	MF(Plate)	Ilshin Environmental Engineering
Paju-si Gyeonggi-do Golf course	300	Pure Envitech	PTFE	MF(Plate)	Gaya Environmental Engineering
Masan-si Kyungsangnam-do	4,000	Kolon Inc.	PVDF	MF(Hollow-fiber)	Kolon Engineering & Construction
Zeongpyung Industrial Complex	2,500	Kolon Inc	PVDF	MF(Hollow-fiber)	Kolon Engineering & Construction

3.3 Desalination/ Reverse Osmotic Membran

In Korea, 40 desalination plants are being installed and operated. The security of living water using desalination is at the beginning stage. In the case of industrial water, desalination plants are operated at some factories, with the first installation of the seawater desalination facility at Boryeong Thermoelectric Power Plant in 1989. Most of the desalination plants are to improve the water quality of saltwater, ground water and industrial wastewater for using them as industrial water. Majority of the desalination plants are industrial water supply facilities, which have a small treatment capacity from hundreds of tons to ten thousands of tons of water per day. The plants for drinking water supply are small size under of tens of tons a day. The **Reverse Osmotic Membrane method** is usually adopted for the desalination system.

Table 7. The status of desalination facilities

Usage	Places	Capacity(m^3/sec)	Remarks
Drinking Water	Hong Island, Heuksan-myeon, Sinan-gun,Junnam Province	100	
	Yeon Island, Jinhae -si, Gyeongnam Province	20	
	Donghang-ri, Yokji-myeon, Tongyeong-si, Gyeongnam Province	20	
	Yeonho-ri, Hansan-myeon, Tongyeong-si, Gyeongnam Province	15	
	Sa Island, Yeocheon-gun, Junnam Province	10	
Industrial Water	Hyeondai Oil	70,000	Cooling Water
	Hansol Paper	10,000	Industrial Water
	Boryeong Thermoelectric Power Plant	820	Cooling Water

The economical value of the desalination business depends on the treatment method, the capacity of a facility, the location and conditions of plant, the unit price of using energy, the purity and the salinity of source water, and demanding salinity degree of produced fresh water. Compared with the producing unit price for the public municipal water of multi-regional waterworks, that of the Reverse Osmotic Membrane(capacity with 100 m^3/day) is expensive as much as 4-5times. If it is compared with industrial water(capacity with 10,000 m^3/day), the Reverse Osmotic Membrane is more expensive as much as 2 times. Consequently, the economical value of it is low at present. After performing a feasibility study and making a long-term master plan, the desalination project will be processed for the islands having a chronic drought damages in the first stage.

RO membranes

- Industrial applications: waste water treatment (desalination, textile and pulp industries, landfill leachate, municipal waste water); boiler and process water treatment; ultra-pure water production; environmental industries;
- Home usage: water purifier for home usage

NF membranes

- Water purification for home usage
- Waste water treatment
- Food and pharmaceutical industries

Brackish water desalination (TORAY MEMBRANE)

This application is process water production from the water pond near the mouth of a river for the petrochemical complex in Korea. Raw water is desalted by low pressure membrane SU-720LF.

Plant Owner: Veolia Water Korea Daesan Co., Ltd.

Location: Daesan, Korea

Start up: December 1990

Product capacity: 63,000 m3/d

Feed water: Lake water

Use: Process water for refinary plant

Membrane: Toray SU-720LF x 2,862pcs

3.4 Hemodialisys

- Membrane module for artificial kidney (PS_f)

3.5 Gas separation

- Oxygen enrichment
- Nitrogen concentration
- Dehumidification
- Hydrogen purifier

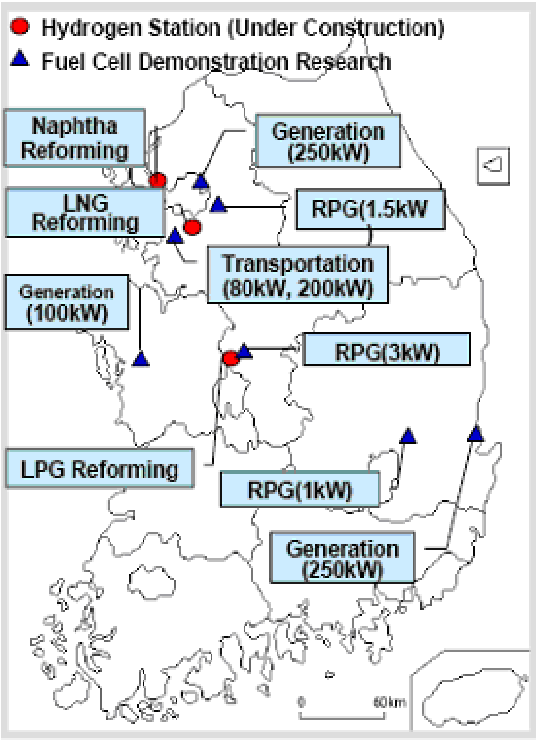
3.6 Electrochemical applications

Among all other membrane applications, a lot of public investments in South Korea concern to Hydrogen production and Fuel Cells R&D. The South Korean government has thrown its weight behind the future development of fuel cell technology. A joint initiative between the Korean government and Hyundai-Kia will see 48 billion won invested in the development of fuel cell buses and cars by 2008.

