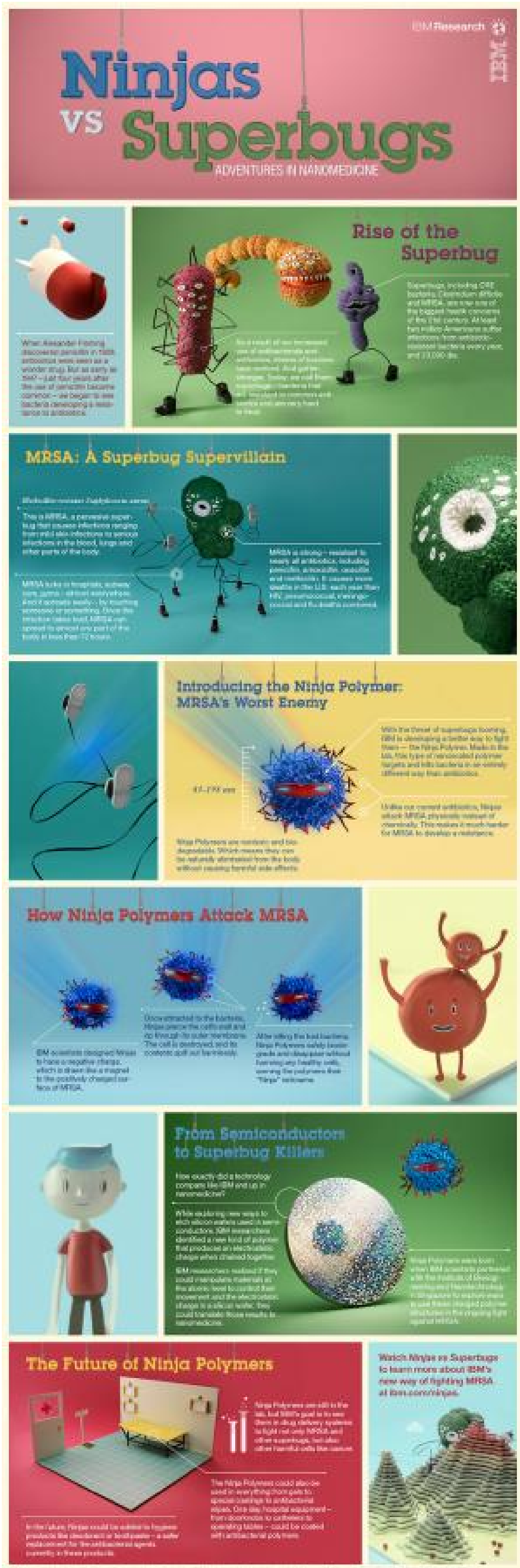
Converting recycled plastics into disease-fighting nanofibers

December 9 2013, by John Galvez


IBM Research
IBM
Ninjas
vs
Superbugs
ADVENTURES IN NANOMEDICINE
Rise of the
Superbug
MRSA: A Superbug Supervillain
Introducing the Ninja Polymer:
MRSA's Worst Enemy
How Ninja Polymers Attack MRSA
From Semiconductors
to Superbug Killers
The Future of Ninja Polymers

Researchers from IBM and the Institute of Bioengineering and Nanotechnology have made a nanomedicine breakthrough in which they converted common plastic materials like polyethylene terephthalate (PET) into non-toxic and biocompatible materials designed to specifically target and attack fungal infections. This research was published today in the peer-reviewed journal, *Nature Communications*.

Over a billion people are affected by fungal infections every year, ranging in severity from topical skin conditions like athlete's foot to life-threatening fungal blood infections. The infection is more likely to occur when the body's immune system is compromised due to an illness like HIV/AIDS, cancer or when receiving antibiotic treatment.

There is a pressing need to develop efficient and disease-specific antifungal agents to mitigate this growing drug resistance problem. Traditional antifungal therapeutics need to get inside the cell to attack the infection but have trouble targeting and penetrating the fungi membrane wall. Also, since fungi are metabolically similar to mammalian cells, existing drugs can have trouble differentiating between healthy and infected cells.

Recognizing this, IBM scientists applied an organic catalytic process to facilitate the transformation of PET, or waste plastic from a bottle, into entirely new molecules that can be transformed into antifungal agents. This is significant as plastic bottles are typically recycled by mechanical grounding and can mostly be reused only in secondary products like clothes, carpeting or playground equipment.

How it Works

These new antifungal agents self-assemble through a hydrogen-bonding process, sticking to each other like molecular Velcro in a polymer-like fashion to form nanofibers. This is important because these antifungal agents are only active as a therapeutic in the fiber or polymer-like form.

This novel nanofiber carries a positive charge and can selectively target and attach to only the negatively-charged fungal membranes based on electrostatic interaction. It then breaks through and destroys the fungal cell membrane walls, preventing it from developing resistance.

According to Dr Yi Yan Yang, Group Leader, IBN, "The ability of these molecules to self-assemble into nanofibers is important because unlike discrete molecules, fibers increase the local concentration of cationic charges and compound mass. This facilitates the targeting of the fungal membrane and its subsequent lysis, enabling the fungi to be destroyed at low concentrations."

Leveraging IBM Research's computational capabilities, the researchers simulated the antifungal assemblies, predicting which structural modifications would create the desired therapeutic efficacy.

"As computational predictive methodologies continue to advance, we can begin to establish ground rules for self assembly to design complex therapeutics to fight infections as well as the effective encapsulation, transport and delivery of a wide variety of cargos to their targeted diseased sites," said Dr. James Hedrick, Advanced Organic Materials Scientist, IBM Research – Almaden.

The minimum inhibitory concentration (MIC) of the nanofibers, which is the lowest concentration that inhibits the visible growth of fungi, demonstrated strong antifungal activity against multiple types of fungal infections. In further studies conducted by Singapore's IBN, testing showed the nanofibers eradicated more than 99.9% of C. albicans, a fungal infection causing the third most common blood stream infection in the United States, after a single hour of incubation and indicated no resistance after 11 treatments. Conventional antifungal drugs were only able to suppress additional fungal growth while the infection exhibited drug resistance after six treatments

Additional findings of this research indicated the nanofibers effectively dispersed fungal biofilms after one-time treatment while conventional antifungal drugs were not effective against biofilms.

The in vivo antifungal activity of the nanofibers was also evaluated in a mouse model using a contact lens-associated C. albicans biofilm infection. The nanofibers significantly decreased the number of fungi, hindered new fungal structure growth in the cornea and reduced the severity of existing eye inflammation. These experiments also showed mammalian cells survived long after incubation with the nanofibers, indicating excellent in vitro biocompatibility. In addition, no significant tissue erosion is observed in the mouse cornea after topical application of the nanofibers.

"A key focus of IBN's nanomedicine research efforts is the development of novel polymers and materials for more effective treatment and prevention of various diseases," said Professor Jackie Y. Ying, IBN Executive Director. "Our latest breakthrough with IBM allows us to specifically target and eradicate drug-resistant and drug-sensitive fungi strains and fungal biofilms, without harming surrounding healthy cells."

More information: K. Fukushima, S. Liu, H. Wu, A. C. Engler, D. J. Coady, H. Maune, J. Pitera, A. Nelson, N. Wiradharma, S. Venkataraman, Y. Huang, W. Fan, J. Y. Ying, Y. Y. Yang and J. L. Hedrick, "Supramolecular High Aspect Ratio Assemblies with Strong

Antifungal Activity," *Nature Communications*, (2013) DOI: 10.1038/ncomms3861

Provided by IBM