Higher Performance of RO Membrane for Drinking Water

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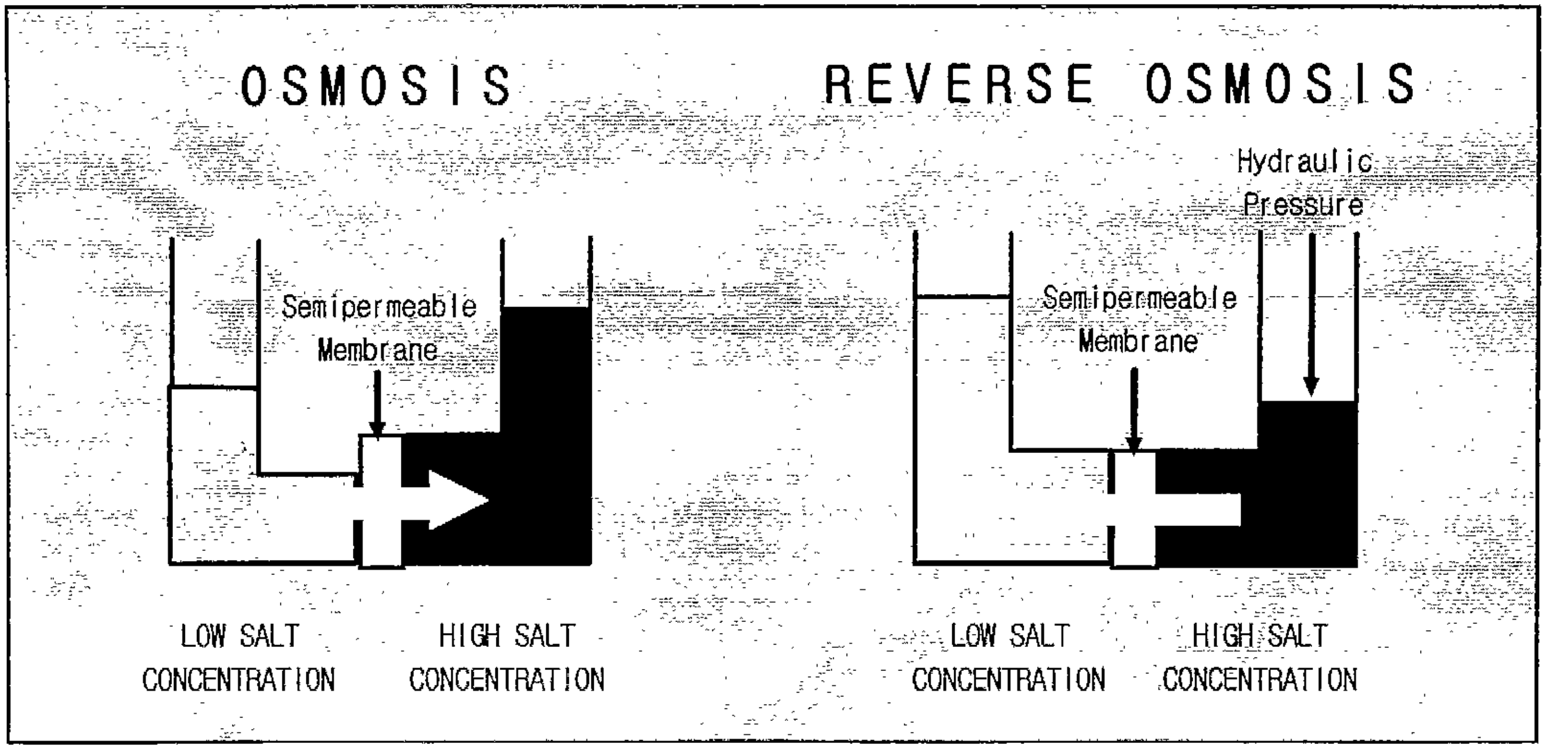
Phenomena of Osmosis and Reverse Osmosis



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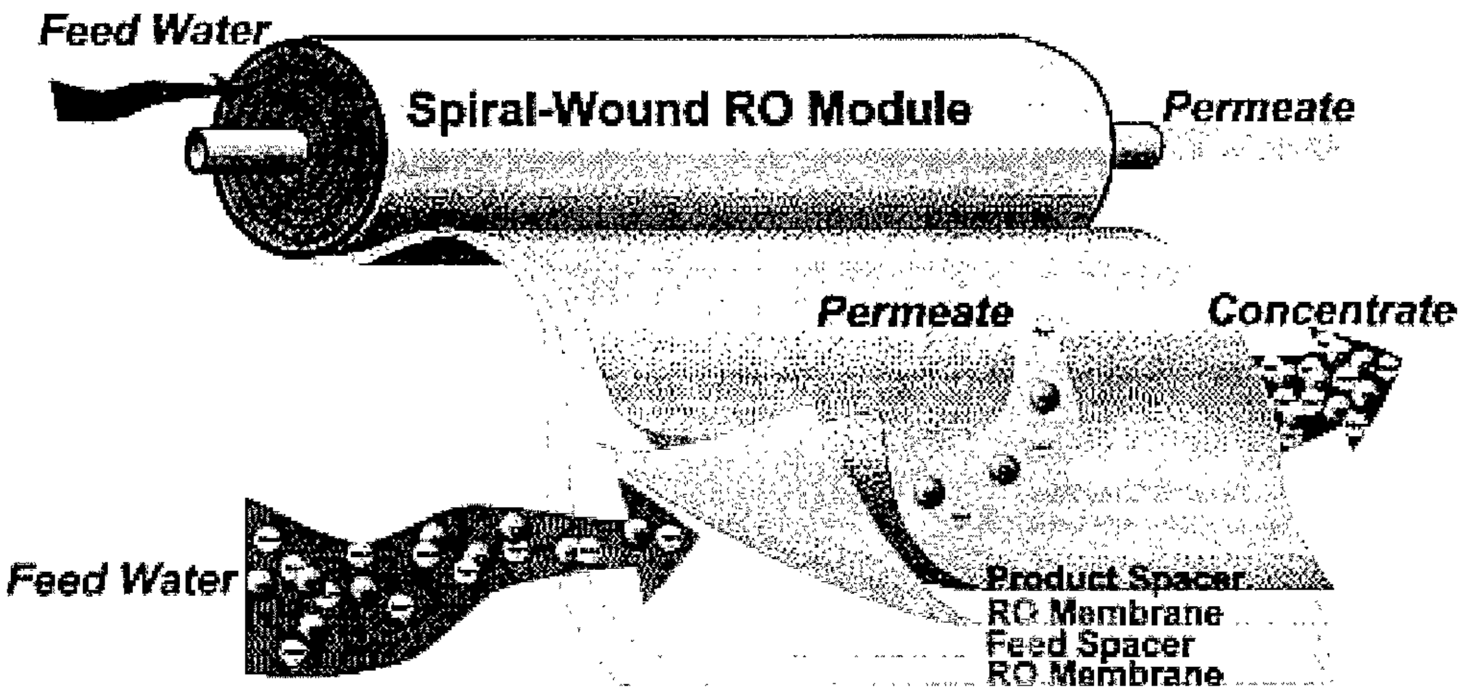
Structure of Spiral Wound Membrane