A global overview on these activities is reported in the table below:

Table 8

Type	*Status*
Hydrogen	Basic technology R&D for production and storage (2003-2006) Hydrogen station using LNG and naphta (2004-2008)
MCFC	100kW demonstration plant under operation (2005) 250 kW system development (2005-2009)
PEMFc for RPG	Proto-type 3kW system development (2004-2006)
PEMFC for Transportation	FC vehicle (80 kW fuel cell) development (2004-2008) FC Bus (200 kW fuel cell) development (2005-2009)
DMFC	50 kW portable power-pack development (2004-2006)
SOFC	1 kW RPG system (2003-2006) 3 kW APU system (2004-2007)



While, in the table below are summarized the R&D Government funds for Hydrogen, fuel cells, Demo and Disseminations:

Table 9. -

	MOCIE (2004-2008)	MOST (2003-2013)	Total
R&D for Hydrogen	$ 94 M	$ 90 M	$ 184 M
R&D for fuel cells	$ 237 M		$ 237 M
Demo % Dissemination	$ 175 M		$ 175 M

3.7 <u>Eco-technopia 21</u>

It aims to transfer and expand the core environmental technology to industries in the 2001-2010. Ministry of environments will invest US $ 1 billion for 10years. The development of highly efficient membrane systems for waste water and drinking water treatment will be funded.

<u>Development and Promotion of Environmental Technology</u>

Eco-Technopia 21 Project

Building upon the experience and capacity developed through the implementation of the G-7 Project (1992-2001), MOE initiated Eco-Technopia 21 Project to find technological answers to environmental newly emerging problems like dioxin and endocrine disrupters. The Project also seeks to bring up the competence of domestic environmental technology to the ranks of advanced countries.

For 10 years starting in 2001, the Korean Government will invest approximately one trillion Korean won to the Eco-Technopia 21 Project with private research institutes and enterprises slated to participate. The planned technology development consists of 30 core tasks across 12 areas, including Clean and Safe Air and Satisfactory Drinking Water.

In 2001, MOE invested 50 billion won from the national treasury to support the development of technologies for export, industrialization, environmental pollution remediation, and public infrastructure necessary for integrated environmental management. In 2002, MOE devised the Technology Road Map as a 10-year master plan for systematic and efficient implementation of the Eco-Technopia 21 Project.

In line with this Road Map, MOE extended support to materials and process technology development in the environmental industry sector, which can be widely used to foster original and cutting-edge technology as well as to mitigate pollution and improve the environment. It is estimated that in 2003, the national budget of 75 billion won will be allocated to promoting the development of new technology.

The outcomes of the project so far show that as of November 2002, there were 37 cases of technology transfer among enterprises, 69 cases of commercialization, 145 cases of enterprise property application and registration, and 837 cases of scholarship presentations. More-over, the Project resulted in 3 billion won in exports, 2.8 billion won in domestic constructions, and 1.7 billion won in product sales.

Promotion of New Environmental Technology

MOE began operating an Environmental Technology Evaluation System for new technologies to objectively appraise and disclose the quality of their technical performance at the request of developers. The System administers a performance test through full activation of new technologies for 3-6 months at pilot plants. Those that demonstrate outstanding functions are designated as New

Technology by the Government, which subsequently provides various incentives such as extra points to New Technology users at public project biddings.

Furthermore, MOE created an Environmental Venture Fund of 13 billion won in 2001 and 11 billion in 2002, and actively identified and supported promising venture companies. MOE also instituted a Venture Nurture Center at the National Institute of Environmental Research to assist venture activities of those at the frontier of environ-mental technology development.

MOE launched the National Environmental Technology Information System in 2000 to effectively publicize innovative technologies, facilitate information exchange and encourage creative technology development efforts. Through the Information System, MOE has been providing information on the latest technology via some 2,500 databases. Each year, presentation and exhibition on new environmental technologies are held, and persons who made notable contribution to environmental improvement and industry growth by developing instrumental environmental technology are identified and rewarded with an Environmental Technology Award.

