Department of Applied Chemistry and Food Science

Key words Polymer solution, Biopolymers, Hydrogels, Food Rheology, Food Texture, Tissue Engineering, Engineered Tissue, Organoids, iPSc, Soft Robotics

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Education

Department of biological and chemical engineering, Faculty of Engineering, Gunma University
Graduate School of Engineering, Gunma University, Master's Course Program
Graduate School of Engineering, Gunma University, Doctor's Course Program

Professional Background

Research Fellowship for Young Scientists, JSPS
Post-doctoral research fellow, Department of Science and Engineering, Kwansei Gakuin University
Assistant Professor, Faculty of Advanced Life Science, Hokkaido University

Consultations, Lectures, and Collaborative Research Themes

Rheological and structural analysis for softmaterials/ Construction of Engineered Tissues with complex hierarchical structures/ Small angle light scattering/ Small angle X-ray scattering/ Fluorescence Microscopy/ Organoid culture/ Animal cell culture/ Bio-robots with autonomous actuations

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Main research themes and their characteristics

「Dialysis-Induced Anisotropic Gelation of Biolpolymer Solutions」

Contacting two solutions with different compositions induces diffusions of ions and low molecular weight compounds between the solutions. The dialysis have been used as a conventional method in chemistry and biology. Dialysis of concentrated biopolymer solutions against multivalent metal cation solutions results in hydrogels with birefringence. This shows that the hydrogels have anisotropic structures.

By investigating experimentally and theoretically, we have elucidated hierarchical structures of the anisotropic hydrogels, established the theoretical model for expressing the anisotropic gelation kinetics, and characterized specific functions and mechanical properties for each anisotropic hydrogels. By summarizing the common characteristics for the dialysis-induced anisotropic gelation, we have shown that the phenomena are universal and irrespective of the kind of polymers. In contrast, we have also found that the hierarchical structures for the anisotropic hydrogels depend on the kinds of polymers and gelling agents. We have elucidated that the variety of hierarchical structures for the anisotropic hydrogels is attributed to changes in gelation conditions, such as temperature, pH and ionic strength, during dialysis process and to other phenomena, such as liquid-liquid and liquid-solid phase separations, simultaneously occurring with the anisotropic gelation.

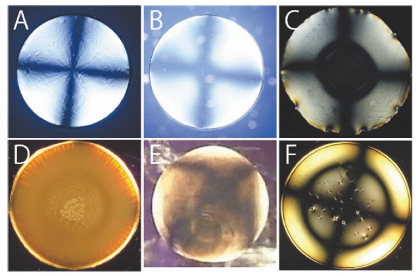

Fig.1 Anisotropic hydrogels prepared by using dialysis-induced anisotropic gelation. A: DNA anisotropic hydrogel B: Alginate anisotropic hydrogel C: Curdlan anisotropic hydrogel D: Carboxymethyl Cellulose anisotropic hydrogel E: Silk fibroin anisotropic hydrogel F: Gelatin anisotropic hydrogel

「Construction of Engineered Tissues by using Multi-Channel Collagen Gels (MCCGs)」

Tissues and organs in our body are the assembles with complex hierarchical structures which consists of various cells and extracellular matrices. The biological functions of tissues and organs are associated to the hierarchical structures. The tissues and organs are consisted of tremendous number of cells, and maintaining the cells in the tissues and organs requires feeding enough amounts of nutrients and oxygen via the blood flow. Therefore, we must reproduce the complex hierarchical structures and equip blood vessel networks for constructing functional engineered tissues.

We have found that dialysis of acidic collagen solutions against phosphate buffer solutions, which neutralizing the pH of the collagen solution, results in collagen hydrogels with anisotropic collagen fiber orientation and multichannel structures (Multi-Channel Collagen Gel: MCCG). The complex hierarchical structure for MCCG well reproduces the hierarchical structures of extracellular matrices in various tissues, such as bone, muscle, and hepatic tissues. Therefore, MCCG can be used as a scaffold materials for reconstructing the hierarchical structure of native tissues and organs. Furthermore, because the collagen is the most major protein in our body, the hydrogel also have well biocompatibility. By using MCCG, we have constructed various engineered tissues with complex hierarchical structures.

We are now integrating the engineered tissues constructed by using MCCG to develop altanatives for the human body in a culture vessel and to reproduce tissue-tissue interactions.

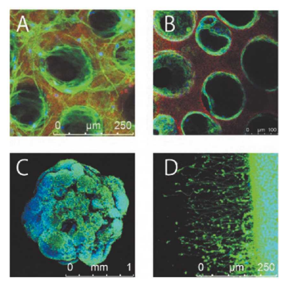

Fig.2 Engineered tissues constructed by using MCCGs.
A: Engineered bone tissue
B: Engineered kidney tissue
C: Engineered liver tissue
D: Engineered nerve tissue

Major academic publications

K. Furusawa, R. Teramae, H. Ohashi, M. Shimizu, "Development of Living "Bio-Robots" for Autonomous Actuations" Journal of Robotics and Mechatronics, 34, (2022) 279-284.

S. Yahata, K. Furusawa, K. Nagao, M. Nakajima, T. Fukuda "Effects of three-dimensional culture of mouse calvaria-derived osteoblastic cells in a collagen gel with a multichannel structure on the morphogenesis behaviors of engineered bone tissues" ACS Biomater. Sci. Eng., 3, (2017) 136-145.

K. Furusawa, S. Sato, J. Masumoto, Y. Hanazaki, Y. Maki, T. Dobashi, T. Yamamoto, A. Fukui, N. Sasaki "Studies on the formation mechanism and the structure of the anisotropic collagen gel prepared by dialysis-induced anisotropic gelation" Biomacromolecules, 13 (2012) 29-39.

K. Furusawa, Y. Narazaki, N. Tomita, T. Dobashi, N. Sasaki, T. Yamamoto "Effects of pH on anisotropic gelation of DNA induced aluminum cations" J. Phys. Chem., 114 (2010) 13923-13932.