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RESEARCH HIGHLIGHTS

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From the Resnick Sustainability Institute
Graduate Research Fellows at the
California Institute of Technology

Polymer Photonic Crystals by Self-Assembly

Raymond Weitekamp

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Global Significance

Urbanization is causing a cascade of negative effects on the environment. A readily apparent example on a local scale is the urban heat island effect, the phenomenon that urban areas often have higher local temperatures than surrounding areas.

A major cause of the heat island effect is the absorption and thermalization of solar energy by modern building materials. A tremendous amount of money and energy is consumed toward cooling in these areas, resulting in increased pollution and degraded living conditions. To minimize the negative effects of urbanization on the environment, great efforts have been directed toward mitigation through design and the development of new technologies.

Because the majority of solar energy is in the form of infrared (IR) radiation, there is strong interest in developing IR-reflecting materials to prevent absorption and thermalization.

This project focuses on the scientific development of materials which have unique IR-reflecting properties that can be developed into useful products such as paints and films.

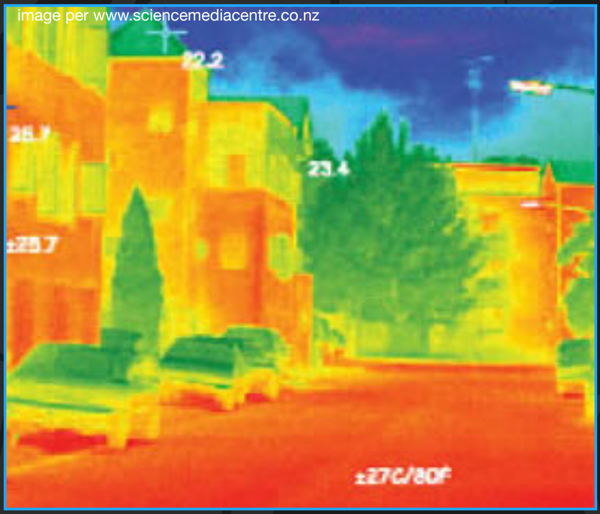


image per www.sciencemediacentre.co.nz

An infrared image depicting the higher temperature of building materials compared to plants.


An array of polymer photonic crystals, synthesized by blending the two samples on each end together in different ratios.

Photo by Victorial Piunova

Polymer Photonic Crystals by Self-Assembly

Raymond Weitekamp

Project Summary

We have developed new polymers that self-assemble to periodic nanostructures under ambient conditions. This has enabled us to make **paintable photonic crystals**, which act as tunable optical filters. The reflected colors change with the average size of the polymers, and span the entire visible spectrum. **We have been able to achieve reflection in the near infrared, and are working to apply this technology towards making heat-rejecting window films and paints** to improve the energy efficiency of buildings and vehicles.

This project crosses disciplines by fusing synthetic chemistry, polymer physics and applied optics to tackle a major technical challenge with a large potential impact.

- The unique polymer architecture enables paintable photonic crystals
- Blending of two different polymers affords continuous tuning across the entire visible spectrum
- The robust synthetic strategy affords exciting nanomaterials from commodity polymers

Potential Impact

- Window films can reject over 50% of the sun’s energy while remaining visibly transparent
- Window films are a carbon negative product, and use 15x less energy than manufacturing a new glass window
- Paintable IR-reflecting coatings enable retrofitting of old buildings to improve energy efficiency

Practical applications for the paintable photonic crystals include heat reflectings window films and paintable coatings.

