The need for speed
Overcoming the bottleneck in optical data transfer

- In high-speed communications, very fast optical signals connect to your office or even your home. But these optical signals have not yet reached end-of-edge terminals such as personal computers and smartphones.
- The prohibitive expense of optical modulators – devices that create very fast optical signals – limits their deployment to personal edge terminals.
- Dr Hideaki Fukuzawa and Mr Takashi Kikukawa (TDK Corporation, Japan) show that it’s possible to make these optical modulators with standard semiconductor industry processing, significantly lowering costs and creating more compact devices.
- Importantly, these modulators can operate at visible light instead of conventional infrared light. This allows further reductions in cost, device size, and power consumption, further expanding the versatility of their application.
Lithium niobate: beyond 5G

So far, lithium niobate has proved difficult to work with for fabricating chip-scale features. Conventional lithium niobate has been fabricated by bulk devices, which are expensive and unsuitable for large volume production, and in addition, the device size is too large to be implemented in personal-edge devices. To solve the issue of large device size, many researchers have adopted ‘sousching processes’ that stick the bulk lithium niobate materials on wafers, but these are generally clunky and expensive. As the TDK Corporation researchers point out in their latest report – for consumer applications above all, ‘a significant cost reduction will be necessary.’

To tackle these issues, TDK Corporation’s Senior Manager in charge of optical devices for AR/VR glasses and beyond 5G optical communications, Fukuzawa, teamed up with Kikukawa, TDK Corporation Manager for lithium niobate devices. Exploiting their collective expertise, they were able to produce high-quality lithium niobate optical modulators using one of the standard processes in the semiconductor industry – sputter deposition for lithium niobate film.

Sputter deposition is a general method which has been widely used for many consumer devices including semiconductor devices. It is suitable for large volume production and consumer use applications, and is much more practical than adhesion process by using bulk lithium niobate. For the first time, the TDK team have successfully achieved optical modulation using sputtered deposited lithium niobate film directly onto a sapphire substrate. X-ray diffraction of lithium niobate reveals that it is good enough to be used for optical modulation.

Seeing the light

With the lithium niobate sputtered film on a wafer, standard semiconductor fabrication processes (such as etching) can be used to shape a waveguide and deposition for the electrodes, creating a functioning optical modulator device. This means that from the beginning of lithium niobate deposition to the end of modulator fabrication, the general semiconductor fabrication process can be adopted, making it far more cost-effective than the conventional method. Importantly, their modulator had another key distinguishing feature. They specifically designed the device to operate at visible wavelengths of light including red, green, and blue light. This has never been previously attempted for devices used in visible wavelengths of light including red, green, and blue light.

As Fukuzawa explains, ‘all the basic visible colours – red, green, and blue’ were successfully modulated by our optical modulator for the first time. In contrast, 5G optical communication uses infrared laser light with a much longer wavelength than visible light. Since the required energy (voltage) for optical modulation is proportional to wavelength, shorter wavelengths of visible laser light can significantly reduce energy for data transfer and can therefore contribute to sustainable solutions for data communication. Since the energy consumption of data communications is so significant, the benefit of adopting visible light for data communications plays an important role.’

Importantly, this work shows for the first time that all the basic visible light – red, green, and blue – can be successfully modulated by lithium niobate modulator. This has not been reported previously, even using bulk lithium niobate instead of sputtered film. This work has significant applications since lithium niobate has great potential for imaging applications. It also has the advantage of lower costs for the consumer.

Until now, visible light communication has not been realised. As Fukuzawa summarises, ‘now that we have demonstrated visible light modulation in devices, fast data speed for consumer applications has great potential. Our optical modulator using sputtered thin film lithium niobate is low cost, and using visible laser light results in a significant reduction in energy. This development opens up an exciting opportunity for making ultrafast data transfer a reality.’

In further tests, the researchers measured the relevant figure of merit for device size and power consumption, revealing that it did scale with the operating wavelength as expected. The TDK Corporation researchers conclude that lithium niobate modulators can be adopted for emerging consumer applications for any applications using visible light with very fast speed.

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