In 2003, MOE plans to revise the relevant laws and lay the legal framework for the acceleration of development and diffusion of new eco-technologies. Among others, the Act will mandate public institutes to deploy new technology when environmental facilities are being installed.

Operation of Regional Environmental Technology Development Centers

With local universities at the center, administrative agencies, research institutes, industries and non-governmental organizations have established a cooperative mechanism and designated Regional Environmental Technology Development Centers to collectively counter unique local environmental problems.

Since the establishment of the first two Centers in Ulsan and Yeosu in Dec 8 1998, more have been built in 2000, followed by 5 in 2001 and 1 in 2002, putting the total at 16 in major universities of 14 cities and provinces across the country. The responsibilities of each center include identification of local environmental pollution, development of enviromental technology, environmental education and technical support to enterprises coping with environmental management problems, and dissemination of new environmental technologies.

The outcomes of the Centers' work indicate that local communities are keenly interested in the resolution of local environmental problems. Up until 2002, these Centers carried out 487 research projects to address specific local problems, in addition to forming a technical support expert pool (1,437 persons) that offers consulting services to enterprises over 951 occasions. Environmental education programs are also being administered, including courses for environmental managers and citizens and joint seminars among industries, research institutes and academic communities.

In tandem with decentralization and pursuit of a science and technology-oriented society, MOE plans to expand government financial support among others, in order to foster Local Environmental Technology Development Centers into a focal point for autonomous environmental management initiatives and researches by industries, research institutes and academia.

3.8 Membrane system: Engineering companies

- Krosys
    - RO system for desalination
    - Membrane contactors for degasification
    - Industrial water treatment
- Dongju Engineering:
    - PP, PE MF membrane
    - Porous stainless steel tube
    - Ceramic membranes
    - Waste water treatment
    - Recovery and concentration of proteins and Dextrose syrup
- Hansei Innotech Inc.:
    - Ceramic membranes system for food (US filter)
    - Bipolar ED system (Aqualytics, Asahi Glass)
    - Water purification system (US Filter)
- Other engineering companies
    - Mirage Engineering, Dong-Il Engineering
    - Sam-Gwang Sugi , Kyung-In, SK Engineering
    - Hyundai Heavy Ind., Samsung Engineering
    - Sung Shin Engineering

- Water purification
    - Woong-jin Coway,
    - Chung-ho
    - SAEHAN
    - KOLON
    - Pure EnviTech

4. Korean membrane companies

In the last 20 years the growth of membrane applications in Korea, mainly in the field of water treatment (KOWACO, Daewoo, KMS, SK Chemicals, etc.), produced a rapid growth in the number of Korean company supplying membranes and membrane devices. Other field of interest for membrane application are related to gas separation (*e. g*. Airrane), hemodialysis (*e. g* KOLON), etc.

1. **KOWACO**: (www.kowaco.or.kr) membrane process (micro and ultra-filtration) for advanced water treatment (http://english.kwater.or.kr/)

2. **DAEWOO E&C**: (www.dwconst.co.kr), Korea's leader in environmental business. Advanced Water/Wastewater Treatment Processes.
   - development of membrane material for water purification
   - development and commercialization of middle/large membrane process for advanced water treatment process: based on membrane separation water purification technology which leading future water treatment industry, we will develop and commercialize integrated, low energy type water purification system which can produce world's best quality drinking water. Not only in domestic but also overseas market we will apply our water treatment technology and then make ET (Environmental Technology) as motive power of state economy growth. Development necessity for the new concept of water treatment technology on 21 century:
     i. water treatment facility: retrofitting of existing treatment plant
     ii. source water: water quality variation (high turbidity, algae, taste and odour)
     iii. need on next generation water treatment process standardization, environment friendly membrane separation advanced water treatment technology

3. **KMS, Korea Membrane Separation** (High Technology Membrane System for Clean Water): (www.koreamembrane.co.kr)

   Korean Membrane Separation was founded as a venture company in September 1998, to develop and manufacture the polyolefin hollow fiber membranes for the first time in Korea. This membrane technology will become the key element in waste water treatment industry to facilitate environmental-friendly process. The waste water treatment products by KMS use in-house developed submerged membranes that provide excellent quality water filtration process.

KMS was committed to provide quality service and products through its intensive R&D and accumulative know-how in manufacturing for the cleaner world in the future.

KMS researchers have 20 years of experience in manufacturing hollow fiber membranes via a variety of materials and processes.

