Spatiotemporal measurements with an ultrafast scanning tunneling microscope

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Spatiotemporal measurements with an ultrafast scanning tunneling microscope
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We use an ultrafast scanning tunneling microscope (USTM) to resolve voltage transients propagating on a coplanar waveguide (CPW). The photoconductive (PC) switch connected to the tunneling tip is illuminated through a fiber with a 100-fs Ti:sapphire laser (Fig. 1). The laser pump beam generates a voltage pulse on the CPW; the probe beam gates the current picked up by the tunneling tip. Sample and probe substrates are low temperature grown GaAs. The use of a fiber enables flexible positioning of the tip over a range of 50 μm (only limited by the scanning range of the piezo tube). The instrument can be used to map out voltage transients generated by different excitation devices switch inside present and future submicron scale CMOS circuits poses substantial challenges. A practical technique must be capable of probing large numbers of devices with time resolution exceeding 100 ps. Ideally, the method should work on conventional devices under normal operation conditions, and require no extra test structures on the chip. The technique must be useful as device dimensions shrink and circuit complexity increases. The increasing number of metalization layers and "flipchip" packaging will add the challenge of a front surface inaccessible at the device level. These technological advances will cause the present internal test method that uses electron beam probing to become ineffective, so alternative methods are urgently needed.

We have found that hot electron light emission is generated as a subnanosecond pulse coincident with the normal switching of each individual FET in a CMOS circuit. Here we use this emission to directly measure the propagation of signals through the individual gates in fully functional CMOS circuits. Our implementation (Fig. 1) uses an imaging microchannel plate photomultiplier as a detector. Time resolution is obtained by photon timing over a repetitive electrical waveform. Gate-to-gate switching delays of less than 50 ps can be resolved, and the switching of hundreds of FETs can be simultaneously observed. As model circuits, we use CMOS ring oscillators and counters (Fig. 2a) fabricated with an effective gate length of 0.6 μm. Images of the optical emission are shown in Figs. 2(b–d). A series of

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Optical imaging of picosecond switching in CMOS circuits
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Measuring the time at which individual devices switch inside present and future submicron scale CMOS circuits poses substantial challenges. A practical technique must be capable of probing large numbers of devices with time resolution exceeding 100 ps. Ideally, the method should work on conventional devices under normal operation conditions, and require no extra test structures on the chip. The technique must be useful as device dimensions shrink and circuit complexity increases. The increasing number of metalization layers and "flipchip" packaging will add the challenge of a front surface inaccessible at the device level. These technological advances will cause the present internal test method that uses electron beam probing to become ineffective, so alternative methods are urgently needed.

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