BACTERIAL CELLULOSE-CHITOSAN MEMBRANE GRAFTED WITH THEOPHYLLINE-IMPRINTED COPOLYMER BY FREE RADICAL COPOLYMERIZATION

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ABSTRACT

In this research, benzyl diethyldithiocarbamate was immobilized on a bacterial cellulose-chitosan membrane via a silane coupler. This treated membrane was grafted with theophylline-imprinted copolymer of methacrylic acid and ethylene glycol dimethacrylate by ultraviolet irradiation. The highest degree of grafting obtained was 0.3334% for r (weight ratio of monomers to bacterial cellulose-chitosan membrane) equal to 3.244 in mmol/ml. The molecularly imprinted polymer-bacterial cellulose-chitosan membrane was prepared by using 0.5% chitosan solution containing 15.0% polyethylene glycol and evaporating the solution for 2.5 hours after coating at room temperature. The relative flux of 3.69 $L/m^2.h$ at 12.5 bar was obtained. The average pore diameter was 135 Å in dry state and 404 Å in wet state. Physical properties and morphology of the molecularly imprinted membrane were examined. The chitosan and polyethylene glycol contents in the chitosan solution had a significant effect on porosity of the membrane and the flow rate of water through the membrane. A relatively large flow rate through the membrane with a stable coating of chitosan membrane was observed at optimized evaporation time. The tensile strength provided by the synthesized membrane was larger than the plain bacterial cellulose support, in both wet and dry states.

ABSTRAK

Dalam penyelidikan ini, benzil diethyldithiokarbamat disekat-gerak pada membran selulosa bakteria – kitosan melalui satu silana pengganding. Membran terawat dilekatkan dengan teofilina kopolimer tertera asid metakrilik dan etilena glikol dimetakrilat oleh penyinaran ultralembayung. Kadar cantuman tertinggi yang diperolehi ialah 0.3334% untuk r (nisbah berat monomer-monomer terhadap membran kitosan selulosa bakteria) bersamaan 3.244 dalam mmol / ml. Fluks banding untuk 3.69 L/m^2.jam pada 12.5 bar diperolehi. Purata diameter pori membran ialah 135 Å pada keadaan kering dan 404 Å pada keadaan basah. Membran molekul polimer-bakteria selulosa-kitosan tercetak yang disediakan dengan menggunakan 0.5% larutan kitosan yang mengandungi 15% polietilena glikol dan larutan itu disejatkan selama 2.5 jam pada tekanan 12.5 bar selepas dilapiskan pada suhu bilik. Sifat fizikal membran diuji dan morfologi membran molekul tercetak diperiksa. Kandungan kitosan dan polietilena glikol di dalam larutan kitosan mempunyai kesan terhadap keporosan membran dan kadar aliran air menembusi membran. Fluks banding yang besar dapat dilihat pada membran di mana salutan kitosan yang stabil disalut pada masa penyejatan yang optimum. Membran molekul tercetak mempunyai kekuatan tegangan lebih besar dalam keadaan kering dan basah berbanding membran selulosa bakteria kosong.

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LIST OF SYMBOLS

%	-	Percentage
°C	-	Degree Celsius
µL	-	Micro Litre
µm	-	Micro Meter
Å	-	Angstrom
A	-	Area (m^2)
A-BC	-	Agitated Bacterial Cellulose
AFM	-	Atomic Force Microscopy
ASTM	-	American Society for Testing and Materials
BC	-	Bacterial Cellulose
BET	-	Brunauer Emmett Teller
BSH	-	Buffered Schamm and Hestrin
C	-	Carbon
$CaCO_3$	-	Calcium Carbonate
C_b	-	The Bulk Concentration
C_p	-	The Permeate Concentration
C_{feed}	-	The Feed Concentration
$C_{filtrate}$	-	The Filtrate Concentration
Cl^-	-	Chloride Ion
C_{MAA}	-	The Concentration of Methacrylic Acid Solution
CBH	-	Cellobiohydrolase
CMC	-	Carboxymethylcellulose
COOH	-	Carboxylic Acid Group
Da	-	Dalton (g/mol)
DD	-	Degree of Deacetylation

DDS	-	Drug Delivery Systems
DMF	-	*N,N*-dimethylform-amide
DNA	-	Deoxyribonucleic Acid
DP	-	Degree of Polymerization
EC	-	Endocellulases
EDMA	-	Ethyleneglycol Dimethacrylate
EDTA	-	Ethylenediaminetetraacetic Acid
FESEM	-	Field Emission Scanning Electron Microscopy
FTIR	-	Fourier Transform Infra Red Spectroscopy
$g\ L^{-1}$	-	Gram per Litre
g	-	Gram
g/L	-	Gram per Liter
GFC	-	Gel Filtration Chromatography
GPC	-	Gel Permeation Chromatography
h	-	Hour
H	-	Hydrogen
HPLC	-	High Performance Liquid Chromatography
J	-	Flux rate ($L/m^2.h$)
K	-	Kelvin
kN	-	Kilo Newton
kN/m^2	-	Kilo Newton per Area
kV	-	Kilo Volt
L	-	Litre
m^2/g	-	Area per Gram
MAA	-	Methacrylic Acid
MIM	-	Molecularly Imprinted Membrane
MIP-BCC	-	Molecularly Imprinted Polymer Bacterial Cellulose Chitosan
ml	-	Mili Litre
ml/g	-	Mili Litre per Gram
mm	-	Mili Meter
mmol/ml	-	Mili Mol per Mili Litre
MPa	-	Mega Pascal
MW	-	Molecular Weight
N	-	Nitrogen

N_2	-	Nitrogen Gas
NaOH	-	Sodium Hydroxide
NH_2	-	Amine Group
nm	-	Nano Meter
NMR	-	Nuclear Magnetic Resonance Spectroscopy
O	-	Oxygen
PC	-	Plant Cellulose
PEG	-	Polyethylene Glycol
R	-	The Ratio of the Heights of the Peaks
r	-	Weight Ratio of Monomers to the Membrane
RIPP	-	Recovery, Isolation, Purification and Polishing
RNA	-	Ribonucleic Acid
RNase A	-	Ribonuclease A
RNase B	-	Ribonuclease A
rpm	-	Revolutions per minute
S-BC	-	Static Bacterial Cellulose
SDS	-	Sodium Dodecyl Sulfate
SEC	-	Size Exclusion Chromatography
SI	-	System International
SPE	-	Solid Phase Extraction
UF	-	Ultrafiltration
UV	-	Ultraviolet
v/v	-	Volume per Volume
V_{MAA}	-	The Volume of MAA Solution
w/v	-	Weight per Volume
W_d	-	The Weights of Dried Membranes
W_g	-	The Weights of Grafted Membrane
$W_{membrane}$	-	The weight of bacterial cellulose-chitosan membrane.
W_o	-	The Weights of Ungrafted Membrane
W_w	-	The Weights of Wet Membranes
λ_{595}	-	Wavelength at 595 nm
ρ	-	Density (kg/m^3)

CHAPTER 1

INTRODUCTION

1.1 Research Background

In nature, most biological processes are governed by mechanisms for molecular recognition. These include the immuno response, the ligand–receptor interaction, and enzyme catalysis. They involve such biological hosts as antibodies, enzymes or receptors strongly and specifically binding to a particular molecular structure. A challenge for the contemporary chemists is to develop synthetic receptors with an affinity and specificity approaching that achieved in nature. To this end, many synthetic low molecular weight organic receptors capable of encapsulating reagents have been designed (Hof *et al.,* 2002; Vriezema *et al.,* 2005). The construction of such receptors, however, usually requires complicated multi-step synthesis, which severely limits their large-scale application. Developing other synthetically more accessible receptors is thus highly desirable. Interest in a new class of artificial receptors, molecularly imprinted polymers (MIPs), has increased rapidly in recent years because of their easy preparation, thermal and chemical stability, and highly selective recognition capabilities (Mosbach, 1994; Shea, 1994; Wulff, 2002; Mosbach and Ramstrom, 1996). Nowadays, the molecular imprinting technique has become a straightforward and versatile method for the generation of biomimetic macromolecular receptors. One of the most distinct characteristics of the molecular imprinting process is its generality, which offers the freedom to prepare receptors for a wide range of templates without appreciably changing the synthetic protocols. It is in this respect, in our opinion, outstanding amongst other non-biological approaches. The binding sites generated during the imprinting process often have an affinity and a selectivity approaching those of antibody antigen systems. MIPs are thus also dubbed ''antibody mimics'' (Vlatakis *et al.,* 1993). They have much higher chemical and physical stability than such biological entities as antibodies and enzymes. In addition, MIPs show remarkable resistance to extreme pH conditions, organic solvents, metal ions, and autoclave treatment. Such highly appealing physical and chemical characteristics make MIPs very promising candidates for many applications, including chromatographic stationary-phase (Turiel and Martin-Esteban, 2004) and solid-phase separation (Sellergren, 1994; Haginaka, 2004), antibody mimics (biomimetic assays and sensors) (Vlatakis *et al.,* 1993; Kriz *et al.,*1997; Haupt and Mosbach, 2000; Haupt, 2003), enzymemimics (Ramström and Mosbach, 1999; Wulff, 2002), organic synthesis (Alexander *et al.,* 2003), capillary electrochromatography (Spégel *et al.,* 2003), and drug delivery (Alvarez-Lorenzo and Concheiro, 2004).