KMS PE hollow fiber membranes were optimized with feed back system of membrane preparations and field test. To meet customer's needs, KMS continuously improve the performances of the membranes, in terms of **membrane characteristics** (high mechanical strength, high water flux, stable removal efficiency, good resistance to fouling), **membrane modules** (thinly spread configuration of hollow fiber membranes can reduce clogging between the fibers. Eight collection parts per unit module gives very effective and even distribution of water over the entire length of the unit module. Unit module is composed of three flat rectangular sub elements. The number of sub elements can be freely controlled according to the field conditions), **frame** (the perpendicular arrangement of membranes in the module minimizes the friction caused by uprising bubble or water. This preferred arrangement also reduces the possibility of fiber membranes being twisted by materials such as human hairs). Easy assembly or disassembly of module makes the cleaning process simple and easy. Good durability and chemical resistance guarantees a long life time.

About the principle of Korea Membrane Separation (KMS) System:

a. Outline: This process produces clean treated water with separating microorganisms from water after decomposing pollutants in water biologically with microorganisms.

b. Characteristics: Water treatment system was developed by domestic technology with polyolefin hollow fiber **membrane**. Excellent and constant quality of treated water guaranted. KMS systems have strong resistance to shock loads. The treated water can be reused conveniently since the separation systems remove organic matters completely.

c. Installation space was minimized: KMS **membrane** module frames can be installed easily into the existing aeration tank. Also, they do not require sedimentation tank or extra tertiary facilities. Easy assembly and disassembly The individual unit assembly and disassembly function is also added.

d. Reduced operation cost: The operation cost was highly reduced by our technical achievements such as: increased **membrane** durability, energy saving through the filtration with the low suction pressure, **membrane** cleaning using the scouring air, improved module to enhance the **membrane** packing density and more than 30% decrease of excess sludge.

e. Simple operation and maintenance: The system can be equipped with unmanned operation and remote control capabilities. Matured technologies certified by Korean Government. KMS technologies were accumulated and market-tested for several years. Our intellectual properties cover broad areas of membrane manufacturing, module development, and system integration process.

The patented technologies include: preparation method of hollow fiber **membrane**, module development of submerged hollow fiber **membrane** and its application on the waste water treatment process. KMS products received the Certificate of New Technology from the Agency for Technology and Standards (ATS) and the Certificate of Excellent Quality Product from the Korea Public Procurement Service.

f. Process:

f-1. Treatment of Organic Matters: aerobic micro-organisms decompose organic substances in water and then only water pass through the membrane.

f-2. Treatment of T-N and T-P: If above process can not meet the anticipated water standards of nitrogen and phosphorous concentration, biological nitrogen and phosphorus removal system must be added. Then clean water is produced by separating microorganisms from water with hollow fiber membrane

f-3. Direct Filtration Process : The pressure-driven modules are inserted into conventional system or clarifier for application of the direct filtration process which can completely remove pin floc, colloidal organic matters and hazardous organisms.

f-4. Recycling Process: The water produced by treatment process of organic matter can be reused directly after activated carbon treatment and UV disinfection.

g. Applicable Fields: Tertiary treatment of sewage water. KMS process can completely remove nutrients like nitrogen and phosphorus as well as organic matters in the sewage water. Highly concentrated organic waste water. KMS process can hold high microorganism concentration in aeration tank and guarantees excellent treated water quality independent of sludge settling property. Therefore, it's very suitable for treatment of highly concentrated organic waste water such as food waste water.

4. **KOLON** (hollow fiber membrane for hemodialysis) (www.ikolon.com)

KOLON Industries, Inc., established in 1957, is active not only in synthetic yarn and fabric, industrial materials, film, electronic materials, plastic and specialty chemicals, but also in such future-oriented areas as membranes and bioengineering.

KOLON Membrane, a part of KOLON Industries, Inc., has researched and developed the hollow fiber membranes for water purification, water treatment, hemodialysis and biopharmaceutical separation. KOLON Membrane achieved the development of hemodialysis membrane for the first time in Korea and has supplied that at home and abroad. The reinforced hollow fiber membrane can be used in ultrafiltration applications for water treatment as a key sector of environmental field.

Most of ultrafiltration membranes are prepared from polymeric materials by a phase inversion process. Some of these materials are listed below:

- polysulfone/poly (ether sulfone)/sulfonated polysulfone
- poly(vinylidene fluoride)
- polyacrylonitrile (and related block-copolymers)
- cellulosics (e.g. cellulose acetate)
- polyimide/poly(ether imide)
- aliphatic polyamides

The ultra-filtration membrane prepared from polysulfone that has high resistance to chemicals and acid/caustic are used over a wide field of applications such as food industry, pharmaceutical industry, water treatment and pure water manufacturing for semiconductor industry and so on.