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RO Membrane Applications

1. Potable water
   - Drinking water, Bathing, Laundry

2. Industrial Applications
   - Rinsing Electronic Components (high quality)
   - Boiler makeup (reducing scaling)
   - Process Water (reduce waste, improve quality of process)
   - High Purity Water (rinsing and cleaning metals, reaction)

3. Special Application
   - Desalting Sea Water
   - Pharmaceuticals and Medical
   - Laboratories

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General Separation Property of RO Membrane (I)

Industrial RO Elements

	RE8040-BE (SAEHAN)	FT30-400 (Dow/Film-Tec)	CPA-3 (Hydranautics)	SU-720F (Toray)
Rejection (%)	99.5	99.5	99.6	99.4
Flux (GPD)	11000	10500	11000	8500
Pressure (psig)	225	225	225±5	220
Temperature (℃)	25	25	25±4	25
NaCl (ppm)	2000	2000	1500±100	1500
pH	6.5 ~ 7	8	6.5~7	6.5
Recovery (%)	15±5	15	10±5	20

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General Separation Property of RO Membrane (II)

Tabwater RO Elements

MODEL NO	FLUX (GPD)		REJECTION (%)		TEST CONDITION	REMARK
	Min.	Avg	Min.	Avg		
RE-1810-30	27	30	92	96	Pressure : 60psig NaCl : 500 ppm Temperature : 25℃ PH : 6.5- 7.0 Recovery : 15± 5%	
RE-1810-50	45	50	92	96		
RE-1812-25	25	32	92	96		
RE-1812-35	32	40	92	96		
RE-1812-60	54	60	92	96		
RE-1812-80	72	80	92	96		
RE-2010-LPM	27	30	90	94	Pressure : 20psig NaCl : 100 ppm Temperature : 25℃ PH : 6.5- 7.0 Recovery : 15± 5%	Low-pressure*
RE-2012-DYM	43	50	90	94		
RE-2010-LPM	60	70	90	94		
RE-3010-TKL	195	230	90	94		

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Recent Trends of RO Membrane Development

1. High Flux Membranes

- Hydranautics, ESPA membrane (45 gfd, flux)

2. High Rejection Membranes

- Toray, UTC 80 membrane (99.8%, salt rejection)

3. Fouling Resistance Membranes

- Trisep, X-20 membrane (Cleaning Cycle prolongation)

4. Chlorine Resistance Membranes

- Not Commercialized

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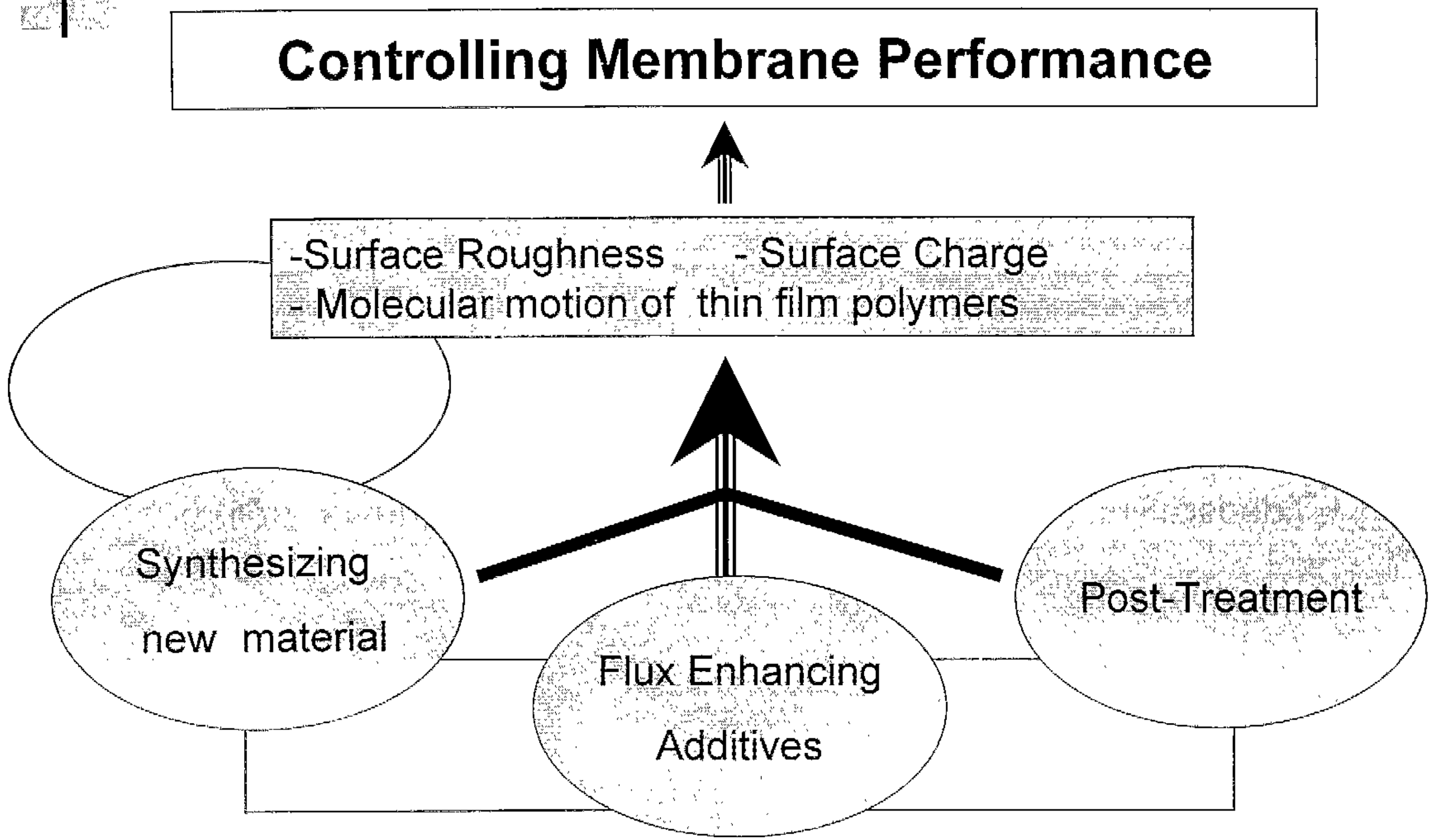
Flux Enhancement in Reverse Osmosis Membrane