MIPs are applicable in a variety of different configurations. In the past few years molecular imprinting has entered many areas of chemistry, biochemistry and biotechnology. Nowadays polymers imprinted with different templates like drugs, herbicides, sugars, nucleotides, amino acids and protein. MIPs have antibody-like specific binding sites for target molecules (templates). MIPs can be synthesized by conventional radical copolymerization of cross-linking monomers and functional monomers which can form reversible complexes with template molecules (Kempe and Mosbach, 1995). MIPs have been applied in affinity assays, separations and chemical sensors (Kobayashi *et al*., 2001). In these studies, MIPs are implemented by free radical copolymerization on the bacterial cellulose membrane produced by natural microorganism that has been integrated with chitosan layer and modified with polyethylene glycerol as the porogen.

Acetobacter xylinum, a gram-negative bacterium produces cellulose extracellularly. This cellulose is formed as gel-like mass (pellicle) at the surface of the medium and can be purified by proper chemical treatments. This material has high crystallinity and large surface area and has been attracting attention as a new form of cellulosic material (Shibazaki *et al*., 1993). When purified pellicle is dried on a flat substrate, a thin translucent cellulose membrane is formed. This membrane is expected to have unique properties because it consists of fine and continuous crystalline microfibrils, not like paper sheets or regenerated cellulose films. One possible application is molecular filtration such as dialysis or ultrafiltration.

Compared with the hydrophobic membranes, cellulose or derived cellulose membranes, hydrophilic in nature, have very low nonspecific binding (Manganaro and Goldberg, 1993). Cellulose fibers are relatively strong, having breaking strengths of up to 1 GN/m^2 (10 000 MPa). Cellulose membranes have been wide used as dialyzers for hemodialysis and also used as mechanical support of membrane with satisfied mechanical properties for fast protein purification (Hou *et al*., 1991). On the other hand, regenerated cellulose membranes have been widely used as a dialysis membrane in aqueous systems, where chemical stability and low toxicity of cellulose are preferable properties, especially in applications for labile biological systems (Shibazaki *et al*., 1993).

However, cellulose membranes offer a poor binding capacity due to crystalline and amorphous regions in their structure; only the hydroxyl groups in the amorphous region and on the surface of the crystalline are available to ligand coupling. Molecularly imprinting polymers is implemented to enhance and improve cellulose’s mechanical and chemical properties.

Recently, chitosan and chitin membranes have been investigated in order to have a high protein binding capacity for protein purification and separation (Zeng *et al*., 1997). These materials provide an excellent binding capacity because chitosan molecules have both amino and hydroxyl groups that can be used to couple with ligands under mild conditions. But their poor mechanical properties prevented them from being used widely. In order to develop a membrane with good mechanical and chemical properties, these studies propose to make a MIP-bacterial cellulose-chitosan (BCC) membrane which combines the advantages of MIP, cellulose and chitosan. Both cellulose and Chitosan are biodegradable, natural materials and very abundant on the earth. They also have good blood compatibility (Jia *et al*., 1999).

1.2 Research Objectives

The objectives of this study are:

i. To develop a membrane of bacterial cellulose-chitosan grafted with theophylline-imprinted copolymer

ii. To characterize its physical and chemical properties of the developed membrane.

1.3 Research Scopes

The scopes of this study include:

i. To evaluate the influence of chitosan, porogen (polyethylene glycerol) contents and evaporation time (ET) on porosity of the bacterial cellulose membrane.

ii. To measure the flux and rejection coefficient of the membrane using pure water and various molecular weights dextran standard solution.

iii. To determine the morphology of the membrane using Field Emission Scanning Electron Microscopy (FESEM), Fourier Transform Infra Red Spectroscopy (FTIR), Atomic Force Microscopy (AFM) and relate it to its performance.

iv. To evaluate weight ratio of monomer, degree of grafting, degree of swelling and living functionality on synthesized copolymer of the developed MIP membrane.

REFERENCES

Aherne, A., Alexander, C., Payne, M.J., Perez, N. *and* Vulfson, E.N. (1996). Bacteria-Mediated Lithography of Polymer Surfaces. *J. Am. Chem. Soc.* 118.

Aimar, P. and Meireles, P. (2009). Calibration of Ultrafiltration Membranes against Size Exclusion Chromatography Columns. *J. Membr. Sci.* 346:233–239.

Albrecht, M., Yulikov, M., Kohn, T., Jeschke, G., Adams, J. and Schmidt, A. (2010). Pyridinium Salts and Ylides as Partial Structures of Photoresponsive Merrifield Resins**.** *J. Mater. Chem.* 20:3025-3034.

Alexander, C., Davidson, L., and Hayes, W. (2003). Imprinted polymers: artificial molecular recognition materials with applications in synthesis and catalysis. *Tetrahedron.* 59: 2025–2057.

Alvarez-Lorenzo, C. and Concheiro, A. (2004). Molecularly imprinted polymers for drug delivery. *J. Chromatogr. B.* 804: 231– 245.

Alvarez-Lorenzo, C.H., Hiratani, H., Gomez-Amoza, J.L., Martinez-Pacheco, R., Souto, C. and Concheiro, A. (2002). Soft Contact Lenses Capable of Sustained Delivery of Timolol. *J Pharm Sci*. 91:2182–92.

Amiji, M.M. (1995). Permeability and blood compatibility properties of chitosan-poly(ethyleneoxide) blend membrane for hemodialysis. *Biomaterials*. 16: 593.

Amiji, M.M. (1995). Permeability and Blood Compatibility Properties of Chitosan-Poly(Ethyleneoxide) Blend Membrane for Hemodialysis. *Biomaterials.* 16:593.

Anderson, J.M. (2006). The Future of Biomedical Materials. *Journal of Materials Science: Materials in Medicine.* 17:1025-1028.

Anderson, R., Wang, S., Osiowy, C. and Issekutz, A.C. (1997). Activation of Endothelial Cells via Antibody-Enhanced Dengue Virus Infection of Peripheral Blood Monocytes. *J. Virol.* 71.

Andersson, H.S. and Nicholls, I.A. (1997). Spectroscopic evaluation of molecular imprinting polymerisation systems. *Bioorg. Chem.* 25: 203–211.

Andersson, L.I., Ekberg, B. and Mosbach, K. (1993). Biosensor and catalysis in molecularly imprinted polymers. *Molecular Interactions in Bioseparation*. 383–394.

Ansell, R.J. and Mosbach, K. (1998). Magnetic Molecularly Imprinted Polymer Beads for Drug Radioligand Binding Assay. *Analyst.* 123:1611-1616.

Arshady, R. and Mosbach, M. (1981). Synthesis of substrate-selective polymers by host–guest polymerization. *Macromol. Chem. Phys.-Makromol. Chem.* 182: 687–692.

Arshady, R. and Mosbach, M. (1981). Synthesis of Substrate-Selective Polymers by Host–Guest Polymerization. *Macromol. Chem. Phys.-Makromol. Chem.* 182:687–692.

Astley, O.M., Chaliaud, E., Donald, A.M. and Gidley, M.J. (2003). Tensile Deformation of Bacterial Cellulose Composites. *International Journal of Biological Macromolecules.* 32:28-35.

Backdahl, H., Helenius, G., Bodin, A., Nannmark, U., Johansson, B.R., Risberg, B. and Gatenholm, P. (2006). Mechanical Properties of Bacterial Cellulose and Interactions with Smooth Muscle Cells. *Biomaterials.* 27:2141-2149.

Baker, R.W. *Membrane Technology and Applications*. England: John Wiley & Sons Ltd. 2004

Beginn, U., Zipp, G., Mourran, A., Walther, P. and Mölle, M. (2000). Membranes Containing Oriented Supramolecular Transport Channels. *Advanced Materials*, 12(7):513-516.

Berger, J., Reist, M., Mayer, J.M., Felt, O., Peppas, N.A. and Gurny, R. (2004). Structure and Interactions In Covalently and Ionically Crosslinked Chitosan Hydrogels for Biomedical Applications. *European Journal of Pharmaceutics And Biopharmaceutics*. 57:19–34.

Bielawski, C.W., Scherman, O.A. and Grubbs, R.H. (2001). Highly efficient syntheses of acetoxy- and hydroxy-terminated telechelic poly (Butadiene)s using ruthenium catalysts containing n-heterocyclic ligands. *Polymer*. 42: 4939– 4945.

Bielecki, S., Krystynowicz, A., Turkiewicz, M. and Kalinowska, H. (2002). *Bacterial Cellulose*. Biopolymers: Vol.5. Polysaccharides I. Munster, Gremany: Wiley-Vch, Verlag Gmbh. 37–90.

Bodhibukkana, C., Srichana, T., Kaewnopparat, S., Tangthong, N., Bouking, P. and Martin, G.P. (2006). Composite Membrane of Bacterially-Derived Cellulose and Molecularly Imprinted Polymer for Use as a Transdermal Enantioselective Controlled-Release System of Racemic Propranolol. *Journal of Controlled Release*. 113 :43–56.

Borzacchiello, A., Ambrosio, L., Netti, P. A., Nicolais, L., Peniche, C.and Gallardo, A. (2001). Chitosan-Based Hydrogels: Synthesis and Characterization. *Journal of Materials Science-Materials In Medicine*. 12:861–864.

Bossi, A., Piletsky, S.A., Piletska, E.V., Righetti, P.G. and Turner, A.P.F. (2001). Surface-Grafted Molecularly Imprinted Polymers for Protein Recognition. *Analytical Chemistry.* 73(21).

Brett, C.T. (2000). Cellulose Microfibrils in Plants: Biosynthesis, Deposition, and Integration into the Cell Wall. *International Review of Cytology*. 199:61-99.

Brown, R. M. and Saxena, I. M. (2000). Cellulose biosynthesis: a model for understanding the assembly of biopolymer. *Plant Physiol. Biochem.* 38: 57–60.