The choice of the module is mainly determined by economic considerations. The hollow fiber module is the configuration with the highest packing density. When porous ultra- or micro-filtration are employed, the hollow fiber module is the best choice of other module configurations from the point of packing density and operating cost.

Kolon Industries, Inc. established in 1957, launched Korea's first synthetic fiber production line. For the past 46 years, the company has been engaged in ongoing research & development, helping to ensure that it remains the industry leader for many years to come.

<u>R&D activity on membranes</u>: Kolon commercialized polysulfone hollow fiber membranes for water purifier and hemodialysis and has been developing various high efficient hollow fiber membranes for industrial applications and gas separation:

- ***Hemopuri*** is highly efficient hollow fiber membrane for hemodialysis. Hemodialysis membranes act to remove accumulated uremic toxins, excess ions and water via dialysate, and to supply from the dialysate those ions that are insufficient. It is primarily through diffusion, resulting from the difference in concentration between the blood and dialysate, that the toxins and ions pass through the dialysis membrane. the

Hemopuri is made of polysulfone which is well-known as a biocompatible polymeric material and it has no filling material for pores, so it does not cause the problems such as complement activation or leucocyte reduction during dialysis. The *Hemopuri* is a well-designed asymmetric membrane and only thin skin layer of membrane is working when the dialysis is performed. This can minimize the friction of materials which permeate through the membrane.

- ***DePyro*** has been widely used for sterile pyrogen-free solutions, in large quantity are required for medical procedures such as peritoneal dialysis, hemodialysis, injection water, hemofiltration and so on. *DePyro* is highly efficient as a pyrogen filter. So it has excellent permeability, and pyrogen rejection rate.

5. **AIRRANE:** gas separation membranes (www.airrane.com); spin off from National Research Laboratory of Membrane of Hanyang University. Airrane produces hollow fibers and modules for oxygen enrichment and nitrogen enrichment as well as CO2 separation and dehumidification. Airrane also produces systems incorporating hollow fiber modules. High performance polysulfone(PSf) membrane modules are effective for the production of high purity nitrogen from pressurized air. Business field of Airrane Co. treats hollow fiber membrane module for O_2/N_2 separation, on-site nitrogen generation system, nitrogen generator for food package, O_2 enrichment system for combustor, oxygen supplier for the inside of vehicle, etc.

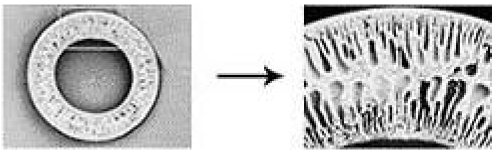
6. **SK CHEMICALS** (Membranes and chemicals - Development of MF/UF membrane material, modulation, performance improvement, management system, etc., Water conditioning chemicals); (www.skchemicals.com)

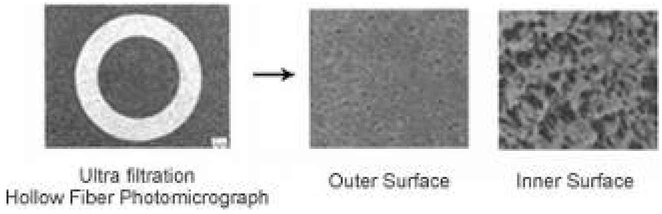
Chemicals has become the first company in Korea to personally develop a hollow-fiber type ultra filter membrane (SKYRANE). SKYRANE is a dual-filter structure where a fine membrane with a highly efficient separation function is formed on both the inner and outer surfaces of the hollow-fiber. This is a world-class quality product patented by SK Chemicals. The main characteristics are:

- - Excellent pressure-resistance
- - Perfect filtration performance by double filtrations
- - Effective back-washin

Ultra filter membrane is generally operated by internal pressure type cross-flow filtration, where filtrate is externally filtered by imposing pressure on the inside of the hollow-fiber.

However, SKYRANE UF membrane has a dual-filter structure, which can be selectively operated by either internal pressure type or external pressure type. Some pictures of SKYRANE membrane sectional view are below reported:





SKYRANE MF is made of hollow-fiber membrane with an external pressure type filtering method. It allows complete water permeability with excellent contaminant screening because the exterior of the membrane has an asymmetrical structure. Since the exterior of SKMF hollow-fiber has a flat and porous surface structure that is uniformly distributed with pores, SKMF removes contaminants at a superior rate to the conventional MF filter. Since the interior of SKMF hollow-fiber is of a porous net-structure, SKMF has excellent permeability with minimum flow resistance.