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Surface Roughness

- *AFM & SEM Study*

- Surface morphology are revealed by atomic force microscopy (AFM) and high-resolution field-emission scanning electron microscopy (FE-SEM)

Membranes	RO performance	
	Water flux (gfd)	Salt rejection (%)
MPD/TMC	28	> 96.0
SH-I	28.4	> 99.1
SH-II	37.2	> 98.7
SH-III	45.4	> 98.4

All the results were obtained with 0.2% NaCl in deionized water and at the operating pressure of 225 psi and the temperature of 25°C

SEM photograph (Surface)

MPD/TMC

SH-I

SH-II

SH-III

× 50000

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Surface morphology

- Surface roughness, surface area, and water flux of RO membranes

Membranes	Surface roughness (μm)	Surface area (μm^2)	Water flux (gfd)
MPD/TMC	0.042	171.2	28
SH-I	0.040	147.4	28.4
SH-II	0.043	148.8	37.2
SH-III	0.084	180.9	45.4

Surface roughness ; SH-III > SH-II > MPD/TMC > SH-I

Surface area ; SH-III > MPD/TMC > SH-II > SH-I

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Molecular motion of thin film polymers

Solid-state NMR spectroscopy

- The relaxation and molecular motion of the thin-film polymers are characterized by solid-state ^1H NMR spectroscopy
- The surface area alone was no longer related to the relative increase in flux.
- The molecular mobility of the aromatic polyamides forming thin films played an important role in controlling the RO permeability.
- The membrane composed of the thin-film polymer with relatively longer correlation time, τ_c shows higher water permeability.
- We can predict the RO permeability with the information of the molecular motion of the thin-film polymers.

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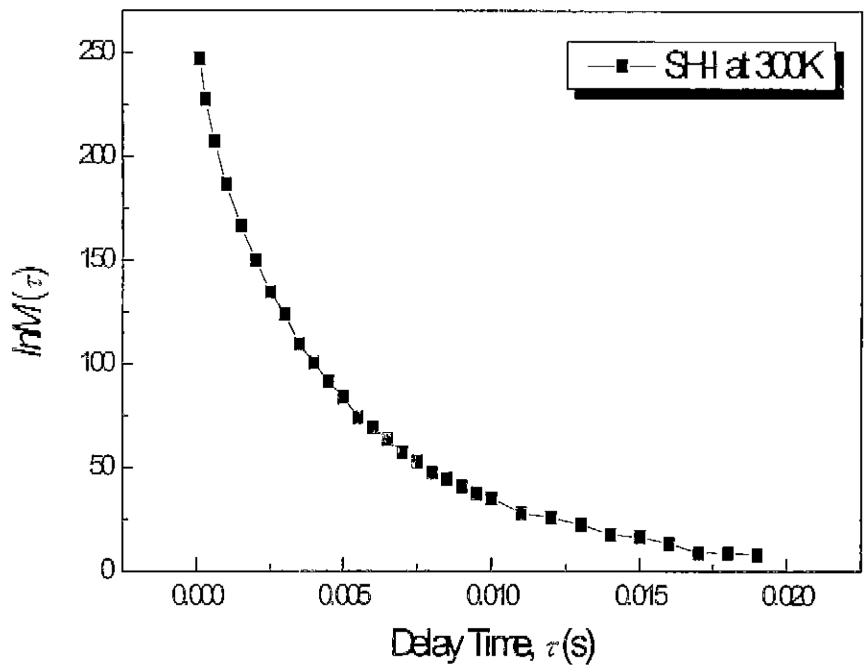
NMR spectroscopy data

Semilogarithmic plots of magnetization intensity for SH-I aromatic polyamide at 300K



$$M(\tau) = M_0 \exp(-\tau/T_{1\rho})$$

➡ The $T_{1\rho}$ relaxation time is determined from the slope.

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Calculation of the correlation time, τ_c from the relaxation time $T_{1\rho}$

$$\frac{1}{T_{1\rho}} = \frac{3}{10}\frac{\gamma^4 \hbar^2}{r^6}\left[\frac{2.5\tau_c}{1+\omega_0{}^2\tau_c{}^2} + \frac{\tau_c}{1+4\omega_0{}^2\tau_c{}^2} + \frac{1.5\tau_c}{1+4\omega_1{}^2\tau_c{}^2}\right]$$