Brown, R.M. (1989). Microbial Cellulose as A Building Block Resource for Specialty Products and Processes Therefore. *Pct Int. Appl.* WO 8912107 A1:37.

Brown, R.M. (1996). The Biosynthesis of Cellulose. *Journal of Macromolecular Science, Pure and Applied Chemistry*. 10:1345-1373.

Brune B.J., Koehler J.A., Smith P.J. and Payne G.F. (1999). Correlation between Adsorption and Small Molecule Hydrogen Bonding. *Langmuir*. 15:3987–3992.

Cannon, R.E. and Anderson, S.M. (1991). Biogenesis of Bacterial Cellulose. *Crit. Rev. Microbiol.* **17:**435–447

Carvalho, P., Goder, V. and Rapoport, T.A. (2006). Distinct Ubiquitin-Ligase Complexes Define Convergent Pathways For The Degradation Of ER Proteins. *Cell*. 126:361–373.

Castro, B., Whitcombe, M.J., Vulfson, E.V., Vasquez-Duhalt, R. and Bárzana, E. (2001). Molecular Imprinting for the Selective Adsorption of Organosulphur Compounds Present in Fuels. *Anal. Chim. Acta* . 435: 83– 90.

Cervera M.F., Heinamaki J., Krogars K., Jorgensen A.C., Karjalainen M., Colarte A.I. and Yliruusi J. (2004). Solid-State And Mechanical Properties Of Aqueous Chitosan-Amylose Starch Films Plasticized With Polyols. *Aaps Pharm. Sci. Technol.* 5: E15-E15.

Chao, Y., Ishida, T., Sugano, Y. and Shoda, M. (2000). Bacterial Cellulose Production by Acetobacter Xylinum in A 50 L Internal-Loop Airlift Reactor. *Biotechnol. Bioeng.* 68: 345–352.

Charpentier, P.A., Maguire A. and Wan W. (2006). Surface Modification of Polyester to Produce a Bacterial Cellulose-Based Vascular Prosthetic Device. *Applied Surface Science.* 252:6360-6367.

Chen R.H. and Tsaih M.L. (1998). Effect of Temperature on the Intrinsic Viscosity and Conformation of Chitosans in Dilute HCl Solution. *International Journal of Biological Macromolecules*. 23.

Chen, R.H. and Hwa, H.D. (1996). Effect Of Molecular Weight of Chitosan with the Same Degree of Deacetylation on The Thermal, Mechanical and Permeability Properties of the Prepared Membrane. *Carbohydrate Polymers*. **29**:353–358.

Chianella, I., Lotierzo, M., Piletsky, S.A., Tothill, I.E., Chen, B.N., Karim, K. and Turner, A.P.F. (2002). Rational Design of a Polymer for Microcystin-LR Using a Computational Approach. *Anal. Chem*. 74: 1288– 1293.

Choi, Y., Ahn, Y., Kang, M., Jun, H., Kim, I.S. and Moon, S. (2004). Preparation and Characterization of Acrylic Acid-Treated Bacterial Cellulose Cation-Exchange Membrane. *Journal Of Chemical Technology And Biotechnology.* 79:79-84.

Choi, Y.J., Ahn, Y., Kang, M.S., Jun, H.K., Kin, I.S. and Moon, S.H. (2004). Preparation and Characterization of Acrylic Acid-Treated Bacterial Cellulose Cation-Exchange Membrane. *Journal Of Chemical Technology Biotechnology*. 79:79–84.

Chung, T.S. and Hu, X.D. (1997). Effect of Air-Gap Distance on the Morphology and Thermal Properties of Polyethersulfone Hollow Fibers. *J. Appl. Polym. Sci.* 66:1067–1077.

Chung, Y. and Shyu, Y. (1999). The Effects of Ph, Salt, Heating and Freezing On The Physical Properties of Bacterial Cellulose Nata. *Int. J. Food Sci. and Tech.* 34: 23-2.

Cienchanska, D. (2004). Multifunctional Bacterial Cellulose/Chitosan Composite Materials For Medical Applications. *Fibres and Textiles In Eastern Europe.* 12:69-72.

Coleman, J.N., Khan, U. and Gunko, Y.K. (2006). Mechanical Reinforcement of Polymers Using Carbon Nanotubes. *Advanced Materials.* 18:689-706.

Costeron, J.W. (1999). The Role of Bacterial Cellulose Exopolysaccharides in Nature and Disease. *J. Ind. Microbiol. Biotechnol*. 22:551-563.

Cousins, S.K. and Brown, R.M. (1997). X-Ray Diffraction and Ultrastructural Analyses Of Dyealtered Celluloses Support Van Der Waals Forces as the Initial Step in Cellulose Crystallization. *Polymer*. 38:897-902.

Crescenzi, C., Bayoudh, S., Cormack, P.A.G., Klein, T. and Ensing, K. (2001). Determination Of Clenbuterol in Bovine Liver by Combining Matrix Solid Phase Dispersion and Molecularly Imprinted Solid Phase Extraction Followed by Liquid Chromatography/Electrospray Ion Trap Multiple Stage Mass Spectrometry. *Anal Chem*. 73:2171–2177.

Cui, D.X. and Gao, H.J. (2003). Advances and Prospects of Bionanomaterials. *Biotechnol. Prog.* 19: 683– 692.

Czaja, W., Krystynowicz, A., and Bielecki, S. (2006). Microbial Cellulose the Natural Power to Heal Wounds. *Biomaterials.* 27: 145–151.

Czaja, W., Krystynowicz, A., Bielecki, S., and Brown R.M. (2006). Microbial Cellulose-The Natural Power to Heal Wounds. *Biomaterials*. 27:145-51.

Czaja, W., Young, D.J., Kawechi, M. & Brown, R.M. Jr. (2007). The Future Prospects of Microbial Cellulose in Biomedical Applications. *Biomacromolecules*. 8:1-12.

Davies, M.P., De Biasi, V. and Perrett, D. (2004). Approaches to The Rational Design Of Molecularly Imprinted Polymers. *Anal. Chim. Acta.* 504: 7 – 14.

Dickert, F.L. and Hayden, O. (2002). Bioimprinting of Polymers and Sol-Gel Phases. Selective Detection of Yeasts with Imprinted Polymers. *Analytical Chemistry.* 74(6):1302-1306.

Doman, K., Kim, Y., Park M. and Park, D.J. (1999). Modification of *Acetobacter Xylinum* Bacterial Cellulose using Dextransucrase and Alternansucrase. *Microbiol. Biotechnol.* 9:704-708.

Dong, X., Sun, H., Lue, X., Wang, H., Liu, S. and Wang, N. (2002). Separation of Ephedrine Stereoisomers by Molecularly Imprinted Polymers. Influence of Synthetic Conditions and Mobile Phase Compositions on the Chromatographic Performance. *Analyst*.127:1427– 1432.

Duffy, D.J., Das, K., Hsu, S.L., Penelle, J., Rotello, V.M. and Stidham, H.D. (2002). Binding Efficiency and Transport Properties of Molecularly Imprinted Polymer Thin Films. *J. Am. Chem. Soc.* 124: 8290–8296.

Earnshaw, R.G., Price, C.A., O'donnell, J.H. and Whittaker, A.K. (1986). Determination of Residual Unsaturation in Highly Crosslinked, Dough-Moulded Poly(Methyl Methacrylate) Dental Polymers by Solid-State ^{13}C NMR. *J. Appl. Polym. Sci.* 32:5337– 5344.

Fontana, J. D., De Souza, A. M., Fontana, C. K., Torriani, I. L., Moreschi, J. C. and Gallotti, B.J. (1990). Acetobacter Cellulose Pellicle as a Temporary Skin Substitute. *Applied Biochemistry and Biotechnology.* (24/25): 253–263.

Fu, L.H. and Cheng, J.Q. (2006). Effect of Interaction between Chitosan and Cellulose on the Paper Property. *Zhongguo Zaozhi Xuebao/Transactions Of China Pulp And Paper*. 21: 48–51.

Fu, Q., Sanbe, H., Kagawa, C., Kunimoto, K.K. and Haginaka, J. (2003). Uniformly Sized Molecularly Imprinted Polymer for (S)-Nilvadipine. Comparison of Chiral Recognition Ability with HPLC Chiral Stationary Phases Based on a Protein. *Anal. Chem.* 75: 191–198.

Gamage, A. and Shahidi, F. (2007). Use of Chitosan for the Removal of Metal Ion Contaminants and Proteins From Water. *Food Chemistry*. 104:989–996.

Gonçalves V. L., Laranjeira M. C. M. and Fávere V. T. (2005). Effect of Crosslinking Agents on Chitosan Microspheres in Controlled Release of Diclofenac Sodium. *Polymer Science and Technology.* 15(1): 6-12.

Guo, H. and He, X. (2000). Study of the Binding Characteristics of Molecular Imprinted Polymer Selective for Cefalexin In Aqueous Media. *J. Anal. Chem.* 368: 461–465.

Guo, W., Shang, Z., Yu, Y. and Zhou, L. (1994). Membrane Affinity Chromatography Of Alkaline Phosphatase. *J. Chromatogr. A*. 685:344–348.

Guo, W., Shang, Z., Yu,Y. and Zhou, L. (1994). Membrane Affinity Chromatography Of Alkaline Phosphatise. *J. Chromatogr. A*. 685: 344–348.

Gupta, B., Anjum, N. and Sen, K. (2002**).** Development of Membrane by Radiation Grafting of Acrilamide into Polyethilene Films: Properties and Metal Ion Separation. *Journal of Applied Polymer Science.* 85: 282-291.

