Chemical Engineering Approaches to Injectable Biomaterials:

From Adhesion Prevention and Intraperitoneal DDS to Artificial Oxygen Carriers

Prof. Taichi Ito,

The University of Tokyo, Japan

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Abstract:

Injectable biomaterials provide a versatile platform for minimally invasive medical interventions by enabling local delivery, tissue sealing, and regulation of biological microenvironments. In this seminar, hosted by Professor Satyavrata Samavedi, I will present our recent research on injectable hydrogels, postoperative adhesion prevention materials, intraperitoneal drug delivery systems (DDS), and artificial oxygen carriers, with an emphasis on material design principles rooted in chemical engineering and biomaterials science.

I will first introduce injectable, shear-thinning, and in situ cross-linkable hydrogels based on polysaccharides and synthetic polymers, including alginate, hyaluronan, chitosan, gelatin, and polyethylene glycol. By employing dynamic covalent bonds, ionic cross-linking, and supramolecular interactions, we established structure–property–function relationships that balance injectability, mechanical integrity, self-healing behavior, and tissue adhesion. These concepts have been applied to develop postoperative adhesion barriers and tissue sealants, demonstrating effective prevention of peritoneal, dural, and gastrointestinal adhesions in clinically relevant animal models while maintaining operability and hemostatic balance.

Next, I will focus on intraperitoneal DDS for cancer dissemination, where transport phenomena and reaction–diffusion processes play central roles. We developed hyaluronan-based nanogels, hybrid nanogel–hydrogel systems, and metal-ion–crosslinked networks for localized intraperitoneal delivery of anticancer agents such as cisplatin and pemetrexed. These systems achieved prolonged residence in the peritoneal cavity, enhanced local drug concentration, and reduced systemic toxicity. More recently, we extended this strategy to bioactive nucleic acid systems, including DNA aptamers targeting hepatocyte growth factor, to modulate fibrinolysis and mesothelial–mesenchymal transition for the prevention of postoperative peritoneal adhesion.

I will then present our work on artificial oxygen carriers inspired by red blood cells, fabricated as micro- and nano-sized core–shell particles using Shirasu porous glass (SPG) membrane emulsification. By controlling particle size, shape, shell mechanics, and surface chemistry, we elucidated how these parameters govern oxygen transport, microvascular perfusion, protein adsorption, and macrophage phagocytosis.

Finally, I would like to discuss how integrating materials synthesis, transport analysis, computational modeling, and biological validation enables a predictive framework for designing next-generation injectable biomaterials and DDS. This seminar will highlight opportunities for synergy with ongoing research at IIT Hyderabad in chemical engineering and biomedical engineering.

Taichi Ito, Ph.D.,

Professor
Department of Chemical System Engineering,
Department of Bioengineering,
Department of Radiology and Biomedical Engineering,
The University of Tokyo, Japan

Lab: https://ito-lab.t.u-tokyo.ac.jp/index_english.html
E-mail: itotaichi@g.ecc.u-tokyo.ac.jp

2020-2023 Professor, Center for Disease Biology and Integrative Medicine, Faculty of Medicine/Department of Chemical System Engineering/School of Engineering/Department of Bioengineering, School of Engineering, The University of Tokyo

2009-2020 Associate Professor Center for Disease Biology and Integrative Medicine, Faculty of Medicine/Department of Chemical System Engineering, School of Engineering/Department of Bioengineering, the University of Tokyo

2007-2009 Assistant Professor, Chemical Resources Laboratory, Tokyo Institute of Technology

2006-2007 Assistant Professor, Department of Chemical System Engineering, School of Engineering, the University of Tokyo

2004-2006 Post doctoral fellow Department of Chemical Engineering, Massachusetts Institute of Technology, USA

2002-2004 Ph.D. Department of Chemical System Engineering, School of Engineering, The University of Tokyo

1998-2001 Researcher TORAY Co.