Materials World Magazine, 01 Jun 2009

Published on IOM3: The Global Network for Materials, Minerals & Mining Professionals (http://www.iom3.org)

Silicon all-optical integrated circuits

Silicon organic hybrid waveguides

All-optical broadband and telecommunications signal processing using silicon may soon be possible at transmission speeds above 100Gbit/s, according to a European research consortium.

The team, led by the University of Karlsruhe in Germany, claims to have proven the viability of silicon-organic hybrid (SOH) waveguides with highly non-linear and ultra-fast performance. Silicon-based devices are widely used in the electronics industry because they are inexpensive to manufacture.

'Silicon-based all-optical switching is challenging due to the slow dynamics caused by free carriers that are generated by two-photon absorption,' explains Professor Wolfgang Freude at the University of Karlsruhe. 'So far, the data rate achieved using bare silicon waveguides is limited to 40Gbit/s.'

The SOH approach overcomes this intrinsic limitation by combining deep-ultraviolet lithography, which is used for mature complementary metal-oxide-semiconductor processing of light waveguides, with molecular beam deposition of the organic polymer DDMEBT.'

This molecule has a third-order non-linearity and allows optical switching without introducing significant absorption. A key feature of this material and the deposition process is the ability to homogeneously fill the traditional 100nm wide slot between waveguides.

Freude says the SOH approach is compatible with existing silicon circuit manufacture as applying DDMEBT can be a back-end processing step.

Traffic jam

This research could be crucial for transforming broadband and telecommunications.

'Over the next 10 years Internet capacity is expected to increase by a factor of 100 and electronics will not be able to cope with the speed and the amount of data transmitted,' says Freude. 'We need the technology for a Petabit network [the equivalent in storage capacity of one million Gigabit], and one route to this goal is optical, instead of electronic, switching so that optics and electronics work together in an integrated fashion.'

However, the relatively slow pace of electrons through silicon-based components reduces the overall efficiency of conventional optoelectronic devices. All-optical processing overcomes this by removing the need for optical-to-electronic and electronic-to-optical conversions, which also reduces energy consumption.

To achieve this, researchers at the University, in collaboration with IMEC in Leuven, Belgium, Lehigh University, USA, and ETH Zurich, in Switzerland, have fabricated a four millimetre-long SOH slot waveguide with a record non-linearity coefficient of 100000/(W km) in the 1.55μm telecommunications window. Based on these waveguides, all-optical demultiplexing of a 170.8Gbit/s telecommunication signal to four data streams of 42.7Gbit/s each was performed using four-wave mixing.

Dr William Whelan-Curtin from the School of Physics and Astronomy at the University of St Andrews, UK, believes the research is promising.

'Since the development of the slot waveguide, there have been a number of ideas to add value to silicon in this or a related manner,' he explains. 'However, this is a tough field, requiring both excellent waveguides and polymers. This consortium seems to have a very good polymer and are quite a distance ahead of the rest.

'On the downside, telecommunications is a poor market for silicon since it is low volume and requires high performance. It will be some time before this changes. But a low power all-optical multiplexer, taking a large number of 10Gbit/s channels and combining them, would be very attractive.'

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Source URL: http://www.iom3.org/news/silicon-all-optical-integrated-circuits