Haginaka, J. (2004). Molecularly Imprinted Polymers for Solid-Phase Extraction Analytical and *Bioanalytical Chemistry.* 379(3):332-334.

Hall, A.J., Manesiotis, P., Mossing, J.T. and Sellergren, B. (2002). Molecularly Imprinted Polymers (Mips) Against Uracils: Functional Monomer Design Monomer–Template Interactions in Solution and MIP Performance in Chromatography. *Mater. Res. Soc. Symp. Proc.* 723: 11 – 15.

Hamlyn, P.F., Crighton, J., Dobb, M.G. & Tasker, A. (1997). *Cellulose Product*. (U.K. Patent 2314856 A)

Han, N. S. and Robyt, J. F. (1998). The Mechanism of Acetobacter Xylinum Cellulose Biosynthesis: Direction of Chain Elongation and the Role of Lipid Pyrophosphate Intermediates in the Cell Membrane. *Carbohydr. Res.* 313: 125–133.

Hattori, K., Hiwatari, M., Iiyama, C., Yoshimi, Y., Kohori, F., Sakai, K. and Piletsky, S.A. (2004). Gate Effect of Theophylline-Imprinted Polymer Grafted to The Cellulose by Living Radical Polymerization. *J. Memb. Sci.*, 233:169–173.

Hattori, K., Yoshimi, Y. and Sakai, K. (2001). Gate Effect of Cellulosic Dialysis Membrane Grafted with Molecularly Imprinted Polymer. *J. Chem. Eng. Jpn.* 11: 1466–1469.

Haupt K. (2003). Imprinted Polymers: Tailor-Made Mimics of Antibodies and Receptors. *Chem. Commun.* 171–178.

Haupt, K. and Mosbach, K. (2000). Molecularly Imprinted Polymers and Their Use in Biomimetic Sensors. *Chem. Rev*. 100: 2495–2504.

Haupt, K., Dzgoev, A. and Mosbach, K. (1998). Assay System for the Herbicide 2,4-Dichlorophenoxyacetic Acid using a Molecularly Imprinted Polymer as an Artificial Recognition Element. *Analytical Chemistry*. 70:628-631.

Hayashi, K. and Ito, M. (2002). Antidiabetic Action of Low Molecular Weight Chitosan in Genetically Obese Diabetic Kk-Ay Mice. *Biological and Pharmaceutical Bulletin*. 25:188–192.

Hennen, W.J. *Chitosan*. Woodland Publishing. 31; 1996

Hirai, A., Tsuji, M., Yamamoto, H. and Horii, F. (1998). In Situ Crystallization of Bacterial Cellulose. Influences of Different Polymeric Additives on the Formation of Microfibrils as Revealed by Transmission Electron Microscopy. *Cellulose*. 5:201-213.

Hirano, S., Noishiki, Y. and Kinugawa, J. (1985). Chitin and Chitosan for Use as Novel Biomedical Materials. *Polym. Mater. Sic. Eng*. 53: 649.

Hjertberg, T., Hargitai, T.and Reinholdsson, P. (1990). Carbon-^{13}CP-MAS NMR Study on Content and Mobility of Double Bonds in Poly(Trimethylolpropane Trimethacrylate). *Macromolecules*. 23(12):3080–3087.

Hjertén, S., Liao J.L., Nakazato, K., Wang, Y., Zamaratskaia, G. *and* Zhang, H.X. (1997). Gels Mimicking Antibodies in Their Selective Recognition of Proteins. *Chromatographia.* 44:227–234.

Hof, F., Craig, S.L., Nuckolls, C. and Rebek, J., Jr. (2002). Molecular Encapsulation. *Angew. Chem. Int. Ed.* 41: 1488–1508.

Hong, L., Wang, Y. L., Jia, S. R., Huang, Y., Gao, C., and Wan, Y. Z. (2006). Hydroxyapatite/Bacterial Cellulose Composites Synthesized Via A Biomimetic Route. *Materials Letters*. 60: 1710–1713.

Hou, K.C., Zaniewski, R. and Roy, S. (1991). Protein A Immobilized Affinity Cartridge for Immunoglobin Purification. *Biotechnol. Appl. Biochem.* 13: 257.

Iguchi, M., Yamanaka, S. and Budhioko, A. (2000). Bacterial Cellulose – A Masterpiece Of Nature's Arts. *J. Mater. Sci.* 35: 261–270.

Ishida, T., Sugano, Y., Nakai, T. and Shoda, M. (2002). Effects of Acetan on Production of Bacterial Cellulose by *Acetobacter Xylinum. Biosci Biotech Biochem.* 66:1677–1681.

Iwata, T., Indrarti, L. and Azuma, J. (1998). Affinity of Hemicellulose for Cellulose Produced by *Acetobacter Xylinum*. *Cellulose*. 5:215-228.

Jagur-Grodzinski, J. (2006). Polymers for Tissue Engineering, Medical Devices, and Regenerative Medicine. Concise General Review of Recent Studies. *Polymers for Advanced Technologies*. 17:395-418.

Jayakumar, R., Prabaharan, M., Reis, R. L. and Mano, J. F. (2005). Graft Copolymerized Chitosan – Present Status and Applications. *Carbohydrate Polymers.* 62: 142–158.

Jeon, Y.J., Park, P.J. and Kim, S.K. (2001). Antimicrobial Effect of Chitooligosaccharides Produced by Bioreactor. *Carbohydrate Polymers*. 44: 71–76.

Jia, L., Yang, L., Zou, H., Zhang, Y., Zhao, J., Fan, C. and Sha, L. (1999). Protein A Tangential Flow Affinity Cartridge for Extracorporeal Immunoadsorption Therapy. *Biomed. Chromatogr.* 13: 472.

Johnson, D.C. and Neogi, A.N. (1989). *Sheeted Products Formed From Reticulated Microbial Cellulose*. (U.S. Patent 4863565).

Jonas, R. And Farah, L. F. (1998). Production and Application of Microbial Cellulose. *Polym. Degrad. Stabil.* 59: 101–106.

Jonas, R. and Farah, L.F. (1998). The Production and Application of Microbial Cellulose. *Poly. Deg. Stab.* 59:101–106.

Jonas, R. and Farah, L.F. (1998). Production and Application Of Microbial Cellulose. *Polymer Degradation and Stability*. 59:101-106.

Joseph, G., Row, G.E., Margaritis, A. and Wan, W. (2003). Effects of Polyacrylamide-Co-Acrylic Acid on the Cellulose Production By *Acetobacter Xylinum*. *Journal of Chemical Technology and Biotechnology*. 78:964-970.

Karlsson, J.G., Karlsson, B., Andersson, L.I. and Nicholls, I.A. (2004). The Roles of Template Complexation and Ligand Binding Conditions on Recognition in Bupivacaine Molecularly Imprinted Polymers. *Analyst*. 129: 456– 462.

Katz , A. and Davis, M.E. (1999). Investigations into the Mechanisms of Molecular Recognition with Imprinted Polymers. *Macromolecules*, 32: 4113– 4121.

Kempe, M. (1996). Antibody-Mimicking Polymers as Chiral Stationary Phases in HPLC. *Analytical Chemistry***.** 68(11):1948-1953.

Kempe, M. and Mosbach, K. (1995). Receptor Binding Mimetics: A Novel Molecularly Imprinted Polymer. *Tetrahed. Lett.* 36: 3563–3566.

Kempe, M., Glad, M. and Mosbach, K. (1995). An Approach towards Surface Imprinting using the Enzyme Ribonuclease A. *Journal Of Molecular Recognition.* 8:35-39.

Keshk, S. and Sameshima, K. (2006). Influence of Lignosulfonate on Crystal Structure and Productivity of Bacterial Cellulose in a Static Culture. *Enzyme and Microbial Technology*. 40(1): 4–8.

Kim, D., Kim, Y. M. and Park, D. H. (1999). Modification of Acetobacter Xylinum Bacterial Cellulose using Dextransucrase and Alternansucrase. *J. Microbiol. Biotechnol.* 9: 704–708.

Kittur, F.S., Kumar, A.B.V. and Tharanathan, R.N. (2003). Low Molecular Weight Chitosans Preparation by Depolymerization with *Aspergillus Niger* Pectinase and Characterization. *Carbohydrate Research*. 338:1283–1290.

Klein, E., Eichholz, E. and Yeager, D.H. (1994). Affinity Membranes Prepared from Hydrophilic Coatings on Microporous Polysulfone Hollow Fibers. *J. Membr. Sci.* 90: 69.

Klein, E., Eichholz, E., Theimer, F. and Yeager, D. (1994). Chitosan Modified Sulphonated Poly(Ethersulfone) as a Support for Affinity Separations. *J. Membr. Sci.* 95:199.

Klein, E., Eichholz, E., Theimer, F. and Yeager, D. (1994). Chitosan Modified Sulphonated Poly(Ethersulfone) as a Support for Affinity Separations, *J. Membr. Sci.* 95:199.

Klein, E., Eichholz, E.and Yeager, D.H. (1994). Affinity Membranes prepared from Hydrophilic Coatings on Microporous Polysulfone Hollow Fibers. *J. Membr. Sci.* 90:69.

Klemm, D., Schumann, D., Udhardt, U. and Marsch, S. (2001). Bacterial Synthesized Cellulose-Artificial Blood Vessels for Microsurgery. *Progress in Polymer Science*. 26:1561–1603.

Klemm, D., Schumann, D., Udhardt, U. and Marsch, S. (2001). Bacterial Synthesized Cellulose Artificial Blood Vessels for Microsurgery. *Progress in Polymer Science.* 26:1561-1603.