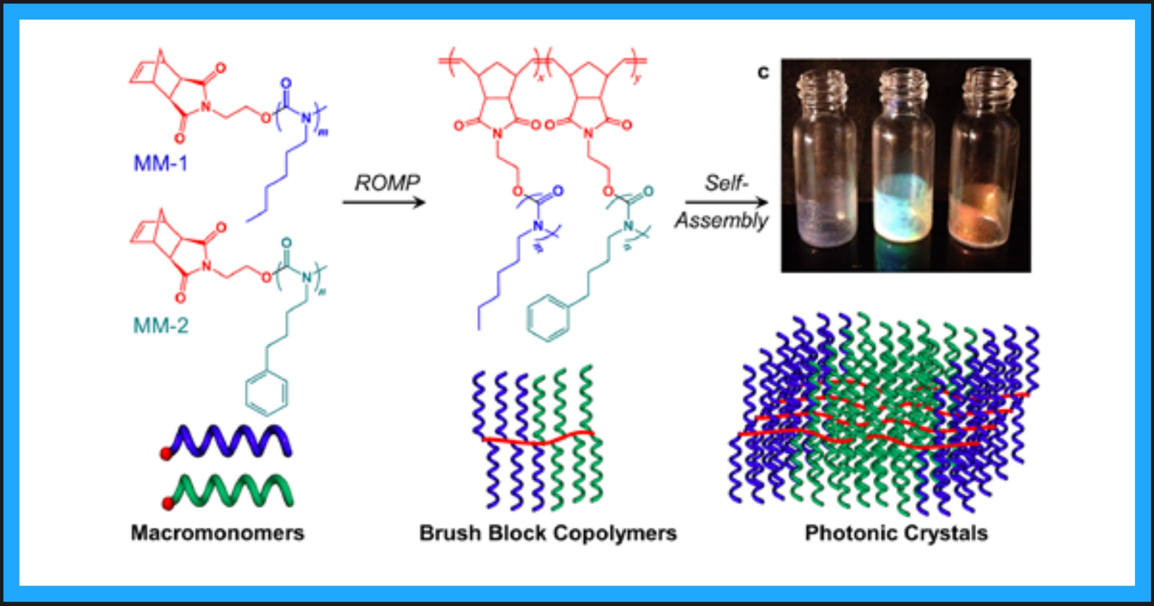
image per http://www.apexfilms.ca

Polymer Photonic Crystals by Self-Assembly

Raymond Weitekamp

The Science

We have synthesized high molecular weight brush block copolymers that self assemble into lamellar nanostructures with very large domains. Due to the highly branched nature of this class of macromolecules, the energetic barrier due to chain entanglement is drastically lowered. Due to the size of these alternating structures, they exhibit photonic bandgaps near visible frequencies of light. We have been able to show tunable reflection from the ultraviolet to the near infrared, by changing the molecular weight of the polymers.



Key Results & Future Steps

In this recent work, we have achieved paintable photonic crystals that are chemically robust, and have not shown any signs of degradation for over 18 months. We have developed two unique systems that can achieve reflection peaks in the near IR, through thermal annealing and direct solvent casting under ambient conditions. Due to the rigid architecture of these novel polymeric materials, they rapidly self-assemble through simple controlled evaporation to photonic crystal materials that reflect light from the ultra-violet, through the visible, into the near-infrared. We have also demonstrated the ability to blend these copolymers to tune the wavelength of reflection, enabling an economically attractive approach to application-tailored photonic crystals.

We are currently working on new polymers and methods of self-assembly to render high fidelity photonic crystals. As well, we are exploring new block copolymer compositions to access 2D and 3D morphologies. New, economically attractive synthetic routes are being developed to improve the overall cost of the technology.

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Publications

- **Precisely Tunable Photonic Crystals From Rapidly Self-Assembling Brush Block Copolymer Blends.** Garret M. Miyake, Raymond A. Weitekamp, Victoria A. Piunova, and Robert H. Grubbs. Angew. Chem. Int. Ed., (2012) 51: 11246–11248. doi: 10.1002/anie.201205743
- **Synthesis of Isocyanate-Based Brush Block Copolymers and Their Rapid Self-Assembly to Infrared-Reflecting Photonic Crystals.** Garret M. Miyake, Raymond A. Weitekamp, Victoria A. Piunova, and Robert H. Grubbs. Journal of the American Chemical Society 2012 134 (34), 14249-14254
- **Rapid Self-assembly of Brush Block Copolymers to Photonic Crystals.** Benjamin R. Sveinbjörnsson, Raymond A. Weitekamp, Garret M. Miyake, Yan Xia, Harry A. Atwater, and Robert H. Grubbs. PNAS 2012 109 (36) 14332-14336; published ahead of print August 21, 2012, doi:10.1073/pnas.1213055109