The CATALYST

Helping you react with chemical reactions

Issue 9
September 2022

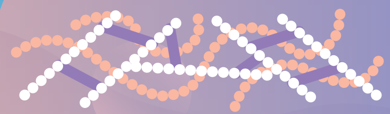
The strength and utility of polymers

ICReDD
Institute for Chemical Reaction Design and Discovery
HOKKAIDO UNIVERSITY

The strength and utility of polymers

Designing and discovering new chemical reactions can often lead to the creation of new materials. Many natural materials and manmade materials are made up of molecules with large molecular weights called polymers. Polymers are chain-like molecules made of many repeating subunits. By changing the length of this molecular chain, the order of the chain links, and how the chains are connected, materials with a wide range of properties can be created!

What is a double network hydrogel?



A double network hydrogel (DN gel) is made up of two different polymer networks. One network is more rigid, providing strength, while the other is more flexible, providing elasticity.

1. Polymers in everyday life

Polymers exist all around us and even inside of us, ranging from plastics and rubbers to proteins and genes. A polymer's chain can consist of one single subunit that repeats over and over, such as in certain plastics used to make bottles for water or soda. Polymers can also have a chain that consists of more than one type of subunit repeated either in a disordered fashion or in some pattern. Genes inside our bodies are polymers that consist of four different repeating subunits. The order of these repeating subunits in the gene's polymer chain is what gives each of us our unique characteris-tics!

2. Branching out

Polymers are often more complex than just a single chain. Polymers can have branch points where one chain splits into two chains, or two different polymer chains can be connected via chemical reactions through what is called a cross-link. The presence of cross-links makes the polymer tougher, and joining many polymer chains via crosslinker molecules can form a polymer network with formidable strength. For example, a rubber band may be soft and stretchy, but heating rubber with sulfur forms cross-links, making rubber into a durable material suitable for making tires.

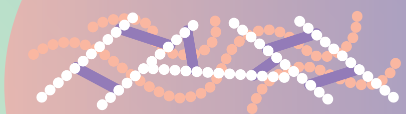
3. Balancing strength and flexibility

In addition to chemical bonds, physical interactions between polymer chains can also influence a material's properties. The longer the polymer chains, the more likely it is for the chains to get tangled up. This can affect the material's viscosity (how well it flows), and its elasticity (how much it deforms when stretched and how well it returns to its original shape when let go). Cross-links can also affect a material's elasticity. Adding cross-links makes the material harder and stronger but adding too many cross-links can make a material brittle, causing it to suddenly break when sufficient force is applied. Controlling a polymer's physical entanglements and cross-link concentration is a key factor for designing polymer materials with a desirable balance of strength and flexibility.

4. Stretching the limits

Researchers at ICReDD are working at the cutting-edge of polymers, exploring the possibilities of materials called double-network hydrogels (DN gels). Despite being made of over 90% water, two separate polymer networks give these soft DN gels the strength and elasticity of rubber! The Gong group is researching the potential of DN gels to function as artificial cartilage, and a collaboration with the Tanaka group found that DN gels can revert cancer cells back into cancer stem cells. This phenomenon could be used to help develop new drugs that target cancer stem cells!

What is a double network hydrogel?



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Activation!

Quiz

Cross-links cause a polymer to be_________.

Send us your answer!

- **A** stronger
- **B** softer
- **C** faster flowing
- **D** all of the above

Check our Instagram highlights for the answer to the quiz! #ReactWithUs

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ICReDD News

September 2022

New Researchers

Phillipe Gantzer
Cheminformatics, Molecular Dynamics

Wei Li
Polymer Networks, Structure-Property Relationships

Min Gao
Quantum Chemistry, Catalysis

Pinku Nath
Computational Material Science, Ontology

Selected Publications

(from June 2022 to August 2022)

In silico reaction screening with difluorocarbene for N-difluoroalkylative dearomatization of pyridines
(H. Hayashi, H. Katsuyama, H. Takano, Y. Harabuchi, S. Maeda, T. Mita)
DOI: 10.1038/s44160-022-00128-y

Mechanochemically Generated Calcium-Based Heavy Grignard Reagents and Their Application to Carbon–Carbon Bond-Forming Reactions
(P. Gao, S. Maeda, K. Kubota, H. Ito)
DOI: 10.1002/anie.202207118

