

Young Career Focus: Dr. Jia Niu (Boston College, USA)

Background and Purpose. SYNFORM regularly meets young up-and-coming researchers who are performing exceptionally well in the arena of organic chemistry and related fields of research, in order to introduce them to the readership. This Young Career Focus presents Dr. Jia Niu (Boston College, USA).

Biographical Sketch



Dr. J. Niu

Jia Niu was born and raised in Shijiazhuang, Hebei Province (P. R. of China) and obtained a Bachelor of Science degree with the highest honor in chemistry from Tsinghua University (P. R. of China) in 2005. After completing a Master of Science degree under the guidance of Professor Xi Zhang in 2008, also at Tsinghua, he moved to the United States and joined Professor David R. Liu's group at Harvard University to pursue his Ph.D. degree. In the Liu group, he developed an enzyme-free strategy capable of translating DNA templates to sequence-defined synthetic polymers structurally unrelated to nucleic acids – essentially an artificial translation system that did not need ribosomes in spite of other necessary restrictions. After graduate school, he became a joint postdoctoral scholar with Professor Craig J. Hawker and Professor H. Tom Soh at University of California, Santa Barbara (USA) in 2014. During his postdoc, Jia led two technology development projects: (1) a strategy to engineer live cell surface with functional polymers via light-mediated, cytocompatible controlled radical polymerization; and (2) a platform to discover carbohydrate-modified aptamers for lectin recognition with high specificity. The graduate and postdoctoral training experiences have shaped Jia's interests in combining organic chemistry approaches with polymer synthesis to generate novel polymeric structures, and he uses them to address pressing needs in biomedicine, materials, and environmental sciences. Jia started his current assistant professor appointment in Boston College, USA in the summer of 2017. He is the recipient of the 2019 Thieme Chemistry Journals Award.

INTERVIEW

SYNFORM *What is the focus of your current research activity?*

Dr. Niu Research in the Niu group is currently focused on the development of strategies for the synthesis of macromolecules with novel architectures, functions, and sequences, and the use of these polymeric materials in applications ranging from biomedicine to environmental sciences. Our approach is centered around integrating cutting-edge synthetic organic chemistry principles with macromolecule synthesis towards generating novel macromolecules with bioactive functions or high material performance – essentially positioning our research activities at the interdisciplinary interfaces of organic chemistry, polymer science, and chemical biology (Figure 1).

SYNFORM *When did you get interested in synthesis?*

Dr. Niu I became interested in organic synthesis and polymer chemistry when conducting undergraduate research in Professor Xi Zhang's group at Tsinghua University. My research project at the time involved fabricating polyelectrolyte thin films by iteratively depositing two polyelectrolytes carrying opposite charges onto a substrate, also known as the Layer-by-Layer (LbL) technique. I was awed by the polymer chemist's ability to design and manipulate the backbone and side-chain structures of the polyelectrolytes and use them to fabricate polymer thin films for a variety of applications ranging from building uniquely shaped cavities for molecular recognition to fabricating materials with special wetting properties that mimic the body coatings of the water strider bug. I also realized that despite these impressive capabilities, compared to biopolymers such as DNA, proteins, and polysaccharides, synthetic polymers still lack the critical control over sequence, structure, or molecular weight. I thought that this discrepancy created great opportunities in polymer chemistry for the synthesis of precision macromolecules that approach the structural and functional prowess of biopolymers, and decided to pursue polymer synthesis in my further studies.