Kobayashi, T., Murawaki, Y., Reddy, P.S., Abe, M. and Fujii, N. (2001). Molecular Imprinting of Caffeine and Its Recognition Assay by Quartz-Crystal Microbalance. *Anal. Chem. Acta*. 435:141–149.

Kochkodan, V., Weigel, W. and Ulbricht, M. (2002). Molecularly Imprinted Composite Membranes For Selective Binding of Desmetryn from Aqueous Solutions. *Desalination.* 149:323–328.

Kochkodan, V., Weigel, W. and Ulbricht, M. (2002). Molecularly Imprinted Composite Membranes for Selective Binding of Desmetryn from Aqueous Solutions. *Desalination.* 149 (1-3):323-328

Kouda, T., Naritomi, T., Yano, H. and Yoshinaga, F. (1998). Inhibitory Effect of Carbon Dioxide on Bacterial Cellulose Production by Acetobacter in Agitated Culture. *J. Ferment. Bioeng.* 85:318–321.

Kovali, A. S. and Sirkar, K. K. Stable Liquid Membranes. (2003). *Advanced Membrane Technology Pages*. 984:279–288

Koyama, M., Helbert, W., Imai, T., Sugiyama, J. and Henrissat, B. (1997). Parallel-Up Structure Evidence the Molecular Directionality during Biosynthesis of Bacterial Cellulose. *Proc. Natl. Acad. Sci. USA*. 94:9091–9095.

Krajewska, B. (2004). Application of Chitin and Chitosan-Based Materials for Enzyme Immobilizations: A Review. *Enzyme and Microbial Technology.* 35:126–139.

Kriz, D., Ramström, O. and Mosbach, K. (1997). Molecular Imprinting: New Possibilities For Sensor Technology. *Anal. Chem.* 69: 345A–349A.

Kriz, D., Ramström, O., Svensson, A. and Mosbach, K. (1995). Introducing Biomimetic Sensors Based on Molecularly Imprinted Polymers as Recognition Elements. *Anal. Chem.* 67: 2142–2144.

Kudlicka, K. (1989). Terminal Complexes in Cellulose Synthesis. *Postpy Biologii Komorki.* 16: 197-212.

Kugimiya, A. and Takeuchi, T. (2001). Surface Plasmon Resonance Sensor using Molecularly Imprinted Polymer for Detection of Sialic Acid. *Biosens. Bioelectron.* 16: 1059–1062.

Lanza, F. and Sellergren, B. (1999). Method for Synthesis and Screening of Large Groups of Molecularly Imprinted Polymer. *Anal. Chem.* 71: 2092– 2096.

Lanza, F. and Sellergren, B. Molecularly Imprinted Polymers Via High-Throughput And Combinatorial Techniques. *Macromol. Rapid Commun*. 25 (2004) 59–68.

Lanza, F., Ruther, M., Hall, A.J., Dauwe, C. and Sellergren, B. (2002). Studies on the Process of Formation, Nature and Stability of Binding Sites in Molecularly Imprinted Polymer. *Mater. Res. Soc. Symp. Proc*. 723: 93– 103.

Lee, H.J., Nakayama, Y. and Matsuda, T. (1999). Spatio-Resolved, Macromolecular Architectural Surface: Highly Branched Graft Polymer via Photochemically Driven Quasiliving Polymerization Technique. *Macromolecules.* 32: 6989–6995.

Lee, Y. M., Kim, S. H. and Kim, S. J. (1994). Preparation and Characterization of B-Chitin and Poly (Vinyl Alcohol) Blend. *Polymer*. 37: 5897–5905.

Legeza, V.I., Galenko-Yaroshevskii, V.P., Zinov'ev, E.V., Paramonov B.A., Kreichman, G.S., Turkovskii, I.I., Gumenyuk, E.S., Karnovich, A.G. and Khripunov, A.K. (2004). Effects of New Wound Dressings on Healing of Thermal Burns of the Skin in Acute Radiation Disease. *Bulletin of Experimental Biology and Medicine*. 138:311-315.

Legge, R.L. (1990). Microbial Cellulose as a Specialty Chemical. *Biotech. Adv.* 8:303–319.

Levi, R., Mcniven, S., Piletskaya, S.A., Cheong, S.H., Yano, K. *and* Karube, I. (1997). Optical Detection of Chloramphenicol using Molecularly Imprinted Polymers. *Anal. Chem*. 69:2017–2021.

Li Z., Zhuang, X. P., Liu, X. F., Guan, Y. L. and Yao, K. D. (2002). Study on Antibacterial Ocarboxymethylated Chitosan/Cellulose Blend Film From Licl/N,Ndimethylacetamide Solution. *Polymer*. 43: 1541–1547.

Liao, J.L., Wang, Y. *and* Hjertén, S. (1996). A Novel Support with Artificially Created Recognition for the Selective Removal of Proteins and For Affinity Chromatography. *Chromatographia.* 42:259–262.

Liu N., Chen, X.-G., Park, H.J., Liu, C.G., Liu, C.S. and Meng, X.H. (2006). Effect Of MW And Concentration Of Chitosan On Antibacterial Activity Of Escherichia Coli. *Carbohydrate Polymers*. 64: 60–65.

Lu, Y., Zhang H. and Liu, X. (2003). Study on the Mechanism of Chiral Recognition with Molecularly Imprinted Polymers. *Anal. Chim. Acta.* 489: 33– 43.

Lübke, C., Lübke, M., Whitcombe, M.J. and Vulfson, E.N. (2000). Imprinted Polymers prepared with Stoichiometric Template– Monomer Complexes: Efficient Binding of Ampicillin from Aqueous Solutions. *Macromolecules*. 33:5098–5105.

Lübke, M., Whitcombe, M.J. and Vulfson, E.N. (1998). A Novel Approach to the Molecular Imprinting of Polychlorinated Aromatic Compounds. *Journal of the American Chemical Society.* 120:13342-13348.

Mahdavinia, G. R., Pourjavadi, A., Hosseinzadeh, H. and Zohuriaan, M. J. (2004). Modified Chitosan for Superabsorbent Hydrogels Form Poly(Actylic Acid-Co-Acrylamide) Grafted Chitosan with Salt and Phresponsiveness Properties. *European Polymer Journal*. 40:1399–1407.

Manesiotis, P., Hall, A.J., Emgenbroich, M., Quaglia, M., De Lorenzi, E. and Sellergren, B. (2004). An Enantioselective Imprinted Receptor for Z-Glutamate Exhibiting a Binding Induced Colour Change. *Chem. Commun.* 2278– 2279.

Manesiotis, P., Hall, A.J., Emgenbroich, M., Quaglia, M., De Lorenzi, E. and Sellergren, B. (2004). An Enantioselective Imprinted Receptor for Z-Glutamate Exhibiting a Binding Induced Colour Change. *Chem. Commun*. 2278– 2279.

Manganaro J.L. and Goldberg B.S. (1993). Protein Purification with Novel Porous Sheets Containing Derivatized Cellulose. *Biotechnol. Progr.* 9:285.

Manganaro, J.L. and Goldberg, B.S. (1993). Protein Purification With Novel Porous Sheets Containing Derivatized Cellulose. *Biotechnol. Progr.* 9: 285.

Markel, G., Lieberman, N., Katz, G., Arnon, T. I., Lotem, M., Drize, O., Blumberg, R. S., Bar-Haim, E., Mader, R., Eisenbach, L. (2002). CD66a Interactions between Human Melanoma And NK Cells: A Novel Class I MHC-Independent Inhibitory Mechanism Of Cytotoxicity. *J. Immunol*. 168:2803-2810.

Masaoka, S., Ohe, T. and Sakota, N. (1993). Production of Cellulose from Glucose by Acetobacter Xylinum. *J. Ferment. Bioeng.* 75: 18–22.

Matsuoka, M., Tsuchida, T., Matsuchita, K., Adachi, O. and Yoshinaga, F. (1996). A Synthetic Medium for Bacterial Cellulose Production by Acetobacter Xylinum Subsp. Sucrofermentans. *Biosci. Biotechnol. Biochem*. 60: 575–579.

Matthysse, A.G., Thomas, D. and White, A.R. (1995). Mechanisms of Cellulose Synthesis in *Agrobacterium Tumefaciens*. *Journal of Bacteriology*. 177:1076-1081.

Matyjaszewski, K. (2003). Controlling Polymer Structures By Atom Transfer Radical Polymerization And Other Controlled/Living Radical Polymerizations. *Macromol. Symp.* 195: 25– 31.

Mi, F.L., Kuan, C.Y., Shyu, S.S., Lee, S.T. and Chang, S.F. (2000). The Study of Gelation Kinetics and Chain-Relaxation Properties of Glutaraldehyde-Cross-Linked Chitosan Gel and Their Effects on Microspheres Preparation and Drug Release. *Carbohydrate Polymers*. 41(4):389-396.

Mondal, I. H. and Kai, A. (2000). Control of the Crystal Structure of Microbial Cellulose during Nascent Stage. *J. Appl. Polym. Sci.*79, 1726–1734.

Mormino, R. Gostomski, P. and Bungay, H. Plate and Disk Bioreactors for Making Bacterial Cellulose in Biological Systems Engineering. ACS Symposium Series 830, 2002.

Mosbach, K. (1994). Molecular Imprinting. *Trends Biochem. Sci*. 19: 9–14.

Mosbach, K., Ramstrom, O. (1996). The Emerging Technique of Molecular Imprinting and Its Future Impact on Biotechnology. *Bio/Technology*. 14: 163–170.

Nakai, T., Tonouchi, N., Konishi, T., Kojima, Y., Tsuchida, T., Yoshinaga, F., Sakai, F. and Hayashi, T. (1999). Enhancement of Cellulose Production by Expression of Sucrose Synthase in Acetobacter Xylinum. *Proc. Natl. Acad. Sci. USA*. 96: 14–18.

