Electro-Optic Polymers Allow Faster, More Efficient Data Transmission

The polymer industry for fiber communications is growing quickly. With the correct positioning for scale, volume and performance, electro-optic polymers are poised to enable optical network system businesses to be much more competitive.

By Dr. Michael Lebby / *Lightwave Logic*

Over the past two years, people across the country grappled with working, attending school, shopping and socializing remotely. Lives have changed considerably. For the most part, people adapted quickly to the new lifestyle – but it hasn't always been easy. Some struggled with the bandwidth of data coming into their homes. At certain times, they had to turn cameras off or ask other family members not to use the internet so they could upload their work or schoolwork. This raised the question: How can broadband providers increase the bandwidth of data going into and out of homes or workplaces?

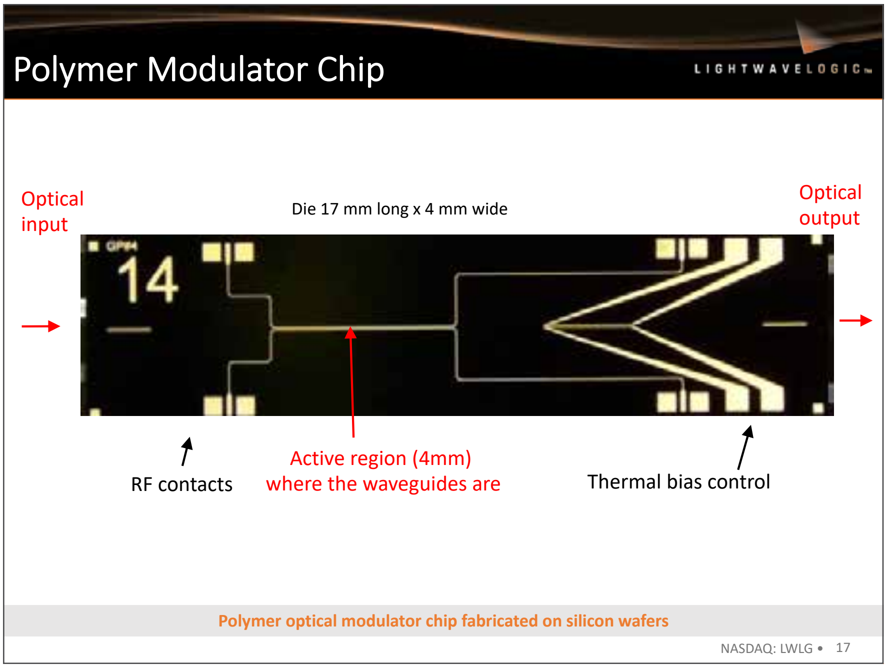
To address the question, figuring out what the internet is and how it works is important. In a nutshell, it's a network of fiber optic cables with architectures all over the country. The glass-based fiber optic cables carry digital signals that contain the information needed when users want to access websites or email or video call their families. Lasers and modulators produce digital signals that send light to generate ones and zeroes. A laser produces the light, and a modulator switches the light to create a one and a zero. This is a bit like eyes blinking very fast: When a person's eyes are open, light can travel so it's a one. When the person blinks, light can't travel, so it's a zero. Encoded light carries information across the internet as people access websites and communicate.

One key component of the internet is the modulator. As noted above, this is the device that regulates the speed of light as it is encoded to send data information. A faster modulator means essentially a faster internet. Today, modulators are used everywhere in the internet; however, they are semiconductor-based and relatively slow. Modulators made from electro-optic polymers have been shown to switch light more than three times faster than the speed of data on the internet using the modulators' natural, organic material properties. What's more, the modulators are not limited in speed: They can actually go much faster. Electro-optic polymers have a number of interesting attributes. They lower the power consumption of modulators, which in turn helps address the ever-increasing power issue that big data-center-type facilities encounter as part of internet architecture.

In today's world, industry, corporations and manufacturing require high data rates, allowing easier access to high-quality data flow, which supports high-quality information and more efficient product development. Though people want more speed, lowering power consumption has been a key priority for data centers and is becoming a design criterion and an Achilles' heel for next-generation network architectures.

Today, demands for high data rates and internet bandwidth are forcing architects and optical network planners to rethink their strategies. They are being pushed to figure out how to increase optical device speed as opposed to using very expensive and complex electronics that do not address raw data rates. In fact, the electronics assist the optics but at great costs because of the big, complex, integrated circuit (IC) chips that consume lots of power.

The simple solution is to increase the speed of the optics and lower power consumption by using more-power-efficient optics. This is where polymer optical modulator devices make a huge impact: They switch light much faster than existing optical semiconductor devices at power levels much lower than available today. This advantage relieves network architects of expensive, power-hungry electronic ICs, which also reduces power consumption.



ELECTRO-OPTIC POLYMER MODULATORS

What are electro-optic polymer modulators? To answer this question, consider the characteristics of a modulator: It switches light and is a polymer-based material. These two characteristics are common in today's consumer world. For example, optical switching is evident every day in TV and display screens that use LCDs, which switch light, albeit very slowly.

LCD technologies have given way to a polymer technology: organic light emitting diodes (OLEDs). Some people today have beautiful OLED TVs, which are all polymer-based. Combining the function of super-fast optical switching with polymers creates electro-optic polymers, which have characteristics ideal for switching optical data in fiber communications. Though LCDs have been replaced in part with OLEDs, the success of polymers in OLEDs has been incredible over the past decade.

