NORIAKI HORIUCHI

In-depth discussions were carried out among the attendees during the interactive poster session constituted by about 800 posters.

minimal loss of energy is important for the development of efficient environmental sensors and biosensors. To achieve this, Susumu Noda from Kyoto University developed a method for concentrating broadband sunlight into a narrowband spectrum by accumulating thermal energy in a device made of photonic crystals. The narrowband output spectrum was tailored such that it coincided with the absorption spectrum of solar cells. As a proof-of-principle experiment, the researchers injected currents into the photonic crystal to demonstrate the spectral narrowing of thermal radiation. The spectral width of the thermal radiation from the photonic crystal was a thirtieth of that from the reference sample. The conversion of broadband sunlight into narrowband light near a wavelength of 10 μm attracted significant interest from the audience.

"The reported conversion efficiency of our solar cells is so far around 10–20% due to the large amount of unabsorbed sunlight. The percentage of renewable energy in sunlight can be increased if the broad spectrum of sunlight can successfully be converted into narrowband light without energy loss. We expect to achieve conversion efficiencies of more than 40% using our method," said Noda. He also added that the theoretical maximum conversion efficiency of 70% is achievable if the thermal energy loss in the photonic crystal can be significantly reduced. Although the thermal loss is large, the conversion efficiency of a solar-cell system using the photonic crystal would be at least 40%.

The next JSAP meeting will be held at the Kanagawa Institute of Technology on 27–30 March 2013. ❐

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VIEW FROM... GROUP IV PHOTONICS

Industry meets academia

Silicon photonics and devices based on group IV elements are overcoming the tough economic downturns that have rocked industry over the past 12 years. Cross fertilization between academia and industry may lead to new devices that are both innovative and profitable.

David Pile

In 2004, Hong Kong hosted the first IEEE International Conference on Group IV Photonics, an annual meeting dedicated to silicon photonics and photonic materials and devices based on group IV elements. Since then, the conference has been hosted across Asia, Europe and the USA. This year's meeting — co-chaired by Mehdi Asghari from Kotura and Jurgen Michel from the Massachusetts Institute of Technology — was held in San Diego, California, on 29–31 August 2012.

Aside from the exciting meeting schedule and competitive post-deadline session, one aspect of the conference in particular stood out as being refreshing, practical and innovative: the fact that around half the contributors were from industry. This ratio also holds true for the co-chairs — one being from academia and the other from industry. Those involved in the conference came from a wide range of backgrounds, including venture capitalists, software designers, electronic chip manufacturers, wafer manufactures and sub-system and system companies. On the industrial side, talks focused on topics such as the future of silicon photonics, the need for on-chip photonic integration for large data-warehouse switches, photonics for scaling the internet, developments in complementary metal–oxide–semiconductor (CMOS) photonics, photonics for access network technologies, platforms for sub-picojoule-per-bit macrochip interconnects, and the latest developments in InP and other materials technology. From academia came themes such as photonic nanostructure transceiver devices for advanced optical networks, GeSn light-emitting p-i-n diodes on Si and Ge-on-Si to form electrically pumped CMOS lasers.

One particular highlight of the meeting occurred on the sunset boat cruise banquet on the San Diego bay, during which Andrew Rickman told his inspiring life story. After gaining a PhD in photonics, Richman founded one of the first companies to commercialize silicon photonics, and finally went on to chair a venture capitalist company (Rockley Group). He commented on the economic downturns that have hurt so many companies in the field, but was positive about recognizing the mistakes of the past made by companies in the silicon photonics industry. He also noted that new types of devices will hopefully realize a stable industry in the future.

Interesting talks from industry included an invited paper by Glenn Li (Oracle) on the technical progress towards a CMOS photonics toolkit for Oracle's Macrochip vision. In a post-deadline paper, Li and co-workers group also reported a >40 Gbit s^{-1} silicon CMOS microring modulator with a low voltage of 2 V (peak-to-peak at the device) and a high extinction ratio of 7 dB. Joint Kotura–Oracle papers also gave impressive results. Aaron Zilkie and co-workers presented a group III–V/silicon laser with an uncooled external DBR laser cavity that can reach a record wall plug efficiency of 9.5%. Dazeng Feng and co-workers, also from Kotura–Oracle, presented a GeSi electroabsorption modulator operating over 30 nm near 1,550 nm with a 3 dB bandwidth of 40.7 Ghz at a bias of 2.8 V.