Nakayama, Y. and Matsuda, T. (1999). In Situ Observation of Dithiocarbamate-Based Surface Photograft Copolymerization using Quartz Crystal Microbalance. *Macromolecules.* 32: 5405–5410.

Nakayama, Y., Sudo, M., Uchida, K. and Matsuda, T. (2002). Spatio-Resolved Hyperbranched Graft Polymerized Surfaces by Iniferter-Based Photograft Copolymerization. *Langmuir.* 18: 2601–2606.

No, H. K., Park, N.Y., Lee, S.H. and Meyers, S.P. (2002). Antibacterial Activity of Chitosans and Chitosan Oligomers with Different Molecular Weights. *International Journal of Food Microbiology.* 74(1-2):65-72.

No, H.K. and Meyers, S.P. (2000). Application Of Chitosan For Treatment Of Wastewaters. *Reviews of Environmental Contamination and Toxicology*. 163:1-27.

Noble, R.D. (1992). Generalized Microscopic Mechanism Of Facilitated Transport In Fixed Site Carrier Membranes. *Journal of Membrane Science*. 75(1-2):121-129.

Nogi, M., Handa, K., Nakagaito, A.N. and Yano, H. (2005). Optically Transparent Bionanofiber Composites with Low Sensitivity to Refractive Index of the Polymer Matrix. *Applied Physics Letters.* 87:1-3.

Nunthanid, J., Puttipipatkhachorn, S., Yamamoto, K. and Peck, G.E. (2001). Physical Properties and Molecular Behavior of Chitosan Films. *Drug Dev. Ind. Pharm.* 27: 143-157.

Okamoto, T., Yamano, S., Ikeaga, H. and Nakamura, K. (1999). Cloning of The *Acetobacter Xylinum* Cellulose Gene and Its Expression in *E. Coli* and *Zymomonas Mobilis. Appl. Microbiol. Biotechnol.* 42:563-568.

Otsu, T. (2000). Iniferter Concept and Living Radical Polymerization. *J. Polym. Sci. Part A: Polym. Chem.* 38: 2121–2136.

Otsu, T., Matsunaga, T., Doi, T. and Matsumoto, A. (1995). Features of Living Radical Polymerization of Vinyl Monomers in Homogeneous System using N,N-Diethyldithiocarbamate Derivatives as Photoinitiators. *Eur. Polym. J.* 31: 67–78.

Patel, A., Fouace, S. and Steinke, J.H.G. (2004). Novel Stereoselective Molecularly Imprinted Polymers via Ring-Opening Metathesis Polymerization. *Anal. Chim. Acta.* 504: 53– 62.

Patel, A., Fouace, S. and Steinke. J.H.G. (2003). Enantioselective Molecularly Imprinted Polymers via Ring-Opening Metathesis Polymerisatio. *Chem. Commun.* 88– 89.

Pawlak, A. and Mucha, M. (2003). Thermogravimetric and FTIR Studies of Chitosan Blends. *Thermochimica Acta*. 396: 153–166.

Peppas, N.A. and Colombo, P. (1997). Analysis of Drug Release Behavior from Swellable Polymer Carriers using the Dimensionality Index. *J Controlled Release.* 45:35–40.

Peppas, N.A., Bures, P., Leobandung, W. and Ichikawa, H. (2000). Hydrogels in Pharmaceutical Formulations. *Eur J Pharm Biopharm*. 50:27–46.

Peppas, N.A.and Khare, A.R. (1993). Preparation, Structure and Diffusional Behavior of Hydrogels in Controlled Release. *Adv Drug Deliver Rev*. 11:1–35.

Phisalaphong, M., Suwanmajo, T. and Sangtherapitikul, P. (2008). Novel Nanoporous Membranes from Regenerated Bacterial Cellulose. *Journal Of Applied Polymer Science.* 107: 292–299.

Piletsky, S.A., Karim, K., Piletska, E.V., Day, C.J., Freebairn, K.W., Legge, C. and Turner, A.P.F. (2001). Recognition of Ephedrine Enantiomers by Molecularly Imprinted Polymers Designed using a Computational Approach. *Analyst.* 126: 1826– 1830.

Piletsky, S.A., Matuschewski, H., Schedler, U., Wilpert, A., Piletskaya, E.V., Thiele, T.A. and Ulbricht, M. (2000). Surface Functionalization of Porous

Polypropylene Membranes with Molecularly Imprinted Polymers by Photograft Copolymerization in Water. *Macromolecules.* 33: 3092–3098.

Piletsky, S.A., Panasyuk, T.L., Piletskaya, E.V., Nicholls, I.A. and Ulbricht, M. (1999). Receptor and Transport Properties of Imprinted Polymer Membranes—A Review. *J. Membr. Sci.* 157: 263–278.

Piletsky, S.A., Piletska, E.V., Karim, K., Freebairn, K.W., Legge, C.H. and Turner, A.P.F. (2002). Polymer Cookery: Influence of Polymerization Conditions on the Performance of Molecularly Imprinted Polymers. *Macromolecules.* 35: 7499–7504.

Piletsky, S.A., Piletskaya, E.V., Yano, K., Kugimiya, A., Elgersma,A.V., Levi, R., Kahlow, U., Takeuchi, T. and Karube, I. (1996). A Biomimetic Receptor System for Sialic Acid based on Molecular Imprinting. *Anal. Lett.* 29: 157–170.

Ping, L., Fei, R., Zhu, X.L., Hu, J.Z. and Yuan, C.W. (2003). Studies on the Preparation of L-2-Chloromandelic Acid-Imprinted Polymer and Its Selective Binding Characteristics. *Acta Polym. Sin.* 5: 724– 727.

Pochanavanich, P. and Suntornsuk, W. (2002). Fungal Chitosan Production and Its Characterization. *Letters in Applied Microbiology*. 35(1):17–21.

Qiu, H.X., Yu, J.G. and Zhu, J.L. (2005). Polyacrylate/(Chitosan Modified Montmorillonite) Nanocomposite: Water Absorption and Photostability. Polymers and Polymer Composites. 13:167–172.

Qin, C.Q., Zhou, B., Zeng, L., Zhang, Z., Liu, Y., Du, Y.M. and Xiao, L. (2004). The Physicochemical Properties and Antitumor Activity of Cellulose-Treated Chitosan. *Food Chem.* 84.

Rachkov, A. and Minoura, N. (2001). Towards Molecularly Imprinted Polymers Selective to Peptides and Proteins. The Epitope Approach. *Biochimica Et Biophysica Acta - Protein Structure And Molecular Enzymology*. 1544(1-2):255-266.

Raju, M. P. and Raju, K. M. (2001). Design and Synthesis of Superabsorbent Polymers. *Journal of Applied Polymer Science*. 80:2635–2639.

Ramström, O. and Mosbach, K. (1999). Synthesis and Catalysis by Molecularly Imprinted Materials. *Curr. Opin. Chem. Biol.* 3:759–764.

Ramström, O., Andersson, L.I. and Mosbach, K. (1993). Recognition Sites Incorporating Both Pyridinyl and Carboxy Functionalities Prepared by Molecular Imprinting. *J. Org. Chem.* 58:7562-7564.

Ramstrom, O., Nicholls, I.A. and Mosbach, K. (1994). Synthetic Peptide Receptor Mimics: Highly Stereoselective Recognition in Non-Covalent Molecularly Imprinted Polymers. *Tetrahedron Asymmetry***.** 5(4):649-656**.**

Ravi-Kumar, M.N.V. (2000). A Review of Chitin and Chitosan Applications. *React. Funct. Polym.* 46:1–27.

Rege, P.R. and Block, L.H. (1999). Chitosan Processing: Influence Of Process Parameters during Acidic and Alkaline Hydrolysis and Effect of the Processing Sequence on the Resultant Chitosan's Properties. *Carbohydr. Res.* 321:235–245.

Rezwan, K., Chen, Q.Z., Blaker, J.J. and Boccaccini, A.R. (2006). Biodegradable and Bioactive Porous Polymer/Inorganic Composite Scaffolds for Bone Tissue Engineering. *Biomaterials.* 27:3413-3431.

Rinaudo, M. (2006). Chitin and Chitosan: Properties and Applications. *Progress in Polymer Science*. 31: 603–632.

Ring, D.F., Nashed, W. and Dow, T.H. (1986). *Liquid Loaded Pad for Medical Applications*. (U.S. Patent 4588400).

Roper, D.K. and Lightfoot, E.N. (1995). Separation of Biomolecules using Adsorptive Membranes, *Journal Of Chromatography A,* 702:3-26.

Rosengren, J.P., Karlsson, J.G. and Nicholls, I.A. (2004). Enantioselective Synthetic Thalidomide Receptors based upon DNA Binding Motifs*. Org. Biomol. Chem.* 2: 3374–3378.

Rosiak, J.M., Ulanski, P., Pajewski, W., Yoshii, F. and Makuuchi, K. (1995). Radiation Formation of Hydrogels for Biomedical Purposes. Some Remarks and Comments. *Radiat. Phys. Chem*. 46 (2):161-168.

Ross, P., Mayer, R. and Benziman, M. (1991). Cellulose Biosynthesis and Function in Bacteria*. Microbiol. Rev.* 55: 35–58.

Ruckert, B., Hall, A.J. and Sellergren, B. (2002). Molecularly Imprinted Composite Materials via Iniferter-Modified Support. *J. Mater. Hem.* 12: 2275–2280.

