Silicon-Based Optical Modulator With Ferroelectric Layer

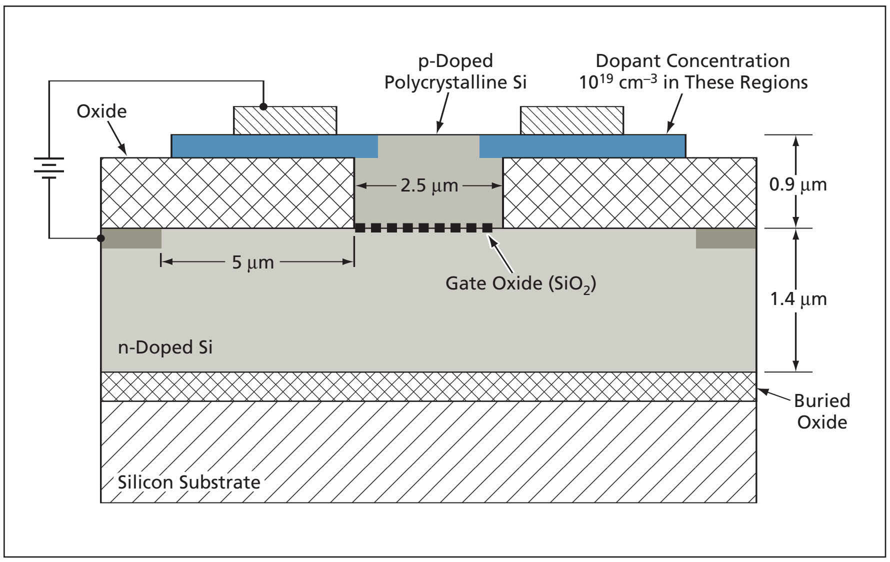
This device would remain switched even with power turned off.

NASA's Jet Propulsion Laboratory, Pasadena, California

According to a proposal, a silicon dioxide layer in a high-speed, low-power, silicon-based electro-optical modulator would be replaced by a layer of lead zirconate titanate or other ferroelectric oxide material. The purpose of this modification is to enhance the power performance and functionality of the modulator.

In its unmodified form, the particular silicon-based electro-optical modulator is of an advanced design that overcomes the speed limitation of prior silicon-based electro-optical modulators. Whereas modulation frequencies of such devices had been limited to about 20 MHz, this modulator can operate at modulation frequencies as high as 1 GHz. This modulator can be characterized as a silicon-waveguide-based metal oxide/semiconductor (MOS) capacitor phase shifter in which modulation of the index of refraction in silicon is obtained by exploiting the free-charge-carrier-plasma dispersion effect. As shown in the figure, the modulator includes an n-doped crystalline silicon slab (the silicon layer of a silicon-on-insulator wafer) and a p-doped polycrystalline silicon rib with a gate oxide layer (the aforementioned silicon dioxide layer) sandwiched between them.

Under accumulation conditions, the majority charge carriers in the silicon waveguide modify the index of refraction so that a phase shift is induced in the optical mode propagating in the waveguide. The advantage of using an MOS capacitor phase shifter is that it is possible to achieve high modulation speed because there are no slow carrier-generation or -recombination processes involved in the accumulation operation.



A **Ferroelectric Oxide Layer** would be substituted for the gate oxide layer in this silicon-based electro-optical modulator.

The main advantage of the proposed substitution of a ferroelectric oxide layer for the silicon dioxide layer would arise from the spontaneous polarization effect of the ferroelectric layer: This spontaneous polarization would maintain accumulation conditions in the absence of applied voltage. Consequently, once the device had been switched to a given optical state, it would remain in that state, even in the absence of applied voltage (in other words, even with power turned off). A secondary advantage is that because the ferroelectric layer would have an index of refraction larger than that of silicon dioxide, there could be some reduction of optical losses attributable to fabrication of the modulator.

This work was done by Douglas Sheldon of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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Multiplexing Transducers Based on Tunnel-Diode Oscillators

Compact, low-power transducers could operate over wide temperature ranges.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multiplexing and differential transducers based on tunnel-diode oscillators (TDOs) would be developed, according to a proposal, for operation at very low and/or widely varying temperatures in applications that involve requirements to minimize the power and mass of transducer electronic circuitry. It has been known since 1975 that TDOs are useful for making high-resolution (of the order of 10^{-9}) measurements at low temperatures. Since that time, TDO transducers have been found to offer the following additional advantages, which the present proposal is intended to exploit:

- TDO transducers can operate at temperatures ranging from 1 K to about 400 K. Most electronic components other than tunnel diodes do not operate over such a wide temperature range.
- TDO transducers can be made to operate at very low power — typically, <1 mW.
- Inasmuch as the response of a TDO transducer is a small change in an arbitrarily set oscillation frequency, the outputs of many TDOs operating at sufficiently different set frequencies

can be multiplexed through a single wire.

- Inasmuch as frequencies can be easily subtracted by means of mixing circuitry, one can easily use two TDOs to make differential measurements. Differential measurements are generally more precise and less susceptible to environmental variations than are absolute measurements.
- TDO transducers are tolerant to ionizing radiation.
- Ultimately, the response of a TDO transducer is measured by use of a frequency counter. Because frequency counting can be easily implemented by use of clock signals available from most microprocessors, it is not necessary to incorporate additional readout circuitry that would, if included, add to the mass and power consumption of the transducer circuitry.

In one example of many potential variations on the basic theme of the proposal, the figure schematically depicts a conceptual differential-pressure transducer containing a symmetrical pair of TDOs. The differential pressure would be exerted on an electrically conductive and grounded diaphragm, which, at zero differential pressure, would nominally be sprung to a middle position between two capacitor plates that would be parts of the two TDOs. The frequencies of the two TDOs would vary in opposite directions as variations in differential pressure bent the diaphragm away from one capacitor plate and toward the other. The outputs of the TDOs would be mixed and low-pass filtered to obtain a signal at the difference between the frequencies of the two TDOs. The difference frequency would be measured by a frequency counter and converted to differential pressure by a computer.

This work was done by Talso Chui, Konstantin Penanen, and Joseph Young of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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