Gary Bulman presented research performed at Research Triangle Institute (RTI) International with Jayesh Bharathan on low-dark-current Ge-on-Si photodiodes grown by chemical vapour deposition. He explained that germanium offers a distinct advantage over silicon not only because of its superior electron and hole mobility, but also because of its direct bandgap of 0.8 eV at 300 K, which makes it possible to design efficient photodetectors operating in the low-loss optical fibre range of 1,300–1,600 nm. Their structures, grown on p-type <100> silicon substrates, consisted of a 0.65-μm-thick undoped germanium film grown through a two-step process, a 10-Å-thick germanium/70-Å-thick silicon superlattice structure with a variable number of periods, and a 1,200-Å-thick n^+ silicon contact layer. This structure confines the high field region to the wide-bandgap superlattice and silicon layers, while lowering the electric field in the photon-absorbing germanium layer, which has a smaller bandgap. The researchers annealed the thick germanium films *in situ* at 900 °C prior to superlattice deposition, which reduced the threading dislocation density. X-ray diffraction analysis of the structure confirmed the presence of the superlattice structure. The researchers studied how the number of superlattice periods affects the dark current and responsivity, and achieved a 50-fold reduction in dark current down to 1.3 mA cm^{-2} at –1 V for a 100-period superlattice, compared with a similar structure not containing the superlattice. Each device also exhibited a photoresponse beyond 1,600 nm. This work demonstrates that a silicon/germanium superlattice-based device structure placed between the photoactive germanium-film and the top electrical contact layer can dramatically reduce dark currents, thereby providing a key approach for designing photodetectors with low leakage currents.


DAVID PILE

Researchers enjoying a harbour cruise at Group IV Photonics, held in San Diego, California, on 29–31 August 2012. The meeting, which brought together researchers from industry and academia, covered topics from fundamental material problems to device-level and systems issues.

Tetsuya Mizumoto from the Tokyo Institute of Technology in Japan presented an optical isolator based on a silicon nanowire Mach–Zehnder interferometer that involves bonding Ce:YIG directly on top of the silicon waveguide. His group obtained a large magneto-optic phase shift and an optical isolation of 18 dB at a wavelength of 1,322 nm. They also presented a transverse electric (TE)–transverse magnetic (TM) mode converter constructed from a single-trench SiON waveguide. The trench is fabricated in a rectangular waveguide core in an asymmetric manner. By choosing an appropriate geometry, two orthogonally polarized eigenmodes propagate along axes rotated by 45° with respect to the horizontal and vertical axes. When the lightwave polarized along either the horizontal (TE) or vertical (TM) axis is launched into the trench waveguide, two eigenmodes are excited with equal amplitude and propagate with different velocities. After propagating half a beat length, there is a π phase difference between the two eigenmodes. This results in a 90° rotation of launched polarization; that is, the launched TE (or TM) mode is converted into a TM (or TE) mode. The device is compatible with a silicon nanowire waveguide and is fabricated through a single mask and etching process. The researchers achieved a TE–TM mode conversion efficiency of 97% at a wavelength of 1,270 nm. The device also exhibits a wide operation wavelength range of ~100 nm with a conversion efficiency more than 94%. The conference wrapped up with a post-deadline session sponsored by *Nature Photonics*, in which authors of the session's 'best postdeadline paper' award were presented with personal subscriptions to *Nature Photonics*. In the winning talk, Hong Nguyen from Yokohama National University in Japan presented a paper on a silicon Mach–Zehnder optical modulator with a sub-100-μm phase-shifter that operates by carrier-depletion at a rate of 40 Gbit s^{-1}. They achieved this by incorporating photonic crystal waveguides to generate slow light with a group index of more than 30, resulting in a slow-light enhancement that is almost 10 times larger than that in rib-waveguide devices and hence enabling a corresponding reduction in the device length to 90 μm. Nguyen explained that although such resonant structures are usually associated with a narrow spectral bandwidth, using a modified photonic crystal waveguide and generating low-dispersion slow light allows bandwidths of 12.5 nm to be achieved in a 50-μm-long device at 10 Gbit s^{-1}.

The 10th International Conference on Group IV Photonics will take place in Seoul, Korea, on 28–30 August, 2013. ❒

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