Ruel, G.E., Shive, M., Bichara, A., Berrada, M., Garrec, D.L., Chenite, A. and Leroux, J. C. (2004). A Thermosensitive Chitosan Based Hydrogel for the Local Delivery of Paclitaxel. *Eur. J. Pharm. Biopharm.* 57: 53–63.

Sagawa, T., Togo, K., Miyahara, C., Ihara, H. and Ohkuboa, K. (2004). Rate Enhancement of Hydrolysis of Long-Chain Amino Acid Ester by Cross-Linked Polymers Imprinted with a Transition-State Analogue: Evaluation of Imprinting Effect in Kinetic Analysis. *Anal. Chim. Acta.* 504: 37– 41.

Sakair, N., Asamo, H., Ogawa, M., Nishi, N. and Tokura, S. (1998). A Method for Direct Harvest of Bacterial Cellulose Filaments during Continuous Cultivation of Acetobacter Xylinum. *Carbohydr. Polym.* 35: 233–237.

Sanbe, H., Hoshina, K., Haginaka, J., Kunimoto, K. and Fu, Q. (2002). Chiral Recognition based on (S)-Nilvadipine-Imprinted Polymers and Chiral Recognition Mechanism. *Chromatography.* 23: 65–66.

Sanchavanakit, N., Sangrungraungroj, W., Kaomongkolgit, R., Banaprasert, T., Pavasant, P. and Phisalaphong, M. (2006). Growth of Human Keratinocytes and Fibroblasts on Bacterial Cellulose Film. *Biotechnology Progress.* 22: 1194–1199.

Sashiwa, H. and Shigemasa, Y. (1999). Chemical Modification of Chitin and Chitosan: Preparation and Water Soluble Property of N-Acylated of Nalkylated Partially Deacetylated Chitins. *Carbonhydate Polymers.* 39:127–138.

Saxena, I. M. and Brown, R. M., Jr. (2006). Cellulose Synthases and Related Protein. *Curr. Opin. Plant Biol*. 3: 523–531.

Schmitt, D.F., Frankos, V.H., Westland, J. and Zoetis, T. (1991). Toxicologic Evaluation of Cellulose Fiber : Genotoxicity, Pyrogenicity, Acute And Subchronic Toxicity. *J. Am. Coll. Toxicol.* 10: 541-554.

Seifert, M., Hesse, S., Kabrelian, V. and Klemm, D. (2004). Controlling the Water Content of Never Dried and Reswollen Bacterial Cellulose by the Addition of Water Soluble Polymers to the Culture Medium. *Journal of Polymer Science: Part A: Polymer Chemistry*. 42:463-470.

Sellergren, B. (1989). Molecular Imprinting by Noncovalent Interactions. Enantioselectivity and Binding Capacity of Polymers Prepared Under Conditions Favoring the Formation of Template Complexes. *Makromol. Chem.* 190: 2703– 2711.

Sellergren, B. (1994). Imprinted Dispersion Polymers. New Easily Accessible Affinity Stationary Phases. *J. Chromatogr.* 673: 133.

Sellergren, B. (1997). Noncovalent Molecular Imprinting: Antibody-Like Molecular Recognition In Polymeric Network Materials. *Trends Anal. Chem.* 16: 310–320.

Sellergen B. and Allender C.J. (2005). Molecularly Imprinted Polymers: A Bridge to Advanced Drug Delivery. *Advanced Drug Delivery.* 57:1733-1741.

Sellergren, B. and Andersson, L.I. (1990). Molecular Recognition in Macroporous Polymers Prepared by a Substrate Analogue Imprinting Strategy. *Journal of Organic Chemistry.* 55: 3381-3383.

Sellergren, B. and Shea, K.J. (1993). Influence of Polymer Morphology on the Ability of Imprinted Network Polymers to Resolve Enantiomers. *J. Chromatogr.* 635: 31– 49.

Sellergren, B., Ruckert, B. and Hall, A.J. (2002). Layer-By-Layer Grafting F Molecularly Imprinted Polymers via Iniferter Modified Supports. *Adv. Mater.* 14: 1204– 1208.

Shah, J. and Brown, R.M. (2005). Towards Electronic Paper Displays Made From Microbial Cellulose. *Applied Microbiology and Biotechnology*. 66:352-355.

Shea, K.J. (1994). Molecular Imprinting of Synthetic Network Polymers: The De Novo Synthesis of Macromolecular Binding and Catalytic Sites. *Trends Polym. Sci.* 2: 166–173.

Shea, K.J. and Sasaki, D.Y. (1991). An Analysis of Small-Molecule Binding To Functionalized Synthetic Polymers by 13CP/MAS NMR and FT-IR Spectroscopy. *J. Am. Chem. Soc.* 113: 4109– 4120.

Shi, H., Tsal, W.B., Garrison, M.D., Ferrari, S. and Ratner, B.D. (1999). Template-Imprinted Nanostructured Surfaces for Protein Recognition. *Nature.* 398(6728):593-597.

Shibazaki, H., Kuga, S., Onabe, F. and Usuda, M., (1993). Bacterial Cellulose Membrane as Separation Medium. *Journal of Applied Polymer Science.* 50: 965-969.

Shoda, M. and Sugano, Y. (2005). Recent Advances in Bacterial Cellulose Production. *Biotechnology and Bioprocess Engineering*. 10:1-8.

Sibrian-Vazquez, M. (2003). *Design, Synthesis and Applications of Bio-Derived Crosslinking Monomers for Molecular Imprinting*. Louisiana State University and Agricultural College, Baton Rouge, Louisiana: Ph.D. Thesis.

Siemann, M., Andersson, L.I. and Mosbach, K. (1996). Selective Recognition of The Herbicide Atrazine by Noncovalent Molecularly Imprinted Polymers. *Journal of Agricultural and Food Chemistry***.** 44(1):141-145.

Silverstein, R.M., Basler, G.C. and Morril, T.C. (1991). *Spectrometric Identification of Organic.* 5th Edition. Toronto. John Wiley & Sons.

Sokolnicki, A.M., Fisher, R.J., Harrah, T.P. and Kaplan, D.L. (2006). Permeability of Bacterial Cellulose Membranes. *Journal of Membrane Science.* 272:15-27.

Spégel, P., Schweitz, L. and Nilsson, S. (2003). Molecularly Imprinted Polymers in Capillary Electrochromatography: Recent Developments and Future Trends. *Electrophoresis.* 24:3892–3899.

Spiers, A.J., Bohannon, J., Gehrig, S.M. and Rainey, P.B. (2003). Biofilm Formation at the Air-Liquid Interface by the *Pseudomonas Fluorescens* Wrinkly Spreader Requires an Acetylated Form of Cellulose. *Molecular Microbiology*. 50:15-27.

Stalbrandt, H., Mansfield, S. D., Saddler, J. N., Kilburn, D. G., Warren, R. A. J. and Gilkes, N. R. (1998). Analysis of Molecular Size of Cellulose by Recombinant Cellulomonas Fimi Bβ-1,4-Glucanase. *Appl. Environ. Microbiol.* 64: 2374–2379.

Striegler, S. and Tewes, E. (2002). Investigation of Sugar-Binding Sites in Ternary Ligand−Copper(II)−Carbohydrate Complexes. *European Journal of Inorganic Chemistry*. 2:487–495.

Svenson, J., Andersson, H.S., Piletsky, S.A. and Nicholls, I.A. (1998). Spectroscopic Studies of the Molecular Imprinting Self Assembly Process. *J. Mol. Recognit*. 11:83– 86.

Takeda, K. and Kobayashi, T. (2005). Bisphenol A Imprinted Polymer Adsorbents With Selective Recognition and Binding Characteristics. *Sci. Tech. Adv. Mater.* 6: 165-171.

Tangpasuthadol, V., Pongchaisirikul, N. and Hoven, V.P. (2003). Surface Modification of Chitosan Films, Effect of Surface Hydrophobicity on Protein Adsorption. *Carbohydrate Research*. 338(9):937–942.

Taqieddin, E. and Amiji, M. (2004). Enzyme Immobilization in Novel Alginate-Chitosan Core Shell Microcapsules. *Biomaterials*. 25:1937–1945.

Teeri, T.T. (1997). Crystallinity Cellulose Degradation New Insight into the Function of Cellulose Biohydrolases. *Tibtech*. 15:160-167.

Tita Puspitasari and Cynthia Linaya Radiman. (2006). Study of Graft Copolymerization of Acrylic Acid onto Nata De Coco and Its Application as Microfiltration Membrane. *Jurnal Atom Indonesia.* 32:119-128

Tong, D., Hetényi, C.S., Bikádi, Z.S, Gao, J.P. *and* Hjertén, S. (2001). Some Studies of the Chromatographic Properties of Gels ('Artificial Antibodies/Receptors') for Selective Adsorption of Proteins. *Chromatographia.* 54:7–14.

Turiel, E. and Martin-Esteban A. (2004). Molecularly Imprinted Polymers: Towards Highly Selective Stationary Phases in Liquid Chromatography and Capillary Electrophoresis. *Anal. Bioanal. Chem.* 378: 1876–1886.

Uhlin, K.I., Atalla, R.H. and Thompson, N.S. (1995). Influence of Hemicellulose on the Aggregation Patterns of Bacterial Cellulose. *Cellulose.* 2:129-144.

Urreaga, J. M., and De La Orden, M. U. (2006). Chemical Interactions and Yellowing in Chitosan-Treated Cellulose. *European Polymer Journal.* 42(10): 2606–2616.

Vallar,L. and Rivat, C. (1996). Regenerated Cellulose-Based Hemodialyzers with Immobilized Proteins as Potential Devices for Extracorporeal Immunoadsorption Procedures: An Assessment of Protein Coupling Capacity and In Vitro Dialysis Performances. *Artif. Organs.* 20 (1): 8.