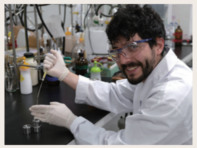
Construction of Heterobimetallic Catalytic Scaffold with a Carbene-Bipyridine Ligand: Gold–Zinc Two-Metal Catalysis for Intermolecular Addition of O-Nucleophiles to Nonactivated Alkynes
(K. Higashida, M. Sawamura)
DOI: 10.1021/acscatal.2c01701

Preparation of photonic molecular trains via soft-crystal polymerization of lanthanide complexes
(Y. Kitagawa, S. Shoji, Y. Hasegawa)
DOI: 10.1038/s41467-022-31164-z

Determination of the critical chain length for macromolecular crystallization using structurally flexible polyketones
(Y. Ide, Y. Kinoshita, J. Pirillo, Y. Hijikata, T. Yoneda, K.I. Shivakumar, Y. Inokuma)
DOI: 10.1039/D2SC03083G

Outreach

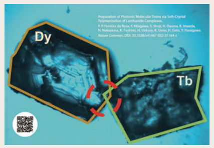
- Monthly News Postcard
- The CATALYST 8th Issue
- Francesco Puccetti worked with the Ito Lab as part of the MANABIYA exchange program
- L-INSIGHT Leadership Program (Kyoto University)
- Visit from University of Melbourne Delegation