7. **Chung AH Filter MFG CO Korea** (http://www.chungahfilter.com)

Detailed Product Description:

Feature: CA PES Pleated Filter Cartridge consist of Polyeathersulphone **membrane** and Polypropylene support components. Applicable to the various fields by excellent removal efficiency of the particle. Configuration of all Polypropylene made by heat-adhesion technology warrants the lengthened durability and no leakage of impurities. All materials and components are acceptable to FDA List,21 CFR for potable and edible liquid. Provide quick rinse up. Removal efficiency is 99.99% at each pore size and all integrity tested

Application: Industrial: Rinse, Oils, Solvents, Paints, Ink, Fine chemicals, Gases , Food & Beverage: Potable liquids, beer, wines, water, soft drinks. Cosmetics & Pharmaceuticals.

8. **KORED CO LTD** (http://www.ekored.com)

Company Profile

Name: Kored Co Ltd

Country/Territory: South Korea

Address: 6f Jinju Bldg,943-1 Sinjeong 4-dong, Yangcheon-gu,, Seoul, Seoul, South Korea

Products/Services We Offer: Flat Sheet Membrane for MBR system

Business Type: Manufacturer

Industry Focus: Water Treatment

Geographic Markets: Worldwide

No. of Employees: 11 - 50 People

Certificates: ISO-9001, ISO-14001

Year Established: 1999

Legal Representative/CEO: Mr, Namdoo Kim

Sell Flat Sheet Membrane for MBR System:

Detailed Selling Lead Description: KOReD Co., Ltd. Is a Korean leading manufacturer of "Submerged Flat Sheet Membrane" for MBR systems in organic wastewater treatment technologies.

Since establishment in 1999, Kored Co is pursuing customer satisfaction based on quality, advanced technology and reliability to realize a clean environment and enhanced quality of living. The R&D center staff have developed and commercialized membrane technologies which have been applied to MBR wastewater treatment industries. These flat sheet membrane modules with frames have a lot of advantages compared with the conventional activated sludge process, such as high flux, high effluent quality, limited space requirement and with the possibilities of a flexible and phased extension of existing wastewater treatment plants. Kored Co produce a flat sheet membrane module called "NEOFIL" which provides the most technically and economically feasible wastewater treatment solution in the world. Kored Co currently export membranes to Japan, where is a place of the most advanced MBR system in the world, and a local agent in Australia and Dubai. The simple systems and flat sheet membranes are for MBR plants, municipal sewerage wastewater, hotel and leisure wastewater, livestock wastewater and many other organic wastewater applications.

9. **Woongjin Chemical (**http://www.wjchemical.co.kr/)

SZ Membrane System (*Water treatment process and waste water treatment*) uses immersed hollow fiber membranes which is back washable to remove suspended solids and bacteria and to reduce turbidity from feed water. This purpose could be achieved by single step of filtration economically and confidently without aids of any other process. Membrane itself is extremely durable to be used at severe conditions in which chlorine concentration is high and heavy fouling is expected as it is made of PVDF with strong support layer.

Reverse osmosis membranes (http://www.saehancsm.com/)

10. **HYOSUNG Co** (www.hyosung.com/eng/)

Hyosung leads the domestic environment industry in the field of water treatment business based on several decades of experience, and also actively executes lots of civil works and energy business related engineering business.

- Municipal wastewater treatment plant in Gumi
- Jeju wastewater treatment plant
- Construction of wastewater treatment process at Hanguk Engineering

More than 25 wastewater treatment plants in cities, plants, industires.

More than 10 drinking water production plants in cities, especially Paldang water supply facilities and Jeju island

11. **GS Engineering & Construction (**http://www.gsconst.co.kr/**)**

Fresh water resources are less than 3 percent of Earthashable to remove suspended solids and bacteria and to reduce turbidity from feed water. This purpose could s water resources are available for direct human consumption and irrigation/agricultural uses. As water demands increase over time due to increase in global population, industrialization, etc., seawater desalination has now become an important water treatment process around the world (especially Middle Eastern countries) where availability of fresh water is limited.

Owing to reverse osmosis (RO) membrane technology, seawater desalination is becoming a more competitive option supplying fresh water. However continuing improvements of desalination process are still necessary to provide high quality fresh water and to reduce cost of water production. In this study pilot scale tests are performed (1) to develop an appropriate pretreatment method for seawater reverse osmosis (SWRO) desalination and (2) to find out an optimized RO configuration for boron rejection by computational modeling.

Task 1. Combined DAF and UF System for Desalination Pretreatment

Appropriate pretreatment of SWRO desalination is always essential to enhance the efficiency and longevity of RO system. Therefore, conventional pretreatment systems (e.g., media filtration), microfiltration (MF), and ultrafiltration (UF) have been used to enhance feed water quality of RO systems. However, it has been reported that media filtration was sensitive to raw water quality change. And though MF and UF are able to provide consistent level of feed water quality of RO systems, their filtration efficiencies can be significantly deteriorated when raw water quality are poor (e.g., high turbidity and suspended solid concentration).

