A Dual-Beam Interferometer for Investigation of ESD Protection Devices under vf-TLP Stress

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Protection against charged device model (CDM) becomes more and more demanded by automotive industry. Understanding device internal behavior and the device interaction within a circuit or a package at short time scale is important for optimization of protection devices against CDM. Recently, backside transient interferometric mapping (TIM) technique in combination with very fast transmission line pulses (vf-TLP) has been used for investigation of trigger delays in ESD protection devices. However, as some devices exhibit pulse to pulse instabilities in triggering behavior, a dual-beam MI has been introduced for the simultaneous measurements of absolute phase shift at two different positions with 0.4 ns time resolution [1].

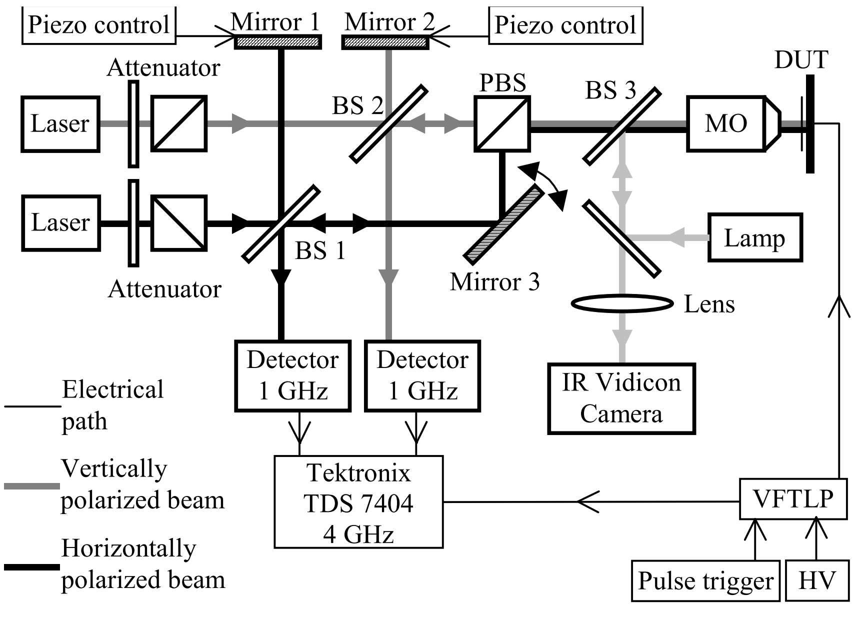
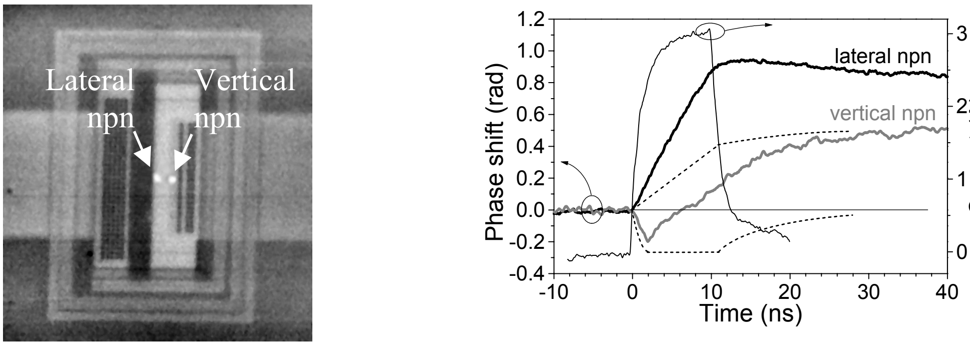


Fig. 1: Simplified schematic of the dual-beam Michelson interferometer setup: BS – beamsplitter, PBS – polarization beamsplitter, MO – microscope objective, DUT – device under the stress; after [1].

The dual beam MI consists of two interferometers combined in one setup, see Fig. 1. Two diode laser sources (λ = 1.3 µm) are used. In order to reduce optical losses the two beams have orthogonal polarization and are combined using polarization beam splitters. Each reference branch is piezo controlled for maximal sensitivity adjustment. Both beams are focused by the microscope objective on the device under stress (DUT) mounted on xyz and rotational stages. One of the beams has a fixed position, while the position of a second beam can be adjusted by a mirror (the maximal beam separation is 0 – 500 µm, the beam spot size is 2 µm). The position of the beam spots can be visualized using an infrared (IR) vidicon camera. The interference signals related to two interferometers are detected by two InGaAs detectors with 400 ps rise time and sampled with an oscilloscope together with the voltage waveform of the vf-TLP signal. The current waveform was properly aligned relative to the phase waveforms taking into account all the signal delay lines. The signal is usually averaged 20 – 40 times to improve the signal to noise ratio. For transient phase signals with amplitude higher than 0.1 rad, the transient behavior can also be studied using a single stress pulse. All setup optoelectronic components are shielded to avoid the induction of electromagnetic pick-ups in the interference signal.