ω_1 ; resonance frequency (rad/s) in B_1 magnetic field

ω_0 ; 200.13 MHz

γ ; magnetogyric ratio

; Planck's constant

r ; internuclear distance

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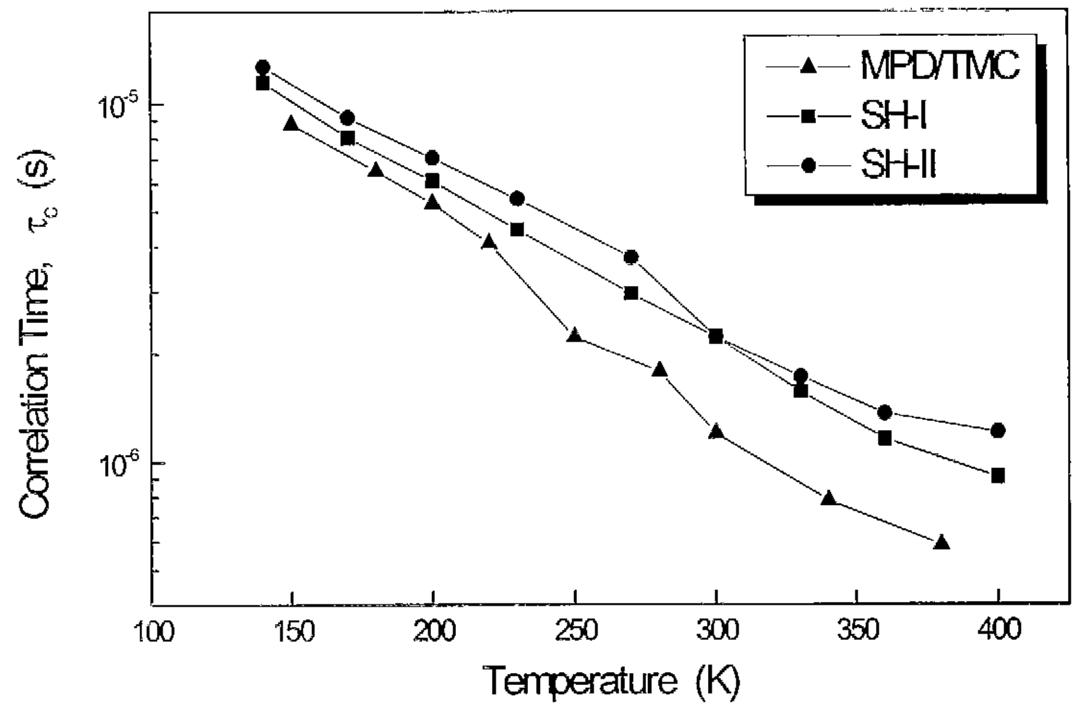
Plot of correlation time vs. temperature for MPD/TMC, SH-I, and SH-II



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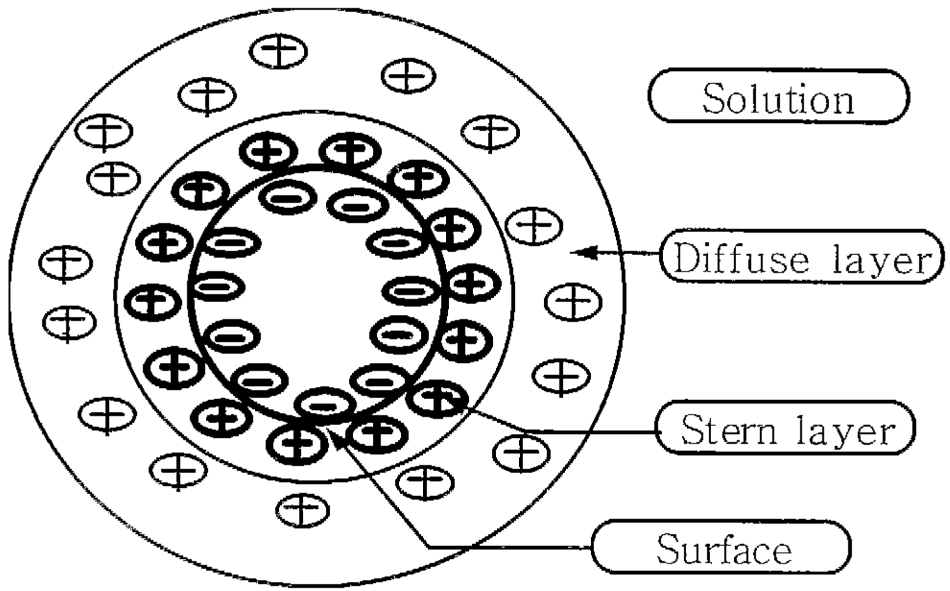
EKA (Electrokinetic Analyzer) Method

- Interaction of Charged Solid and Electrolyte Solution
- Zeta potential



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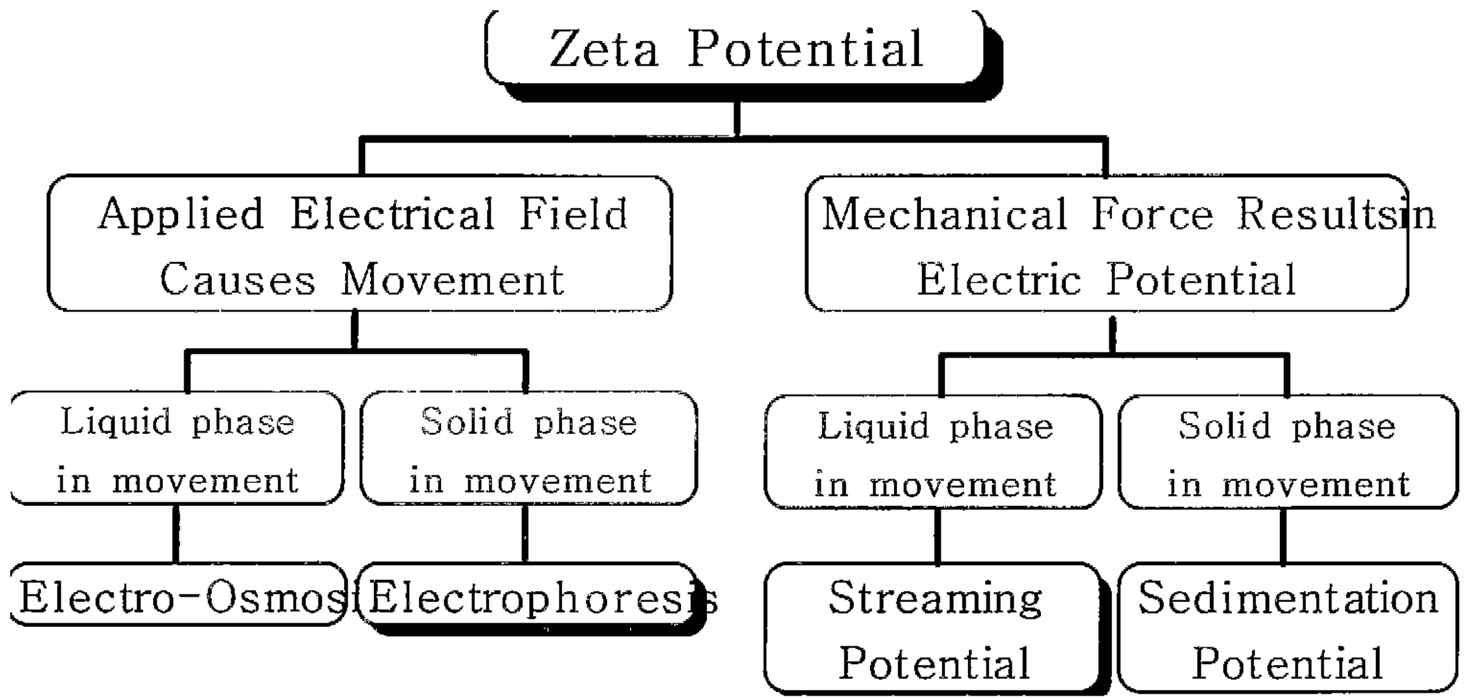
Zeta Potential