In this pilot study, combination of DAF and UF is investigated as a pretreatment option of SWRO desalination to overcome the weaknesses of media filtration, MF, and UF. The pilot plant (150 m^3/day, production capacity) studied is located in Dangjin, South Korea adjacent to West Sea where the seawater turbidity is up to 60 to 70 NTU and average salinity is 32,000 mg/L. The seawater temperature decreases down to 2 degree C in winter. It is expected that the combined DAF and UF pretreatment option applied will greatly improve the specific flux of UF and the feed water quality and RO system. Additionally, backwash and CIP (Clean-In-Place) intervals of RO membranes will be greatly extended compared with ones in the case of either media filtration or UF applied as a pretreatment option.

Task 2. Experiments and Modeling of Boron Rejection by Various RO System Configurations

Boron is present in seawater and its concentration generally ranges 4 to 7 mg/L. Since boron has harmful impacts on humans, animals and plants, its concentration in water is currently regulated. For example, World Health Organization (WHO) recommends reducing its concentration in drinking water down to 0.5 mg/L. However, conventional reverse osmosis (RO) systems have 70 to 90% of boron rejection which is not adequate considering the regulated boron level for drinking water.

The boron concentration of raw water of pilot plant is about 4.0 mg/L. From the pilot plant tests and computational modeling, it will be investigated how the boron rejection is affected by RO system configurations and the operating conditions including pH, flux, pressure, temperature, etc. A predictive model previously developed based on batch test results will be utilized to predict the pilot test results. Furthermore, the model prediction results obtained will be used to find out the optimal RO system configuration for boron rejection.

12. **SEPRATEK (http://www.** specializing in the development, manufacturing and commercialization of robust hollow fiber membranes having heat and solvent resistance, mainly, for pervaporation and vapor permeation. SepraTek pursues highly technology-oriented and R&D-based businesses to provide high performance of membrane products and application insights that improve separation productivity. SepraTek offers reliable and innovated tool, technologies and services by taking on tasks from membrane fabrication to process and system design. SepraTek's experienced R&D staffs continue to develop product

design and function to enable to increase performance and economical value in membrane systems and also to come up with innovative membrane solutions for complex separation problems.

SepraTek's R&D Activities

1. Development of hollow fiber membranes reinforced by a braid of polymeric fibers and metal wires for pervaporation and vapor permeation

SepraTek has established a novel methodology for spinning hollow fiber membrane, by which a thin active layer is formed simultaneously at the inside of a porous hollow fiber when the hollow fiber is spun. The resulting hollow fiber membrane can be composed of two layers; an inner active layer thinner than 1 □layers; an inner active layer thinner than 1 or spinning hollow fiber membrane, by which a thin active layer is formed simultaneously at the inside of a porous hollow fiber when the hollow fiber is spun. The resulting hollow fiber membrane can be composedt layer. After spinning, washing and drying, the hollow fiber membrane show an excellent pressure-resistance as well as a good dimensional stability in organic solvents even at high temperature 100 ^{o}C. Thereby, the novel methodology makes it possible to fabricate a hollow fiber form of vapor permeation and pervaporation membranes, utilizing the significant benefits of hollow fiber membrane shape; high membrane packing density in module, low fabrication cost, flexibility in membrane module design and so on.

2. Membrane module fabrication and system design.

SepraTek has developed diverse hollow fiber membrane module fabrication techniques including potting resin formulation, potting art and module design. Membrane modules which are very stable at high temperature even in contact with aggressive organic solvent can be fabricated by an established methodology.

A membrane system is designed and engineered through systematical simulation and a sequence of groundwork so as to maximize membrane performance as well as the economical value of the membrane process. Recently, SepraTek has develop and installed its first pervaporative dehydration unit with an equivalent treatment capacity of 5000 liter ethanol per day. The unit is equipped with the hollow fiber membranes reinforced by the braid fabric of polymeric fiber yarns and meter wires. Now the continuous operation of the unit is under way to yield design data for scale-up.

3. Innovative TIPS (thermally induced phase separation)

SepraTek has established the innovated TIPS (Thermally Induced Phase Separation) process which enables to produce a large diameter of chemically stable porous hollow fiber membranes without stretching process. The TIPS process can not only produce hollow fiber membranes having a wide range of porosities as well as various diameters but also produce a robust hollow fiber reinforced by a braid. The process can diversify membrane with regard to polymeric material which can not be shaped by the DIPS(Diffusion Induced Phase Separation).