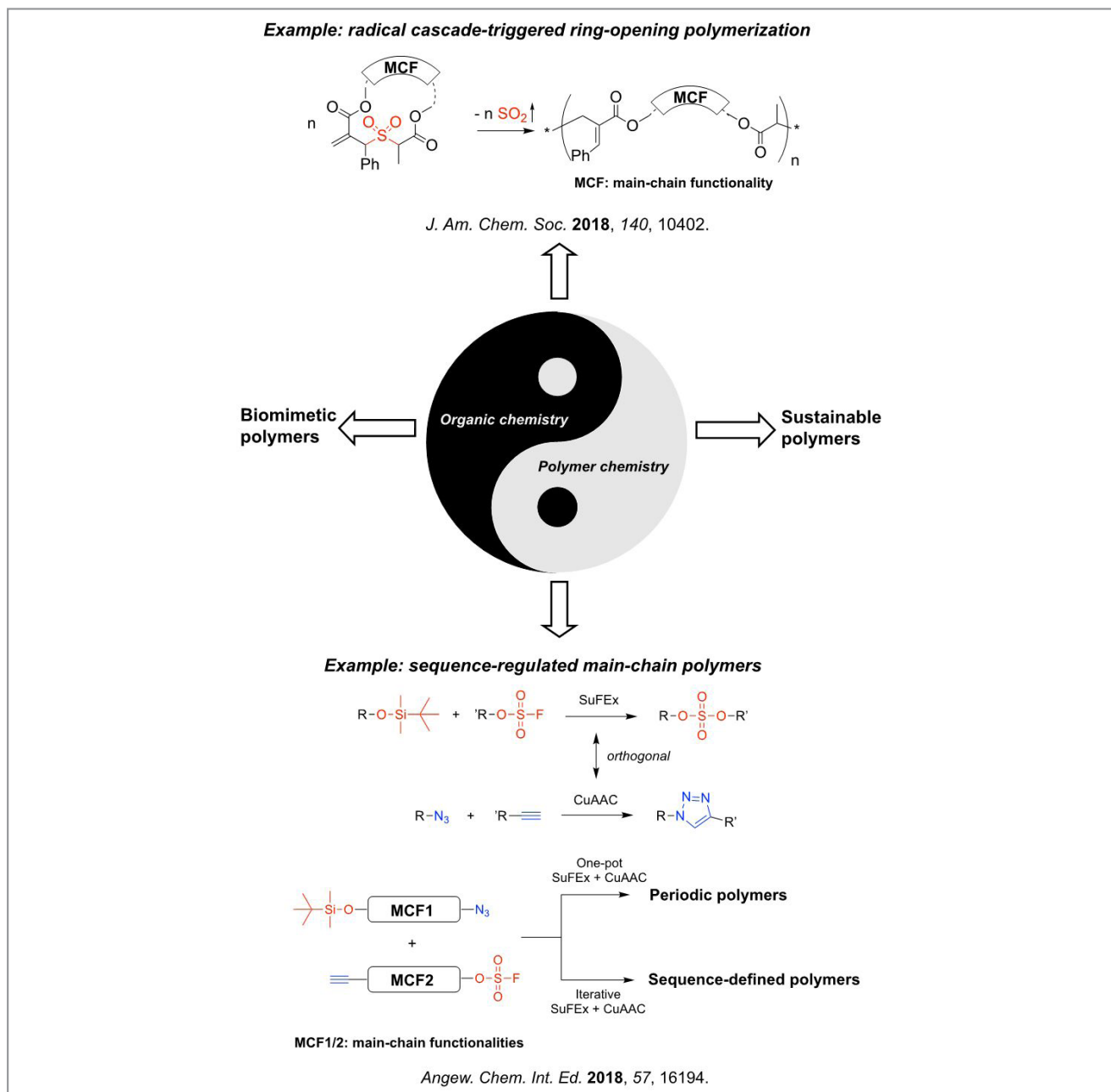


Figure 1 Research overview

SYNFORM What do you think about the modern role and prospects of organic synthesis?

Dr. Niu Organic synthesis, and the tools chemists have developed to enable its execution, have fundamentally changed almost all aspects of modern life and industries. Because of the vast scope of organic synthesis and the great diversity

of innovations taking place in this field, it is difficult for one to predict a general prospect of organic synthesis. I can only discuss my somewhat narrow perspective on this topic. There are two research areas in organic synthesis that motivate me the most: first, discovery of synthetic small molecules and macromolecules that can help to reveal the underlying molecular principles of life and/or can serve as tools to manipulate

the biological processes governed by these principles; second, development of the methodologies that can make organic synthesis and its products sustainable, through the use of renewable raw materials, attaining high atom-economy, developing efficient catalysts, or enabling recycling or controlled degradation of the organic materials. While much progress has been made in these research directions, greater advances are still urgently needed to address some of the most pressing challenges our society faces both currently and in the future.

SYNFORM *Your research group is active at the interface of organic synthesis with chemical biology. Could you tell us more about your research and its aims?*

Dr. Niu Given the short history of our research group, we are only at the beginning of our exploration at the interface of chemistry and biology. One specific direction of our research is to develop novel glycomimetic polymers with unique architectures and sequences for studying the guiding principles of the interactions between polysaccharides and carbohydrate-binding proteins. The interactions of polysaccharides with their cognate protein receptors are essential in many important cellular processes, but how the structures and sequences of polysaccharides regulate these interactions remains poorly understood to date. Central to this limitation is the highly heterogeneous and dynamic nature of polysaccharides *in vivo*, and our current inability to generate synthetic analogues of the natural polysaccharides with fully controlled structures and sequences. We hope that some of the polymer synthesis strategies recently developed in our lab can be extended to address this important challenge, leading to next-generation glycomimetic polymers with controlled architectures and sequences to facilitate our future investigations into polysaccharide-carbohydrate-binding protein interactions. Another specific direction we are pursuing is the synthesis of precision sustainable polymers from simple, readily available bio-based building blocks. Sustainable polymers made from renewable resources provide a promising solution to the current environmental issues associated with the conventional petroleum-based polymers. We are currently investigating the synthesis of precision polymers with tailored structural motifs in both the backbone and side chain, while maintaining control over polymer molecular weight, chain end groups, and dispersity. We hope these sustainable precision polymers will be able to compete with conventional polymers in the realm of high-performance materials.

SYNFORM *What is your most important scientific achievement to date and why?*

Dr. Niu I am excited about our recent report on the principle of radical cascade-triggered ring-opening polymerization (*J. Am. Chem. Soc.* **2018**, *140*, 10402–10406) (Figure 1, top). The radical cascade reaction is a powerful approach that organic chemists adopt to facilitate the construction of complex molecular structures. We demonstrated that this chemistry can also be used to provide the key driving force for the ring-opening polymerization – a process that was traditionally driven by the relief of ring strain in cyclic monomers. To our knowledge, this work represents the first system that allows radical ring-opening polymerization of macrocyclic monomers with low ring strain to be well controlled in either homopolymerization or block copolymerization. In a second recent paper, we described a simple approach for the synthesis of sequence-regulated polymers via orthogonal CuAAC and SuFEx click reactions (*Angew. Chem. Int. Ed.* **2018**, *57*, 16194–16199; corrigendum: *Angew. Chem. Int. Ed.* **2019**, *58*, 655–655) (Figure 1, bottom). The perfect orthogonality of these two click reactions enabled one-pot step-growth polymerization to generate periodic sequence-controlled polymers with high sequence complexity, as well as solid-phase iterative coupling of building blocks to yield sequence-defined oligomers without the need of protecting groups. Taken together, these polymer synthesis technologies open new avenues for many future directions of our group spanning polysaccharide-mimicking polymers and sustainable polymers.

Matthew Fanak