As an example, two BCD technology device types were investigated. First structure is an npn transistor with a lateral and buried collector and short-circuited base/emitter, the second structure is an inverted vertical npn transistor with short circuited base and collector. The devices are stressed by a home-built vf-TLP pulser.

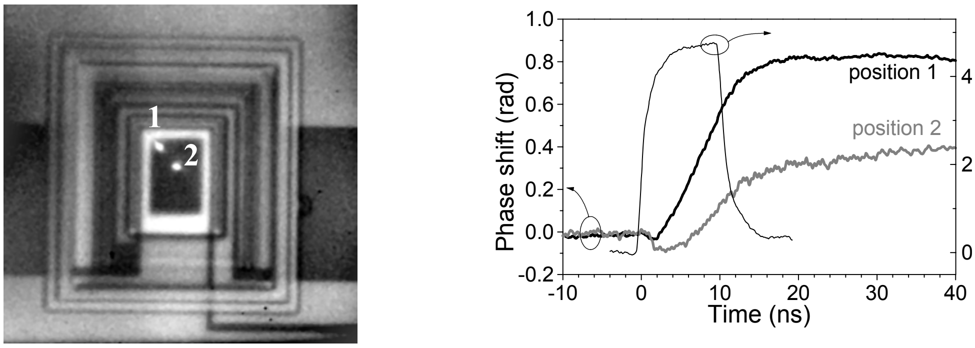


(a) (b)

Fig. 2: (a) Backside IR image of the first npn structure with marked laser beam positions;
(b) phase shift development in marked positions; after [1]

Two hot spots have been observed using the scanning TIM method in the first npn ESD structure: a dominant thermal peak at the position of collector edge due to the heating in the lateral npn transistor and a negative peak due to carrier injection under the n-emitter region. The trigger delay between the lateral and vertical transistor was investigated by the dual beam MI. In the lateral npn transistor (see Fig. 2 (a)), immediately with the begin of the pulse the phase shift nearly linearly increases due to the self-heating effect in the impact ionization region of the base-collector junction, see Fig. 2 (b). After the end of the pulse the heat spreads to the surrounding. At the position of vertical transistor (see Fig. 2 (a)) a rapid decrease occurs after the beginning of the pulse followed by a phase increase. The start of both signals from the lateral and vertical npn is well aligned, indicating a trigger delay within 0.4 ns. The signal at vertical npn is caused by a superposition of a free carrier negative signal, acting in a short time scale, and a thermal signal, which is much slower. These two components are separated and also plotted in Fig. 2 (b) (see the dotted lines). The steady state of free carrier signal is obtained after some 2 ns. After the pulse end, a slower tail is observed, as the high concentration of excess carriers has to decay. The thermal component of the signal exhibits a rise after the pulse end, which is due to heat transfer from the surrounding region.

In second npn structure, the scanning TIM revealed hot spots at the device corners. To investigate if these hot spots indicate an earlier triggering at the corners than in the middle of the emitter, the two beams of the dual beam MI were placed at the corner and in the middle positions; see Fig. 3 (a). At these positions a maximum trigger delay may be expected. At both positions the free carrier negative signal dominates at the pulse beginning; see Fig. 3 (b). At later times the heating dominates as the temperature and thermal energy increase with time. No phase delay has been found between the measuring positions within the measurement precision (0.4 ns).



(a) (b)

Fig. 3: (a) Backside IR image of the second npn structure with marked laser beam positions;
(b) phase shift development in marked positions; after [1].

References

[1] V. Dubec, S. Bychikhin, M. Blaho, D. Pogany, E. Gornik, J. Willemen, N. Qu, W. Wilkening, L. Zullino, A. Andreini, "A dual-beam Michelson interferometer for investigation of trigger dynamics in ESD protection devices under vf-TLP stress", (*ESREF 2003*), Microel. Reliab. 43, 2003, pp.1557-1561