

UW Chemical Engineering

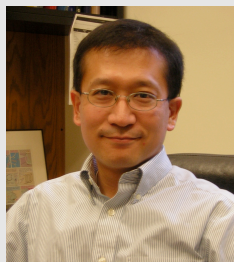
Spring 2013 Seminar Series

Date: Monday, April 22

Time: 4:00 - 5:00 p.m.

Place: PAA A118

Designing Antimicrobial Polymers as Synthetic Mimics of Host-defense Peptides



Kenichi Kuroda

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Biography

Kenichi Kuroda received his B. Eng. in Polymer Chemistry and M. Eng. in Biological Chemistry from Kyoto University, Japan. He joined Prof. Toyochi Tanaka's group at the Department of Physics in the Massachusetts Institute of Technology studied the volume phase transition of polymer gels. After Prof. Tanaka passed away in 2000, Prof. Timothy Swager at the MIT chemistry department became his supervisor. He continued his doctoral research on polymer gels as well as semi-conducting polymers for biosensors in Prof. Swager's group and earned his Ph.D. in Physical Chemistry from MIT in 2003. Prior to joining the faculty at the University of Michigan School of Dentistry in 2006, he was a postdoctoral researcher in Prof. William DeGrado's group at University of Pennsylvania School of Medicine and developed antimicrobials based on polymeric materials. His current research interests include the development of biologically active polymers.

Abstract

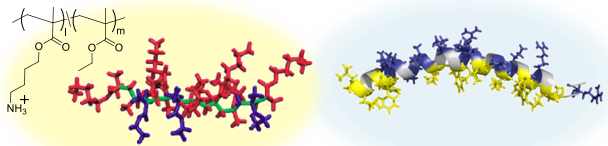
The emergence of antibiotic resistant bacteria "superbugs" is a significant public health concern, diminishing the availability of effective antibiotics. Although an urgent need of new antibiotics is well-documented, the number of new antibiotics has fallen steadily in the last few decades with more than 75%. This is because it has been a scientific challenge to find a new mode of antimicrobial action which can overcome bacterial resistance mechanisms.

Our research is focused on a new molecular design of antimicrobial polymers as synthetic mimics of naturally occurring host-defense antimicrobial peptides. These peptides exert their antimicrobial effect by acting on bacterial cell wall or membranes, which contrast to conventional antibiotics. We synthesized amphiphilic methacrylate random copolymers with primary ammonium groups to mimic the functionality of these peptides. The copolymers displayed antimicrobial activity against a broad spectrum of bacteria including antibiotic-resistant *Staphylococcus aureus* (MRSA) without adverse toxicity to human cells. Bacteria cultured with the copolymers did not develop resistance after 21 passages while the inhibitory concentration of conventional antibiotics increased up to 500 times. Our results also suggest that the copolymers form nano-scaled pores in bacterial cell membranes, which mimics the peptide mechanism. This polymer design has been extended to

include different polymer architectures such as amphiphilic block copolymers. We also recently developed antimicrobial copolymers which disintegrate quickly after antimicrobial action by a self-degradation mechanism to avoid long-term toxicity.

Antimicrobial Peptide-mimic Polymers: Making Antibiotics From Plastics!

Antimicrobial polymers vs. **Antimicrobial peptides**



- Low MWs (MW = 1,500 - 3,000)
- Cationic (-NH₃⁺)
- Amphiphilic
- **Heterogeneous structure**
 - random sequence
 - random coil

- Low MWs (few kDa)
- Cationic (-NH₃⁺)
- Amphiphilic
- **Homogeneous structure**
 - defined sequence
 - secondary structures (α-helix, β-sheet)

These synthetic copolymers can be prepared from inexpensive starting materials and require only few steps for synthesis, allowing for the production of pharmaceuticals and consumer products on a large industrial scale. This antimicrobial peptide-mimetic design will be versatile and applicable to many types of polymers and macromolecules, which will open the door for us to create a new generation of antibiotics.

Selected publications

1. Kuroda K, DeGrado WF. Amphiphilic Polymethacrylate Derivatives as Antimicrobial Agents. *J Amer. Chem. Soc.*, 2005; 127: 4128–4129.
2. Palermo EF, Kuroda K. Structural Determinants of Antimicrobial Activity in Polymers which Mimic Host Defense Peptides (Mini-review). *Appl. Microbiol. Biotechnol.* 2010, 87, 1605.
3. Oda, Y.; Kanaoka, S.; Sato, T.; Aoshima, S.; Kuroda, K.; "Block versus Random Amphiphilic Copolymers as Antibacterial Agents." *Biomacromolecules*, 2011, 12(10), 3581-3591.
4. Palermo, E. F.; Vemparala, S.; Kuroda, K.; "Cationic Spacer Arm Design Strategy for Control of Antimicrobial Activity and Conformation of Amphiphilic Methacrylate Random Copolymers." *Biomacromolecules*, 2012, 13, 1632-41.
5. Mizutani, M.; Palermo, E. F.; Thoma, L. M.; Satoh, K.; Kamigaito, M.; Kuroda, K.; "Design and Synthesis of Self-Degradable Antibacterial Polymers by Simultaneous Chain- and Step-Growth Radical Copolymerization." *Biomacromolecules*, 2012, 13, 1554-63.