First nanowire *n*-type devices

NANOTECHNOLOGY

Researchers from Harvard University led by Charles M. Lieber have fabricated single crystal *n*-type Si nanowires (SiNW) with controlled P doping for the first time [Zheng *et al.*, *Adv. Mater.* (2004) **16** (21), 1890]. Field-effect transistors (FETs) based on these *n*-SiNWs exhibit good device characteristics, with mobilities 100 times greater than previous reports and comparable to planar Si FETs. Although nanowires have been hailed as a promising approach to 'bottom-up' electronics, most attention has focused on *p*-type SiNWs. However, *n*-type SiNWs have significantly higher electron mobilities and complementary *n*-type/*p*-type devices are necessary for a number of applications.

The researchers synthesized the *n*-SiNWs using silane in a Au-nanocluster-mediated vapor-liquid-solid process with phosphine as the dopant precursor. FETs with a back gate geometry were fabricated using standard processes. The resulting *n*-type SiNWs are single crystal and have uniform diameters of ~20 nm. The SiNWs have large on-currents, transconductances, and on/off ratios of >10^4, but also have an unexpected property – electron mobilities depend inversely on dopant concentration. While this unusual dopant dependence could be intrinsic in nature, the researchers believe that it is the result of dopant concentration dependent contact resistances. "These new single crystalline *n*-type Si nanowires have mobilities comparable to that achieved in state-of-the-art planar Si FETs," says Lieber. "[This] opens up a number of opportunities in applications ranging from…inverters and other logic gates, to…sensors for biological/chemical species such as proteins and viruses," he told *Materials Today*.

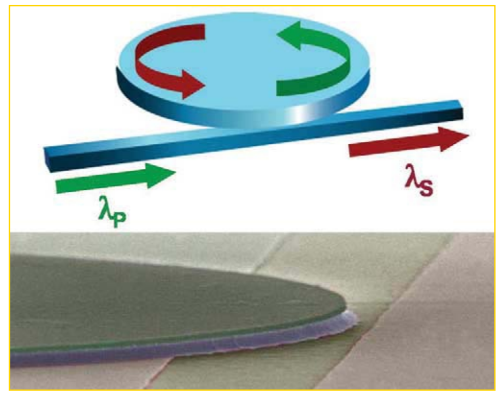
Cordelia Sealy

World's first all-silicon laser

OPTICAL MATERIALS

Researchers from the University of California, Los Angeles funded by DARPA have demonstrated the first Raman laser fabricated from Si [Boyraz and Jalali, *Opt. Express* (2004) 12 (21), 5269].

The device consists of a tapered silicon-on-insulator (SOI) rib waveguide as the gain medium incorporated in a fiber loop cavity (as shown). If pumped with 30 ps wide pump pulses at a 25 MHz repetition rate, the device produces Raman laser emission at 1675 nm. A threshold is observed at 9 W pump pulse power with a slope efficiency of 8.5%. Pulsed operation avoids one of the challenges to obtaining Raman gain in Si, losses resulting from the accumulation of free carriers generated by two photon absorption. However, the necessity for pulsed pumping does constrain the practicality of the device and adds to costs. "Because the Raman laser needs to be optically pumped, it should not be considered as a replacement or competition to traditional semiconductor diode lasers," says Bahram Jalali. However, the Raman laser is widely tunable and can extend the wavelength range of other lasers, particularly in the mid-infrared region. The Si Raman laser could be used for biochemical detection or optical wireless communication. Using a similar approach, researchers from Cornell University have demonstrated fast all-optical switching on Si [Almeida *et al.*, *Nature* (2004) 431, 1081]. The device consists of a 10 µm diameter SOI ring resonator, which is highly light confining and enhances sensitivity to small changes in refractive index. The resonance wavelength can be modified by tuning the effective index of the ring waveguide. The device could be used as a modulator, switch, or router with a response time as fast as 100 ps.



(Top) Si Raman laser consists of a micro disk resonator on top of an optical wire (waveguide). Lasing occurs when the pump signal from the wire interacts with the atomic vibrations of the Si as it circulates around the disk. Light is produced at the desired wavelength (different from the pump wavelength) and exits the device through the other end of the optical wire. (Bottom) Electron micrograph of the device showing the region where the disk overlaps with the optical wire running through the underside of the disk.

Cordelia Sealy

New approach to flexible thin-film transistors

ELECTRONIC MATERIALS

A new transparent amorphous oxide semiconductor could overtake amorphous Si (a-Si:H) as a promising material for transparent flexible electronics.

Hideo Hosono and coworkers at the Tokyo Institute of Technology in Japan have demonstrated room-temperature fabrication and operation of flexible transparent thin film transistors (TTFTs) based on an amorphous oxide semiconductor from the In-Ga-Zn-O system (a-IGZO) [Nomura *et al.*, *Nature* (2004) **432**, 488]. Pulsed laser deposition is used to fabricate a-IGZO on a polyethylene terephthalate (PET) substrate at room temperature. Other techniques such as sputtering or metal-organic chemical vapor deposition could be used and would be suitable for uniform deposition over large areas and mass production. The material is optically transparent in both the visible and near-infrared regions and exhibits Hall effect mobilities of >10 $cm^2V^{-1}s^{-1}$. TTFTs with a-IGZO as the active *n*-channel layer on a 200 µm PET film have good characteristics, such as low off-currents, low leak currents of ~10^{-10} A, on-to-off ratios of ~10^3, and saturation mobilities of 6-9 $cm^2V^{-1}s^{-1}$, which withstand bending. The advantages of this novel material are three-fold, according to Hosono. The performance of a-IGZO is ten times better than a-Si:H or organic semiconductors; it can be fabricated on plastic substrates at room temperature; and is transparent across the whole visible spectrum. The use of this novel semiconductor could get around the problems that plague flexible devices based on a-Si:H and organic semiconductors, especially low mobilities.

Cordelia Sealy