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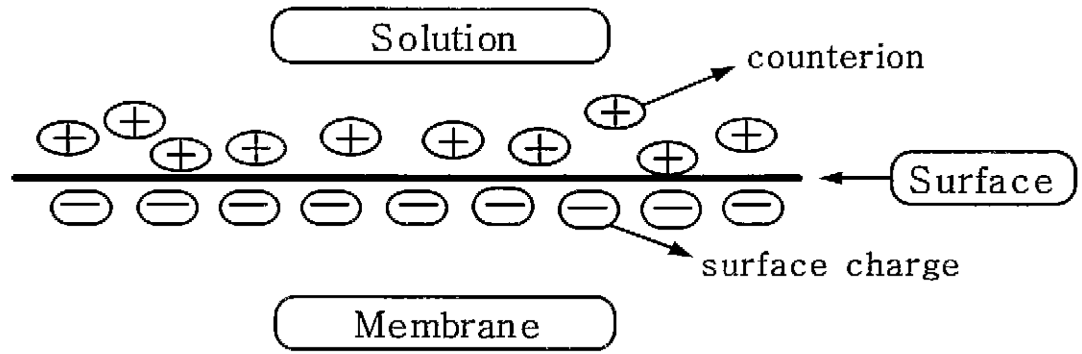
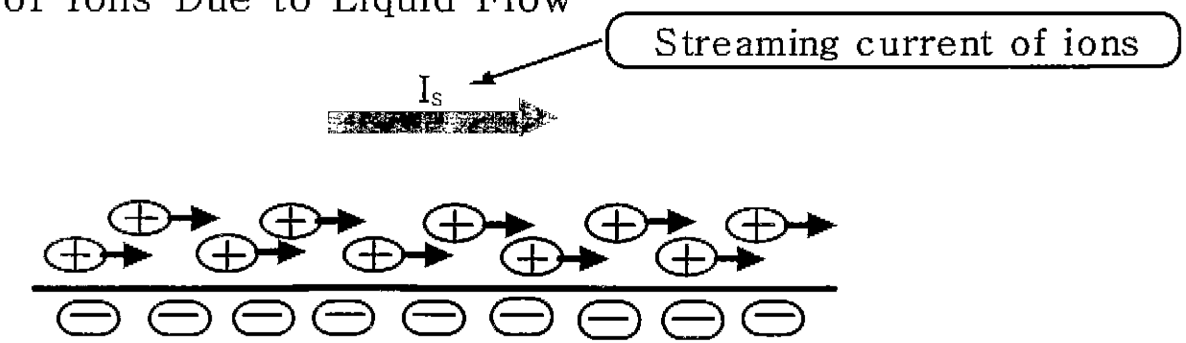
Streaming Potential of Solid-Liquid Interface (I)

A. Electric Double Layer at Rest



B. Movement of Ions Due to Liquid Flow



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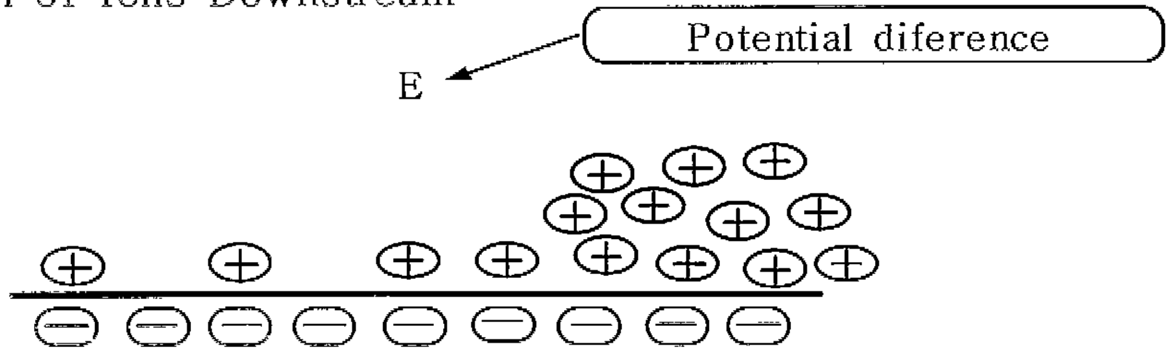
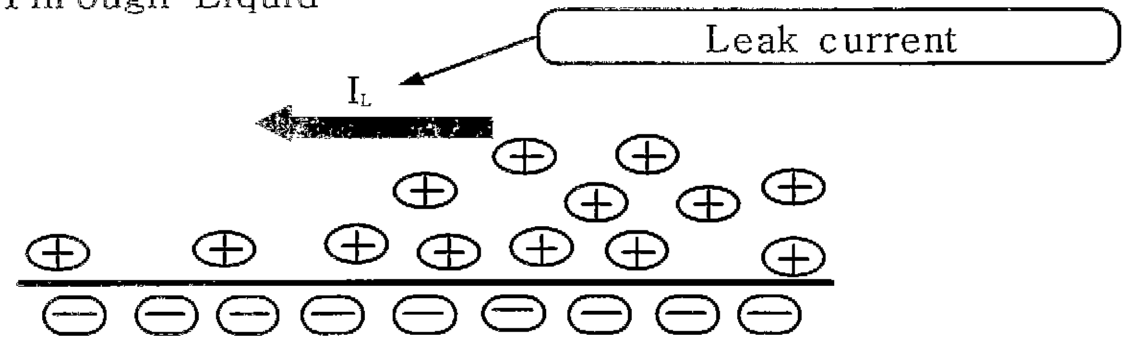
Streaming Potential of Solid-Liquid Interface (II)