4. Permeation membrane analyzers

SepraTek has developed permeation analyzers which are able to precisely, rapidly and directly characterize the permeation behaviors of gas, liquid, and vapor molecules through membrane, respectively, by employing a dual detection system. They are designed to determine the permeability and diffusivity of a permeant through a polymeric membrane simultaneously from its permeation transient curve obtained by precise on-line measurement. They are also very effective to investigate interactive properties of a polymeric material with its exposure to a specific circumstance, like a liquid, vapor or gas, which makes them more than membrane permeation analyzers.

13. SUNG SHIN ENGINEERING CO. LTD (http://www.ssenc.net/)

SUNG-SHIN was established for the purpose of contributing toward prevention of environmental pollution with PCF-filter at the end of 1999. As a result of continuous R&D, we was joined 5 times to the national research projects. Through these works, we have secured 2 of Environmental New Technology Verifications, 2 of National Certificates for Excellent Quality Products(EEC, P-Mark) and 19 of domestic and international patents. The market share of our fiber filter products have been raised rapidly as much as 470 sales in domestic market and 30 sales in foreign market(up to November 2006). Moreover we have prepared our own factory at July 2005 and so we have been ready to bulk orders. We promise to be a paramount company, which offers fiber filter products that prevent the environmental pollution and contribute to the co-prosperity of mankind with high performance, high quality and low price.
A filter layer is formed through pressurizing the non-braided fiber bundles on the surface of the rectangular type perforated plate. Then the filtration is started with the gravity force less than about 30 centimeters of water head.

The backwashing procedure is beginning when the water level is reached at given hight. The backwashing is performed by relaxing the fiber bundles and sparging the backwash air to form intensive upward stream which can give a strong shear force to move the fibers.

When more than two of this kind filters are equipped in a same basin the backwash pumps are not need, since the backwash water is supplied automatically by upward stream coming from neighbor filters. So, it was called PUMPLESS FILTER sometimes.

5. Development and perspective of membrane research and applications in Korea

Saving Energy and resources

- Replacement of energy intensive separation processes (ex.: olefin/paraffin separation, azeotropic distillation)
- Recovery of valuable resources and energy (ex: clean technology)
- Transformation of chemicals energy (ex: fuel cell, battery)

Environmental Applications

- Water purifier for home usage
- Waste and process water treatment
- Gray water production
- VOC removal from water and air
- Soil remediation
- Landfill leachate

Controlled delivery

- Drug delivery
- Biomedical application

Appendix

In the last years several International Conferences, Meetings, Workshops on membranes were organized from Korea Research Institutes or involved Membrane Society of Korea and Aseanian Membrane Society:

- “*The second annual conference of Aseanian Membrane Society*“, organizad by the Aseanian Membrane Society and hosted by the Membrane Society of Korea.
- Water Environment-Membrane Technology [WEMT2004], june 7-10, 2004 Seoul, Korea (organized by Seoul National University, International Water Association)
- “*International Congress on Membranes and Membrane Processes 2005*”, ICOM 2005, organized by the Aseanian Membrane Society and the Membrane Society of Korea.
- International agreement Italia-Korea: “*Development of membranes and membrane processes for clean environment and clean technology*” - Protocol for scientific and technological cooperation between the Italian Republic and the Republic of Korea for the years 2004-2006 ANNEX IV –Joint Research project of particular relevance between CNR-ITM c/o University of Calabria – Cubo 17/C, 87030 Rende CS Korea Research Institute of Chemical Technology (KRICT) Daejon, Corea del Sud
- Italia-Korea workshops on “*Membranes and membrane processes for a clean environment*”. The last one of the series was held in Giardini-Naxos (Sicily, Italy), 29-30 September 2006. In this wonderful scenario the workshop was chaired by Prof. Enrico Drioli from the University of Calabria and Director of the Institute on Membrane Technology of the National Research Council of Italy (ITM-CNR) and Prof. Kew Ho Lee Director of the Membrane and Separation Research Center, Korean Research Institute on Chemical Technology (KRICT). The aim of the workshop has been to promote the discussion on membrane science and technology in the two Countries and in particular on the fundamentals and applications of membranes for a clean environment and energy saving. A variety of new information in the membrane field in Italy and Korea ranging from industrial applications to progresses in the bio-medical field, were presented. The workshop was attended by about 45 researchers coming from Universities, Research Centers and private Companies from Italy and South Korea. The Chairs confirmed the interest to continue the collaboration by developing joint research projects and by promoting researcher’s mobility between the two countries. The 6th Italy-Korea workshop will be held in Korea in the 2008.