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May 27, 2009 | Research

New Nanodiamond Tool for Next-Generation Cancer Treatments

By Megan Fellman

EVANSTON, Ill. --- A research team at Northwestern University has demonstrated a tool that can precisely deliver tiny doses of drug-carrying nanomaterials to individual cells.

The tool, called the Nanofountain Probe, functions in two different ways: in one mode, the probe acts like a fountain pen, wherein drug-coated nanodiamonds serve as the ink, allowing researchers to create devices by “writing” with it. The second mode functions as a single-cell syringe, permitting direct injection of biomolecules or chemicals into individual cells.

The research was led by Horacio Espinosa, professor of mechanical engineering, and Dean Ho, assistant professor of mechanical and biomedical engineering, both at the McCormick School of Engineering and Applied Science at Northwestern. Their results were recently published online in the scientific journal Small.

The probe could be used both as a research tool in the development of next-generation cancer treatments and as a nanomanufacturing tool to build the implantable drug delivery devices that will apply these treatments. The potential of nanomaterials to revolutionize drug delivery is emergent in early trials, which show their ability to moderate the release of highly toxic chemotherapy drugs and other therapeutics. This provides a platform for drug-delivery schemes with reduced side effects and improved targeting.

“ This is an exciting development that complements our previous demonstrations of direct patterning of DNA, proteins and nanoparticles,” says Espinosa.

Using the Nanofountain Probe, the group injected tiny doses of nanodiamonds into both healthy and cancerous cells. This technique will help cancer researchers investigate the efficacy of new drug-nanomaterial systems as they become available.

The group also used the same Nanofountain Probes to pattern dot arrays of drug-coated nanodiamonds directly on glass substrates. The production of these dot arrays, with dots that can be made smaller than 100 nanometers in diameter, provides the proof of concept by which to manufacture devices that will deliver these nanomaterials within the body.

The work addresses two major challenges in the development and clinical application of nanomaterial-mediated drug-delivery schemes: dosage control and high spatial resolution.

In fundamental research and development, biologists are typically constrained to studying the effects of a drug on an entire cell population because it is difficult to deliver them to a single cell. To address this issue, the team used the Nanofountain Probe to target and inject single cells with a dose of nanodiamonds.

“ This allows us to deliver a precise dose to one cell and observe its response relative to its neighbors,” Ho says. “This will allow us to investigate the ultimate efficacy of novel treatment strategies via a spectrum of internalization mechanisms.”

Beyond the broad research focused on developing these drug-delivery schemes, manufacturing devices to execute the delivery will require the ability to precisely place doses of drug-coated nanomaterials. Ho and colleagues previously developed a polymer patch that could be used to deliver chemotherapy drugs locally to sites where cancerous tumors have been removed. This patch is embedded with a layer of drug-coated nanodiamonds, which moderate the release of the drug. The patch is capable of controlled and sustained low levels of release over a period of months, reducing the need for chemotherapy following the removal of a tumor.

“ An attractive enhancement will be to use the Nanofountain Probe to replace the continuous drug-nanodiamond films currently used in these devices with patterned arrays composed of multiple drugs,” Ho says. “This allows high-fidelity spatial tuning of dosing in intelligent devices for comprehensive treatment.”

“ One of the most significant aspects of this work is the Nanofountain Probe’s ability to deliver nanomaterials coated with a broad range of drugs and other biological agents," Espinosa says. "The injection technique is currently being explored for delivery of a wide variety of bio-agents, including DNA, viruses and other therapeutically relevant materials."

Nanodiamonds have also proven effective in seeding the growth of diamond thin films. These diamond films have exciting applications in next-generation nanoelectronics. Here again, the ability to pattern nanodiamonds with sub-100-nanometer resolution provides inroads to realizing these devices on a mass scale. The resolution in nanodiamond patterning demonstrated by the Nanofountain Probe represents an improvement of three orders of magnitude over other reported direct-write schemes of nanodiamond patterning.

The work was supported by the National Science Foundation, the National Institutes of Health, the V Foundation for Cancer Research and the Wallace H. Coulter Foundation.

In addition to Espinosa and Ho, other authors of the paper, entitled "Nanofountain Probe-based High-resolution Patterning and Single-cell Injection of Functionalized Nanodiamonds," are Owen Loh, Robert Lam, Mark Chen, Nicolaie Moldovan and Houjin Huang of Northwestern University.

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