ITO-Based Microheater Platform for Multi-Stage Switching of Phase-Change Materials (#8390)

Expands optical functionalities in hybrid integrated photonic devices through miniaturization of the phase-shifter element

This microheater platform employs optically transparent and electrically conductive indium-tin-oxide (ITO) bridges for fast and reversible switching of phase-change materials (PCMs). Using the phase-change alloy germanium antimony telluride (GST), researchers at Georgia Tech demonstrated reversible switching of the GST phase between crystalline and amorphous states with multiple intermediate states possible. This innovation establishes the possibility of beyond-binary reconfiguration of optical functionalities in hybrid PCM-photonic devices using miniaturized devices with low-power operation.

By properly assigning width and amplitude of electrical pulses to the ITO bridge, the platform further allows for the registration of virtually any intermediate crystalline state into the GST films integrated on the top of the platform. The low optical loss of the ITO film allows the platform to be directly integrated on silicon-based, silicon nitride-based, and other photonic devices for the realization of low-power electrically reconfigurable optical functionalities.

In a representative demonstration, researchers integrated the microheater platform into the arms of a Mach-Zehnder interferometer (MZI) to achieve electrically reconfigurable optical modulation and switching through realization of reconfigurable optical phase shifters. By applying optimized electrical pulses to the platform, the phase of an optical signal in one arm of the MZI can be gradually shifted between 0 and 180 degrees with multiple intermediate values corresponding to the intermediate crystalline GST states.

Note: This innovation is related to technologies 8437 and 8530.

Benefits/Advantages

- **Energy efficient**: Permits energy-per-pulse consumed for the amorphous-to-crystalline phase conversion in GST of ~ 6.5 nanojoules (nJ) in the test devices, with the possibility of sub-nJ operation in further optimized device configurations; there is no need for continuous supply of power after changing the GST phase due to the nonvolatility of the process
- **Compact**: Allows production of miniaturized GST-based active and reconfigurable photonic devices
- **Improved performance**: Offers reversible switching of the GST phase with multiple intermediate crystalline states in a repeatable way; no tangible optical loss due to the addition of the electrically controlled ITO heating film

Potential Commercial Applications

- Integrated photonics
- Optical sensing
- Optical signal processing (e.g., for RF and millimeter-wave signals)
- Optical communications and interconnection
- Laser-based ranging and detection
- Data processing and communications
- Integrated optical computing architectures

**Background/Context for This Invention**

Detailed control and manipulation of the refractive index of an optical material forms the backbone of integrated photonics, a notion that constantly seeks alternative material platforms and modulation schemes for achieving new functionalities and better performance measures. Recent trends show a growing interest in hybrid photonic devices based on PCMs with a specific focus on GST alloys.

The success of reconfigurable PCM-based photonic platforms depends on having reliable control of the PCM phase electrically, which can be reversibly switched between amorphous and crystalline states through a controlled heating process. Electrical heating, also known as joule heating, holds a great promise for the ultimate miniaturization of GST-based active photonic devices, primarily because the miniaturized heaters can be integrated into the device platform. However, designing a compact, low-loss, and CMOS-compatible microheater is the major bottleneck for the integration of PCMs into photonic platforms.

Georgia Tech’s innovation solves these challenges with this new microheater platform and expands the use of optical functionalities in hybrid PCM-photonic devices.

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Figure 1: Georgia Tech’s ITO microheaters: Schematic illustration of designed microheaters depicted in (a) top and (b) side views. (c) Optical and (d) SEM images of fabricated devices.
Figure 2: Multi-stage and reversible switching of the GST phase. (a) False-colored SEM image of the device. The GST phase is changed through the Joule heating in the underlying ITO layer and monitored by the measurement of the GST resistance (RGST) between the Au contacts. (b) The GST resistance as a function of the number and amplitude of voltage pulses applied to the ITO heater. The black arrow highlights the re-amorphization of GST. (c) The measured RGST is composed of two side segments close to the left and right electrodes (RI and Rr) and a middle segment (Rm).

For more information about this technology, please visit: https://licensing.research.gatech.edu/technology/ito-based-microheater-platform-multi-stage-switching-phase-change-materials