Vandamme, E. J., De Baets, S., Vanbaelen, A., Joris, K. and De Wulf, P. (1998). Improved Production of Bacterial Cellulose and Its Application Potential. *J. Polymer Degrad. Stabil.* 59 : 93–99.

Vlatakis, G., Andersson, L.I. Müller, R. and Mosbach, K. (1993). Drug Assay Using Antibody Mimics made by Molecular Imprinting. *Nature.* 361: 645–647.

Vriezema, D., Aragones, M., Elemans, J., Cornelissen, J., Rowan, A. and Nolte, R. (2005). Self-Assembled Nanoreactors. *Chem. Rev.* 105: 1445–1490.

Wan, W.K. and Millon, L.E. (2005). *Poly(Vinyl Alcohol)-Bacterial Cellulose Nanocomposite.* (U.S. Patern 2005037082 A1, 16).

Wan, W.K., Hutter, J.L., Millon, L. and Guhados, G. (2006). Bacterial Cellulose and Its Nanocomposites for Biomedical Applications. *Acs Symposium Series.* 938:221-241.

Wang, S.L., Lin, T.Y., Yen, Y.H., Liao, H.F. and Chen, Y.J. (2006). Bioconversion of Shellfish Chitin Wastes for the Production of Bacillus Subtilis W-118 Chitinase. *Carbohydr Res.* 341: 2507-2515.

Wang, S.M., Huang, Q.Z. and Wang, Q.S. (2005). Study on the Synergetic Degradation of Chitosan with Ultraviolet Light and Hydrogen Peroxide. *Carbohydrate Res*. 340: 1143-1147.

Wang, T., Turhan, M. and Gunasekaran, S. (2004). Selected Properties of Ph-Sensitive, Biodegradable Chitosan-Poly(Vinyl Alcohol) Hydrogel. *Polymer International.* 53:911-918.

Wang, W., Qu, X., Ai G., Tetley, L. and If, U. (2004). Self Assembly of Cetyl Linear Polyethylenimine to Give Micelles, Vesicles and Dense Nanoparticles, *Macromolecules.* 37: 9114-9122.

Watanabe, K., Eto Y., Takano, S., Nakamori, S., Shibai, H. and Yamanaka, S. (1993). A New Bacterial Cellulose Substrate for Mammalian Cell Culture. *Cytotechnology*. 13:107-114.

Watanabe, K., Tabuchi, M., Morinaga, Y. and Yoshinaga, F. (1998). Structural Features and Properties of Bacterial Cellulose Produced in Agitated Culture. *Cellulose.* 5: 187–200.

Wei, X., Li, X. and Husson, S.M. (2005). Surface Molecular Imprinting by Atom Transfer Radical Polymerization. *Biomacromolecules***.** 6(2):1113-1121.

Whitcombe, M.J., Rodriguez, M.E., Villar, P. and Vulfson, E.N. (1995). A New Method for the Introduction of Recognition Site Functionality into Polymers Prepared by Molecular Imprinting—Synthesis and Characterization of Polymeric Receptors for Cholesterol. *J. Am. Chem. Soc.* 117: 7105– 7111.

Whitney, E., Gothard, M., Mitchell, J. and Gidley, M. (1999). Roles of Cellulose and Xyloglucan in Determining the Mechanical Properties of Primary Plant Cell Walls. *Plant Physiology*. 121:657-663.

Whitney, S.E.C., Brigham, J.E., Darke, A.H., Reid, J.S.G. and Gidley, M.J. (1998). Structural Aspects of the Interaction of Mannan-Based Polysaccharides with Bacterial Cellulose. *Carbohydrate Research.* 307:299-309.

Wijmans, J.G. and Baker, R.W. (1995). The Solution-Diffusion Model: A Review, *Journal of Membrane Science***.** 107(1-2):1-21

Williams, W.S. and Cannon, R.E. (1989). Alternative Environmental Roles for Cellulose produced by *Acetobacter Xylinum*. *Appl. Environ. Microbiol.* 55:2448-2452

Wu Y.B., Yu S.H., Mi F.L., Wu C.W., Shyu S.S. and Peng C.K. (2004). Preparation and Characterization on Mechanical and Antibacterial Properties of Chitsoan/Cellulose Blends. *Carbohydrate Polymers.* 57: 435–440.

Wulff, G. (2002). Enzyme-Like Catalysis by Molecularly Imprinted Polymers. *Chem. Rev.* 102: 1–28.

Wulff, G., Gross, T. and Schönfeld, R. (1997). Enzyme Models based on Molecularly Imprinted Polymers with Strong Esterase Activity. *Angew. Chem., Int. Ed. Engl.* 36:1962– 1964.

Xu, X.Y., Kim, K.M., Hanna, M.A. and Nag, D. (2005). Chitosan-Starch Composite Film: Preparation and Characterization. *Industrial Crops and Products*. 21:185–192.

Yadav, A.V. and Bhise, S.B. (2004). Chitosan: A potential Biomaterial Effective Against Typhoid. *Current Science*. 87(9):1176-1178.

Yamada, Y. (2000). Transfer Acetobacter Oboediens and A. Intermedius to the Genus Gluconacetobacter as G. Oboediens Comb. Nov. and G. Intermedius Comb. Nov. *Int. J. System. Evolut. Microbiol.* 50: 2225–2227.

Yamada, Y., Hoshino, K. and Ishikawa, T. (1997). The Phylogeny of Acetic Acid Bacteria based on the Partial Sequences of 16 S Ribosomal RNA: The Elevation of the Subgenus Gluconacetobacter to the Generic Level. *Biosci. Biotechnol. Biochem.* 61:1244–51.

Yamamoto H., Horii F. and Hirai A. (1996). In Situ Crystallization of Bacterial Cellulose II. Influences of Different Polymeric Additives on The Formation Of Cellulose Iα And Iβ at The Early Stage of Incubation. *Cellulos.* 3:229-242.

Yamanaka, S., Ishihara, M. and Sugiyama, J. (2000). Structural Modification of Bacterial Cellulose. *Cellulose*. 7:213-225.

Yamanaka, S., Watanabe, K. and Suzuki, Y. (1990). *Hollow Microbial Cellulose, Process For Preparation Thereof, And Artificial Blood Vessel Formed Of Said Cellulose.* (European Patent 0396344A2).

Yang L., Hsiao W.W. and Chen P. (2002). Chitosan–Cellulose Composite Membrane for Affinity Purification of Biopolymers and Immunoadsorption. *Journal of Membrane Science.* 197: 185–197.

Yang, L., Hsiao, W.W. and Chen, P. (2002). Chitosan–Cellulose Composite Membrane for Affinity Purification of Biopolymers and Immunoadsorption. *Journal of Membrane Science*. 197:185–197.

Yang, Y., Yang, H., Yang, M., Liu, Y., Shen G. and Yu R. (2004), Amperometric Glucose Biosensor based on a Surface Treated Nanoporous Zro2/Chitosan Composite Film as Immobilization Matrix. *Anal. Chim. Acta*, 525: 213-220.

Yao, G., Fang, X., Yokota, H., Yanagida, T. and Tan, W. (2003), Monitoring Molecular Beacon DNA Probe Hybridization at the Single-Molecule Level. *Chemistry.* 9:5686-5692.

Yazdani-Pedram, M., Retuert, J., and Quijada, R. (2000). Hydrogels Based On Modified Chitosan. Synthesis and Swelling Behavior Of Poly(Acrylic Acid) Grafted Chitosan. *Macromolecular Chemistry and Physics.* 201:923–930.

Ye, L., Cormack, P.A.G. and Mosbach, K. (1999). Molecularly Imprinted Monodisperse Microspheres for Competitive Radioassay. *Analytical Communications.* 36(2):35-38.

Yilmaz, E., Mosbach, K. and Haupt, K. (1999). Influence of Functional and Cross-Linking Monomers and the Amount of Template on The Performance of Molecularly Imprinted Polymers in Binding Assays. *Ana. Commun*. 36:167–170.

Yin, J., Luo, K., Chen, X. and Khutoryanskiy, V. V. (2006). Miscibility Studies of the Blends of Chitosan with Some Cellulose Ethers. *Carbohydrate Polymers*. 63: 238–244.

Yu, C. and Mosbach, K. (1997). Molecular Imprinting Utilizing an Amide Functional Group for Hydrogen Bonding Leading to Highly Efficient Polymers. *J. Org. Chem.* 62:4057-4064.

Yu, C. and Mosbach, K. (1998). Insights into the Origins of Binding and the Recognition Properties of Molecularly Imprinted Polymers Prepared using an Amide as the Hydrogen-Bonding Functional Group. *Journal of Molecular Recognition*. 11(1-6):69-74.

Yu, Y., Ye L., Haupt, K. and Mosbach, K. (2002). Formation of a Class of Enzyme Inhibitors (Drugs), Including A Chiral Compound by using Imprinted Polymers or Biomolecules as Molecular-Scale Reaction Vessels. *Angewandte Chemie – International Edition*. 41:4459-4463.

Zeng, X. and Ruckenstein, E. (1997). Macroporous Chitin Affinity Membranes for Lysozyme Separation. *Biotechnol. Bioeng.* 56 (6): 610.

Zhang, Y., Ni, M., Zhang, M. and Ratner, B. (2003). Calcium Phosphate-Chitosan Composite Scaffolds for Bone Tissue Engineering. *Tissue Eng.* 9:337-345.

Zydney, A.L. and Xenopoulos, A. (2007). Improving Dextran Tests for Ultrafiltration Membranes: Effect of Device Format. *Journal of Membrane Science.* 291:180–190.