according to the researchers. These nonlinear properties enable the frequencies of the incoming infrared light to be doubled or mixed, through techniques known respectively as second harmonic generation (SHG) or sum frequency generation (SFG), before being emitted as visible light. The result is light that is tunable as well as coherent, which fulfills a technological requirement that has posed a major challenge for both photo-imaging and photo-detection in subwavelength optics.

Bio-imaging may be the field in which this nanowire light source technology has its biggest impact. Optical or visible light microscopy remains at the forefront of biological research because it allows scientists to study living cells and tissues. However, whereas the resolution of optical microscopy is limited by diffraction, through subwavelength techniques it becomes possible to visualize features smaller than visible light wavelengths. For biology, this brings normally invisible subcellular structures into view.

"We hypothesized that a single potassium niobate nanowire would, when optically trapped, be able to double the frequency of the trapping light and then waveguide this locally generated light to its ends, thereby enabling the development of a novel form of scanning light microscopy," said Liphardt. "In addition to demonstrating this scanning transmission mode, we also demonstrated a fluorescence mode."

When a nanowire light source was touched to a fluorescent bead, the bead emitted a distinct orange fluorescence at the contact point. When the nanowire was removed, the orange fluorescence was immediately reduced 80-fold, confirming that the nanowire was the predominant source of fluorescent excitation.

"The work shows that we can create and operate coherent bio-friendly, nanoscale light sources in liquid environments and use them for subwavelength imaging," said Yang.

## Multipass Extrusion Creates Microchanneled YSZ/LSM Solid-Oxide Fuel Cell

In the June 2007 issue of the *Journal of the American Ceramic Society* (p. 1921, DOI: 10.1111/j.1551-2916.2007.01582.x), three researchers from South Korea have reported a novel extrusion process to create a solid oxide fuel cell containing scores of microtubular cells. Researchers B.-T. Lee of Soonchunhyang University, A.H.M. Esfakur Rahman of Kongju National University, and J.-H. Kim of the Technical Research Laboratories at POSCO first extruded single cells with each containing a central carbon fiber core surrounded by three subsequent layers of filaments: a $La_{0.8}Sr_{0.2}MnO_3$ (LSM) cathode layer, an 8 mol% yttria-stabilized zirconia (8YSZ) electrolyte layer, and a NiO-8YSZ anode layer (see Figure 1). Grouping 61 single cells, the researchers extruded the group together into a single green body, fired the material, and obtained a fuel cell with an outside diameter of 2.7 mm and 61 interior microchannels with a diameter of 150 mm. Fuel cells small in size but with high volumetric power density have potential for portable power generation in devices like laptop computers and cell phones.

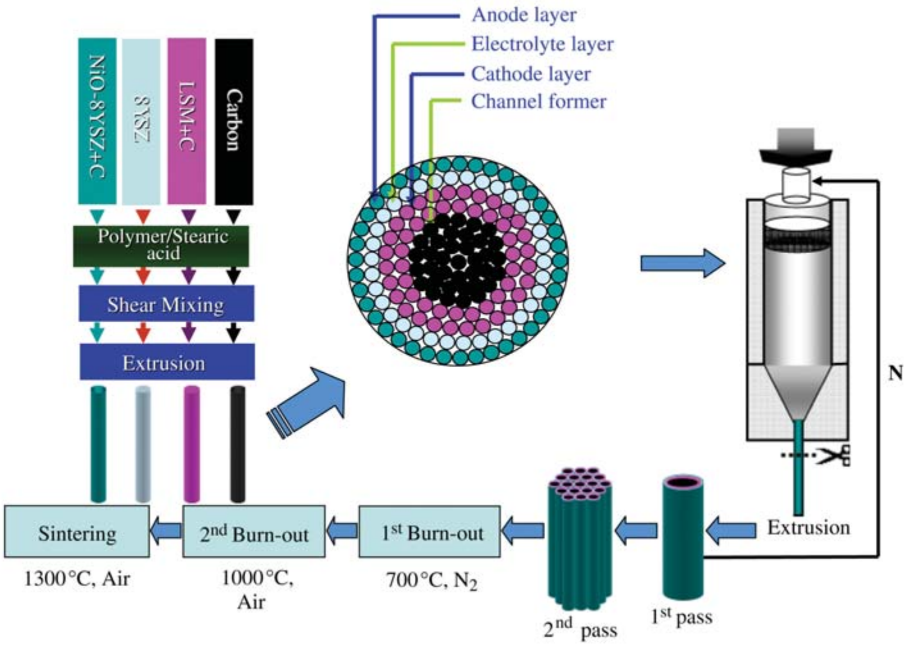


*Figure 1. The process for fuel cell fabrication begins at left with homogenous mixing of materials and extrusion into filaments. Layered filaments then form the feedstock for single cell bodies in the first pass extrusion. Many single cells extruded together generate the final green body in the second pass. Heat treatments complete the fabrication process. Reproduced with permission from* Journal of the American Ceramic Society ***90*** *(6) (June 2007) p. 1921; DOI: 10.1111/j.1551-2916.2007.01582.x. ©2007 American Ceramic Society.*

The multipass extrusion process is novel because of its success in combining single tubular cells and extruding them together to create a fuel cell green body with the original pre-fired single cell diameter (3.5 mm). The researchers chose their materials to maximize conductivity while maintaining mechanical stability in the fuel cell. The relative composition of NiO and 8YSZ in the anode maximized conductivity with the addition of Ni and minimized thermal mismatch between the anode and the 8YSZ electrolyte layer. The starting electrode mixtures contained activated carbon particles.

The green body materials required three rounds of heat treatment. The first fire burned out polymer binders and lubricants. The second fire burned out the central carbon fibers, leaving hollow microchannels to function as fuel passageways, and burned out carbon particles in the electrodes, leaving open pores to facilitate electrochemical reactions at triple phase boundaries. The third heat treatment sintered the materials and created a dense electrolyte and networked anode layers.

Optical micrographs showed that the electrode and electrolyte layers maintained their integrity after the extrusion processes. Scanning electron micrographs and x-ray diffraction profiles further demonstrated that the electrolyte was dense and crack free and that no reaction compounds existed between the electrode-electrolyte layers in the final fuel cell.

Only limited by the diameter of the extrusion die, the process could create fuel cells with many more microchannels, which would increase the power density, according to the researchers.

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