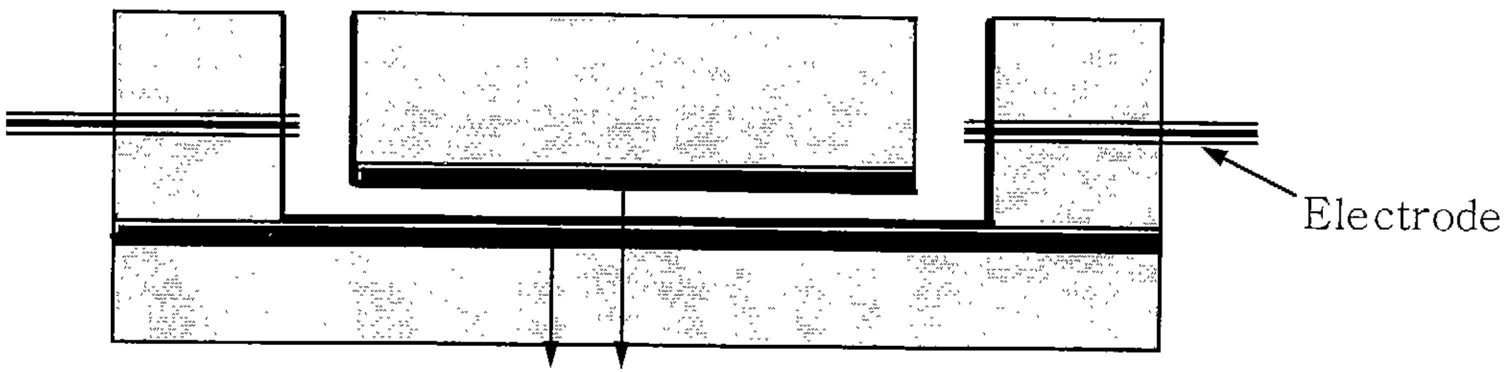
C. Accumulation of Ions Downstream



D. Leak Current Through Liquid



Streaming Potential Measuring



Zeta potential(ξ) : Helmholtz-Smoluchowski equation

$$\xi = \frac{Es}{\Delta P}\frac{\eta}{\varepsilon\varepsilon_o}\frac{L}{A}\frac{1}{R}$$

Es: streaming potential, η: liquid viscosity, R : resistance, ΔP: applied hydraulic pressure, ε: liquid permeability, L,A: length, area of the channel

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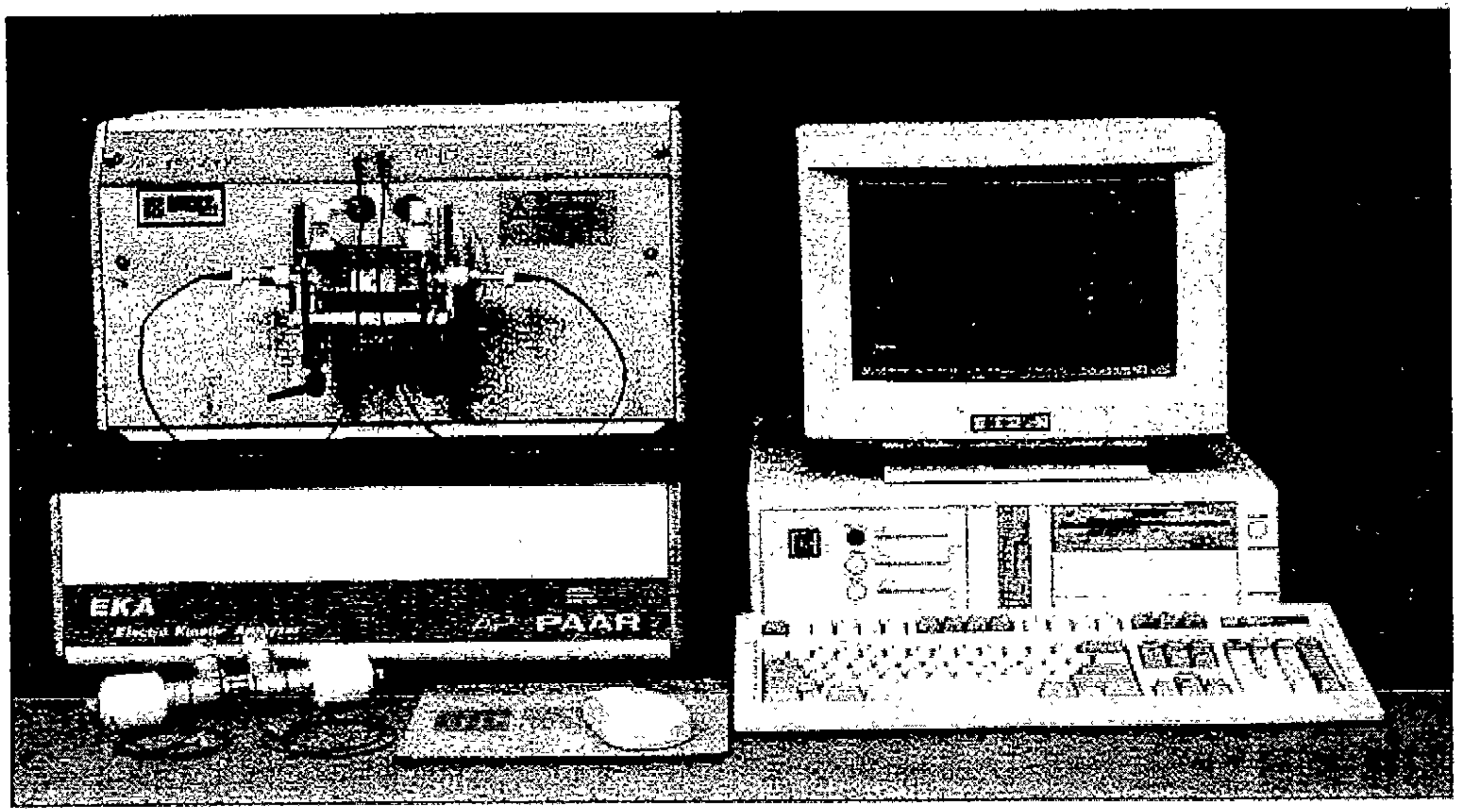
Electrokinetic Analyzer



