Nanorobotic drug delivery

If I only had a heart…

M. Arif Zeeshan[1]*, Kaiyu Shou[1], Kartik M.Sivaraman[1], Thomas Wuhrmann[1], Salvador Pané[1], Eva Pellicer[2] and Bradley J. Nelson[1].

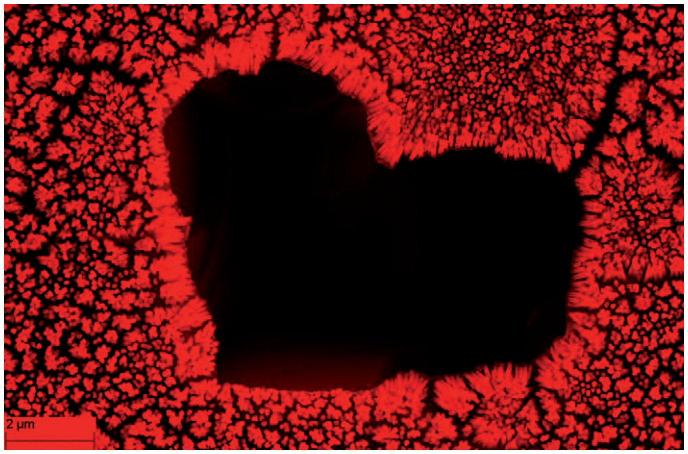
[1] *Swiss Federal Institute of Technology, Switzerland*

[2] *Universitat Autònoma de Barcelona, Spain*

* E-mail: marifzee@ethz.ch

Miniaturizing devices to the nanoscale creates a wealth of new possibilities in nanobiotechnology and nanomedicine, such as targeted drug delivery platforms. While the futuristic vision of nanovehicles capable of reaching and exploring inaccessible tissue within the human body is compelling, combining propulsion, targeting and controlled drug release *in vivo* remains a challenge. One class of disease being considered for treatment using nanovehicles is cancer. Standard treatments such as radiation therapy, chemotherapy and surgery are clearly successful for some types of cancer, but they can be highly invasive and may also damage the surrounding healthy tissue, leading to other negative side effects. A far less invasive approach is based on using a carrier, i.e. a nanorobot, that can be functionalized and manipulated wirelessly to target cancer cells. The most common strategy currently being pursued by researchers relies on injecting the nanorobots intravenously, guiding them by means of magnetic fields and field gradients, and, finally, activating them to promote the diffusion of drugs into the affected tissue. Magnetic nanomaterials such as nanoparticles (NPs) and nanowires (NWs) are promising candidates for drug delivery platforms, especially for the treatment of cancer. The use of magnetic NWs has some advantages over the use of NPs, primarily because NWs exhibit both a high aspect ratio and magnetic shape anisotropy. Moreover, large arrays of ferromagnetic NWs can be controllably and reliably fabricated.

A new process to fabricate NWs was recently developed by growing them within anodic alumina oxide (AAO) templates. By controlling the pore size and the length of the AAO templates, as well as the composition of the electrolytes, many different types of ferromagnetic nanowires can be fabricated. The AAO templates begin as an electron-beam evaporated layer of aluminum on silicon. The Al is subsequently anodized in oxalic acid under current control to produce nanopores in the range of 85 – 100 nm. Using pulsed electrodeposition (PED), the ferromagnetic nanowires are grown inside these pores. In turn, these NWs serve as catalysts for growing multiwalled carbon nanotubes (MWCNTs) using a low pressure chemical vapor deposition (LPCVD) process. The silicon provides a stable platform capable of withstanding the high temperatures encountered during the LPCVD process. The MWCNT coating has multiple utilities; primarily, its outer surface can be functionalized to attach to therapeutic molecules that specifically kill cancer cells. The coating also protects the ferromagnetic NWs from the environment, thus reducing the possibility of NW toxicity when inside the body.



Among the various ferromagnetic materials that can be fabricated in the form of NWs, iron is of particular interest. This is because it is largely biocompatible and possesses a very high magnetic saturation (M_s). Thus, it poses a reduced threat of toxicity in the body, and can be manipulated using lower values of magnetic fields. The current density applied during the PED process plays a crucial role in determining the properties of the NW. Hence, a thorough characterization study has been carried out to understand its effect on the morphology, the structure and the magnetic properties of the NW.

This issue's cover image shows an array of iron NWs after partial dissolution of the AAO template. A novel amino acid based electrolyte was used to grow the NWs. The resulting NWs have a length of approximately 500 nm and a diameter of approximately 85 nm. The template filled with the iron NWs was treated with 5 wt% sodium hydroxide (NaOH) at 40 °C, which resulted in the dissolution of the template while the NWs remained largely unaffected. The image was taken with a Zeiss NVision 40 (Carl Zeiss, Germany) scanning electron microscope at an accelerating voltage of 21 kV, using the SE2 detector. The heart shaped feature shown in the image was an intermediate result seen before the AAO template completely dissolved.

M. Arif Zeeshan is a *Materials Today* cover competition winner, and the first contributor to our new *Uncovered* feature, which brings you the story behind the picture.

Zeeshan has been a PhD research student at IRIS since January 2009, after completing his MSc Thesis at Yale University. He was awarded the Omega Prize for his diploma work by the Institute of Microtechnology at the University of Neuchatel.