OLED displays have replaced many LCD displays, and the reliability of the new displays is high. Electro-optic polymers do not emit red/green/blue light emissions, though they are organic and polymeric. Created from different chemical compositions, they can provide long lifetimes, excellent stability and high reliability when used in products.

Given the natural advantages of electro-polymers, the companies that source organic polymer compositions for modulator device designs will have a big say in how the technology is integrated into and implemented as market applications. With the advancement of polymer performance and characteristics over the past decade, electro-polymers are poised to replace semiconductor incumbent modulator technologies (such as indium phosphide, silicon and lithium niobate) as data rates increase and power consumption requirements decrease.

SPEED AND POWER

In regard to technical metrics, some key properties include low loss at 1310nm and 1550nm wavelengths, a high Pockels effect, a high glass transition temperature and excellent material stability. When the electro-optic polymers are fabricated into Mach Zehnder optical modulators, a device common in the internet to switch light fast, then extremely fast optical switching speeds, and low drive voltages are achieved.

Though semiconductor-based Mach Zehnder modulators are in commercial use today, they suffer from relatively low speed of operation and significantly higher power consumption through their higher voltage drive and complexity. As noted earlier, the broadband industry has been on a plateau of modulator device speed (around 25–40GHz electro-optical bandwidth) and power consumption for the past decade. That's why the industry is increasing data rates through using electronics, which assist in the higher generation of symbols per bit, for example, with pulse amplitude modulation at four levels (PAM4), which is popular today.

One major downside of implementing electronics to increase data rates is that it drives power consumption levels through the roof. Data centers, and the fiber optics industry in general, are becoming more focused on how to bring power consumption down. This is essential because these services now use

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significant electrical grid energy across the country. Innovative and proprietary polymers enable platforms to assist network planners in managing their networks, both to increase speed and lower power consumption.

Today, as data is sent ever faster, higher data rates place a huge burden on servers and routers because data needs to be communicated via fiber into and out of these systems. The place where data flows is the rack-based faceplate, the place on the front of these servers and routers where many pluggable fiber optic transceiver modules are positioned to transduce optical signals from fiber into the electronic switch blades (and vice versa).

A new trend in the industry is to look at on-board optics (OBO) or co-packaged optics (CPO) to circumvent the pluggable transceivers at the faceplate to increase more data flow in and out of the systems. The drive to miniaturization is real; the volume or footprint for either of these solutions is limited. The interest and pull from the networking giants to integrate and miniaturize photonics has steadily increased over the decade. Today, the photonic integrated circuit (PIC) chips need to be turbo-boosted. Existing semiconductor modulators simply are not fast enough and consume too much power.

ORGANIC POLYMERS

Electro-optic polymers directly address the issues above. What's more, polymers are additive to silicon photonics. This means that they can be fabricated using standard silicon semiconductor techniques and foundry process development kits (PDKs) and turbo boost the performance of silicon photonics. For example, polymer materials in liquid form can be spun using standard wafer spinners and added to existing silicon photonics wafers, increasing speed and keeping power consumption low.

Furthermore, electro-optic polymers can be designed to work in smaller devices called slot modulators. In these designs, electro-optic polymer technology can be fabricated into a PIC platform with increased performance and a very small footprint, which saves money through the use of less real estate. The good news for electro-optic polymers is that it does not matter whether a transceiver is pluggable or is onboard; both transceiver designs (the incumbent pluggable or new efforts for co-packaged) need high-speed modulation at lower power consumption levels.

The performance advantages of using electro-optic polymers are evident in the performance of Mach Zehnder modulator devices. Using polymers, the modulators easily achieve electro-optical bandwidths of 70–100GHz (two to three times those of existing semiconductor devices) with the potential to be three to five times faster in the future. When modulators are driven at 1 volt or less, the low voltage eliminates the need for dedicated driver ICs, which in turn allows the optical system architect to drive the modulators directly from the CMOS electronics. That saves the system power and money.

Similarly, with polymer slot modulator design, the footprint is smaller, the integration with a full PIC is easier, and the bandwidths far exceed 100GHz at sub-voltage levels. Slot modulators provide the future-proofing the industry is looking for as demand for traffic and data rates continually rise over the next decade.

HOW WILL THE TECHNOLOGY BE IMPLEMENTED?

Both the polymers added to integrated photonics and electro-optic polymer slot technology platforms are now based on the use of large CMOS silicon foundries. These are fabrication plants that focus on silicon semiconductors, and have traditionally set up their PDKs for integrated circuits ICs.

Over the past few years, many silicon foundries have looked at increasing their wafer throughput by servicing silicon photonics solutions. These foundries are catalysts for volume scale when polymers are added to silicon photonics. Transporting standard semiconductor fabrication techniques to a large foundry in terms of a PDK is relatively straightforward because the processes are compatible.

For polymer modulators to be ubiquitous across the industry, key challenges must be addressed at record pace: developing advanced and mature electro-optic polymers, developing simple, standard fabrication in large-scale volume, and implementing packaged modulator devices in commercial applications.

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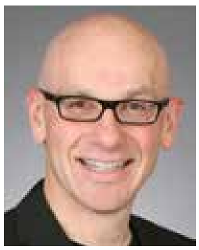

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