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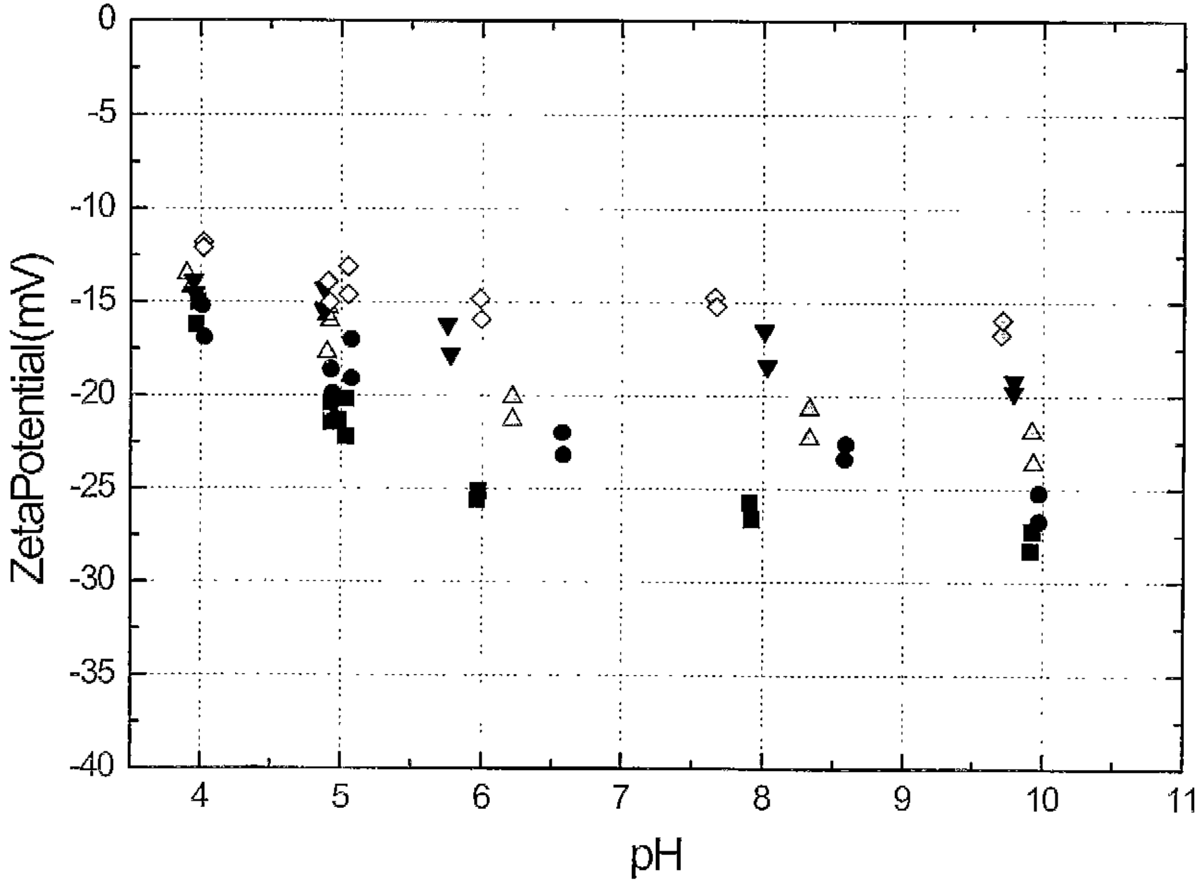
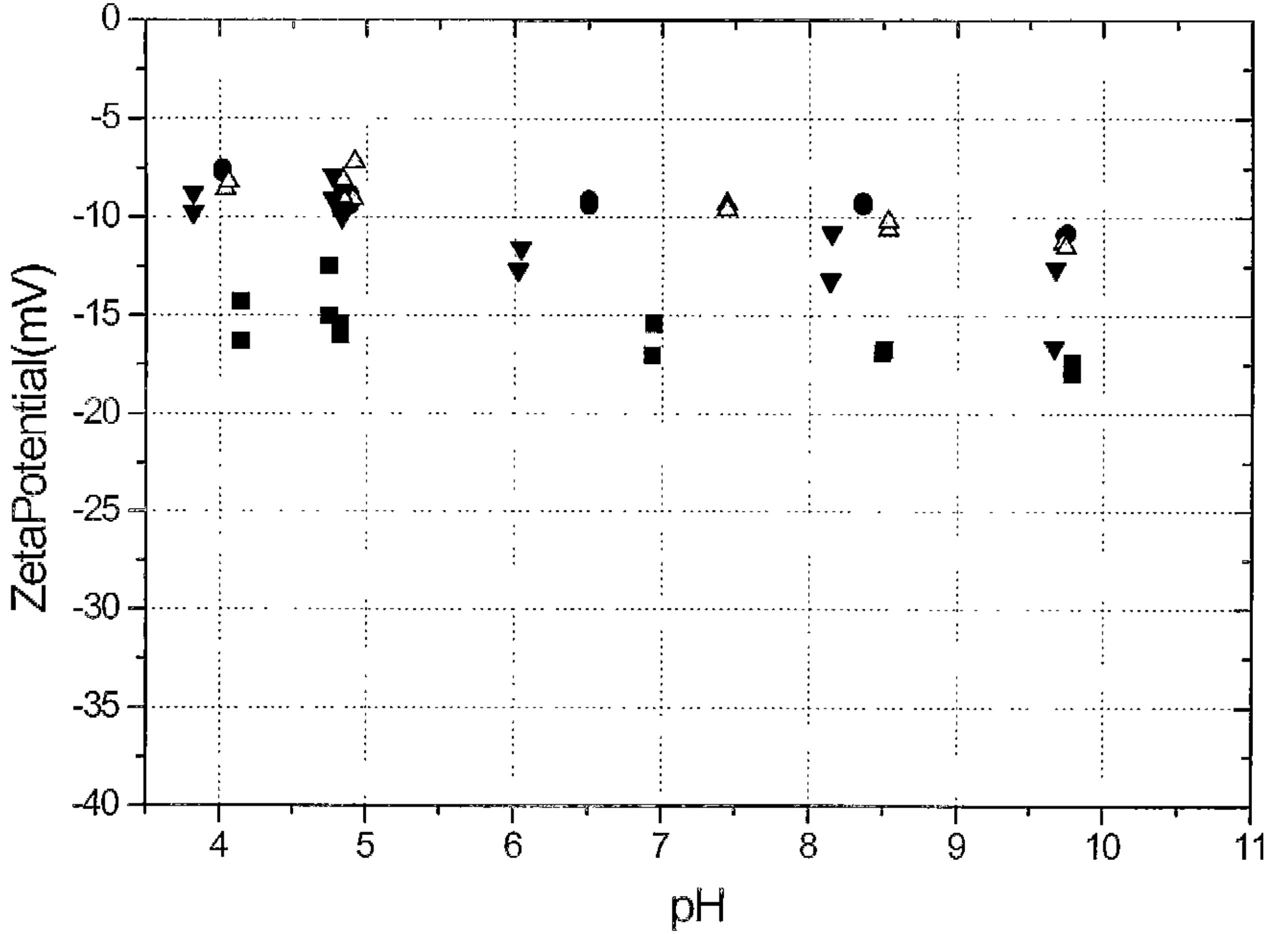
Surface Charge Control