Francesco Puccetti

L-INSIGHT Leadership Program

Visit from University of Melbourne Delegation



Monthly News Postcard

The CATALYST 8th issue

Researcher Profile

vol.9

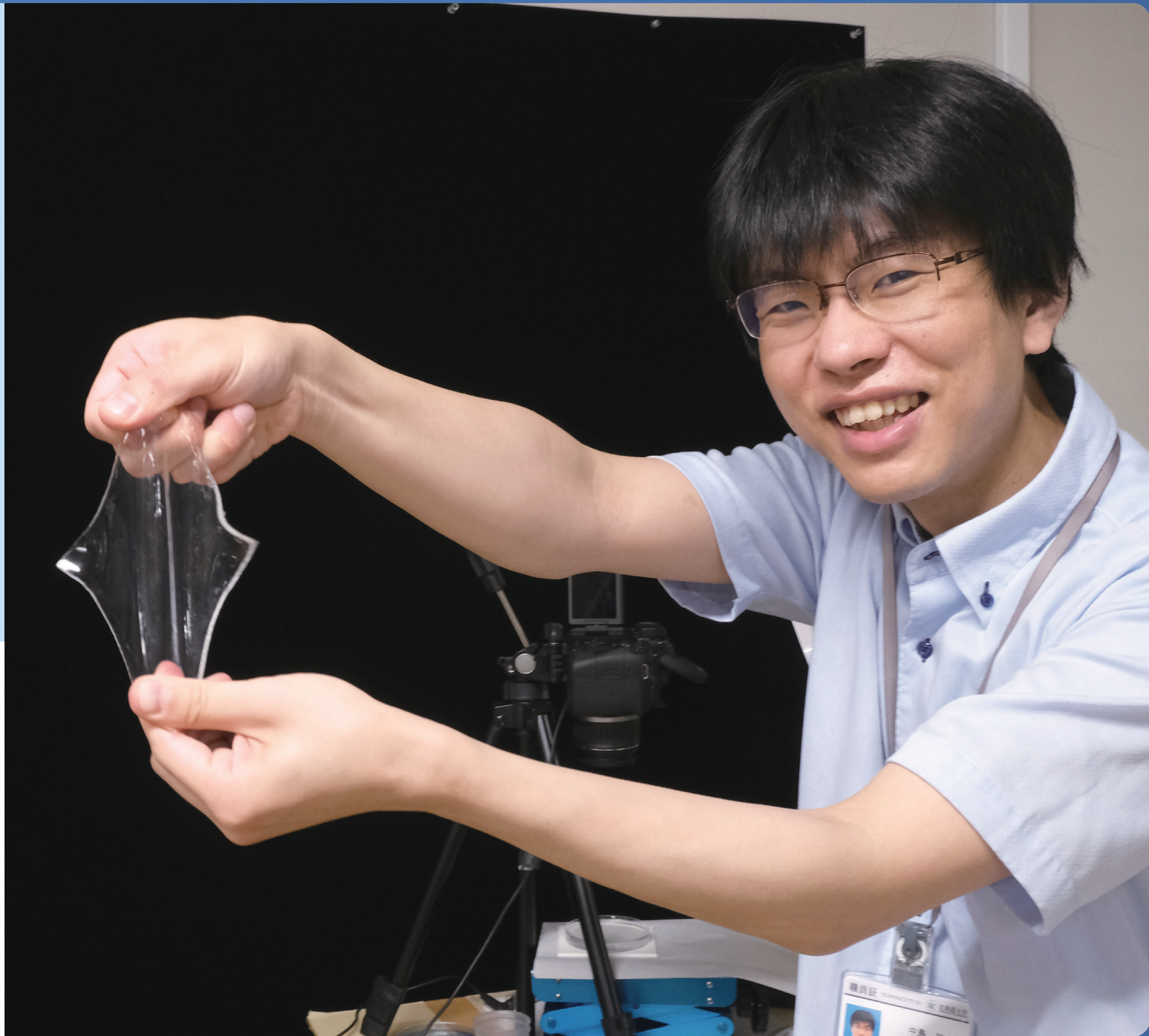
Tasuku Nakajima

Associate Professor Nakajima utilizes soft, wet gels as a system for synthesizing a wide variety of high strength, highly functional materials. For example, he is working on gels that metabolize and grow like a living organism.

Representative Papers:
J. Am. Chem. Soc., 2022, 144, 3154-3161
Science, 2019, 363, 504-508
Adv. Mater., 2019, 31, 1900702

Short Biography

Associate Professor and Distinguished Researcher at ICReDD and the Faculty of Advanced Life Science at Hokkaido University. After receiving his PhD from Hokkaido University in March 2011, Prof. Nakajima was a JSPS Research Fellow at the University of Tokyo. From October 2011, he joined the Faculty of Advanced Life Science at Hokkaido University as an Assistant Professor, and was promoted to Associate Professor in April 2019. He was given the additional title of Distinguished Researcher in April 2022.



About ICReDD

The development of new chemical reactions is intrinsically entangled with the prosperity of humanity and the preservation of the environment. A recent example of such transformative chemical reactions with profound impact is cross-coupling reactions, the discovery of which was awarded with the 2010 Nobel Prize in Chemistry. These reactions are used to produce approximately 20% of all medicinal reagents, and almost all liquid crystalline and organic electroluminescent materials. The industrial use of these chemical reactions contributes ~60 trillion yen per annum to the global economy. The development of new chemical reactions thus significantly affects the evolution of society.

ICReDD is the Institute for Chemical Reaction Design and Discovery, a WPI center at Hokkaido University where researchers from different disciplines combine their strengths to take full control over chemical reactions. The institute was born out of the realization that the purposeful design of chemical reactions requires cross-sectional collaborations at every step. Working on such a fundamental natural process, quantum-chemical computations, information technology, modern experimental techniques, and the development of advanced materials can no longer be separate fields if we want to achieve significant breakthroughs. Rather, they have to become part of a diverse toolbox for truly integrated research.

After over a 2 year break due to the COVID-19 pandemic, ICReDD was finally able to host an in-person seminar! Held in collaboration with the Frontier Chemistry Center, this international seminar featured Professor Michael Krische from the University of Texas-Austin in the U.S.A. as the speaker. Prof. Krische gave a talk on "Hydrogen Mediated C-C bond formation". The seminar was a hybrid format, with the in-person seminar taking place at the Hokkaido University Conference Hall.

The Catalyst is inspired by catalysts used in chemistry to bring molecules together, to reduce reaction barriers, and to activate molecules—to make reactions happen faster. In this spirit, this poster series should enable its readers to make the connection between chemical reactions and the wellbeing of our society, and to look at the world in a new way, seeing how chemical reactions and chemistry shape the world around them. And if we can take this opportunity to introduce ourselves, too, this may also catalyze new friendships and opportunities. #ReactWithUs

React With Us!

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with what's happening at ICReDD,
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