- Industrial Membrane



Surface Charge Control

– Tap water RO



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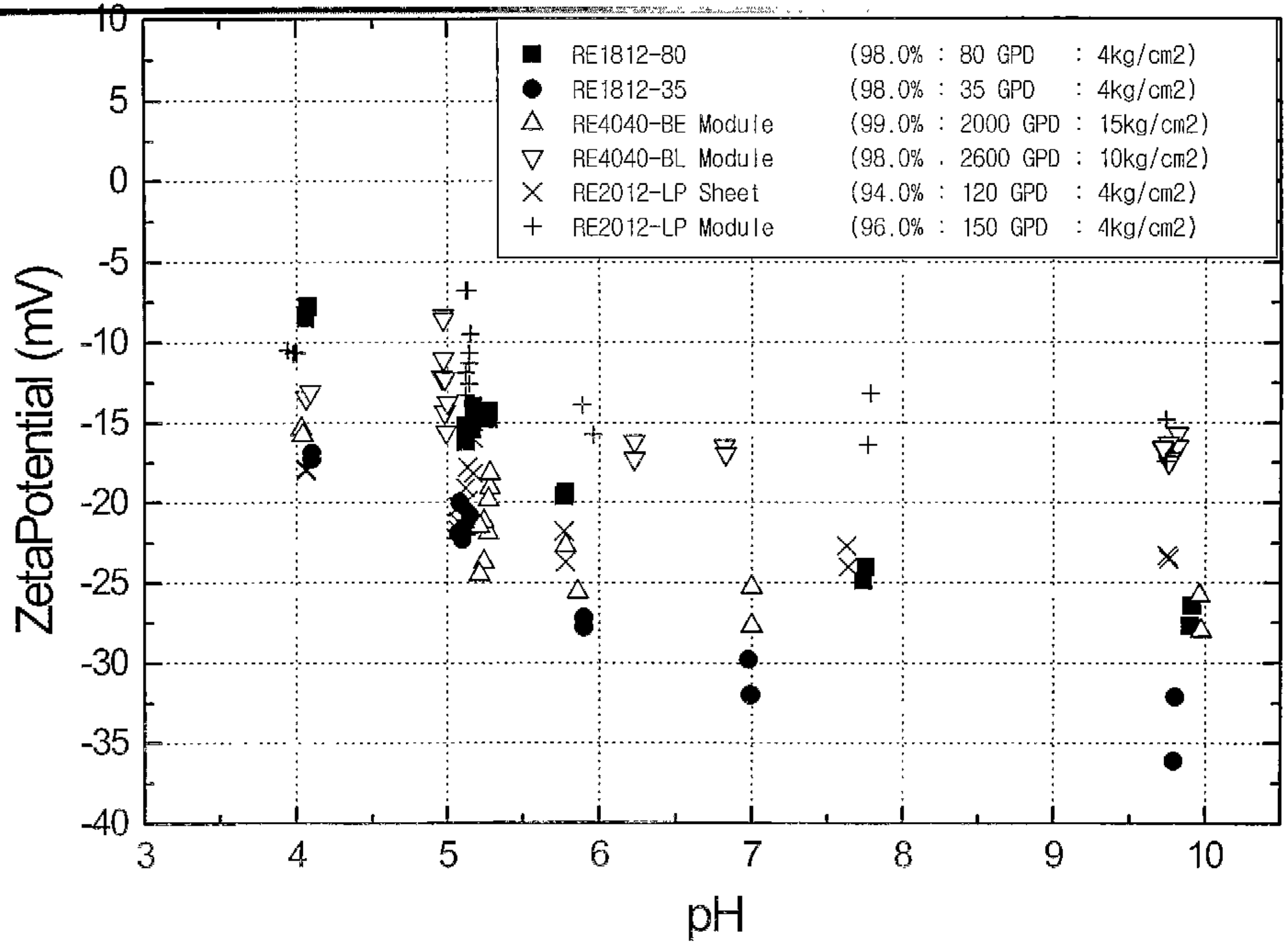
Surface Charge Control



Conclusion

- Higher surface area structure of polyamides is a prerequisite for a good membrane to yield high flux.
- The molecular mobility of the aromatic polyamides forming thin films played an important role in controlling the RO permeability.
- Less charged surface of polyamides lead to relatively increasing in flux.

History of SAEHAN RO Membrane Development

- 1990 – Started basic research on RO membranes
- 1994 – Began the production of the 13 inch wide RO membrane
- 1995 – Began to build the manufacturing facility
- 1996 – Began to produce the 40 inch long RO elements
- 1997 – Received ISO 14001 and 9002 approval
- 1998 – Began to produce Pleated microfilter element
- 1999 – Special purchase agreements with Zenon, US filter, ASI, Argo

- Certification
  FDA, WQA, IR 52 Award, KT mark

Organization Chart of Filter Company Division