# Study of Trigger Instabilities in ESD Protection Devices Using Backside Laser Interferometry

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The self-heating effect is the main failure cause in electrostatic discharge protection devices (ESD PDs). Inhomogeneous current flow, non-destructive current filaments of larger size, are often found in ESD PDs. The current filamentation is related to a negative differential resistance (NDR) region in the device IV characteristics. Another temperature effect, plausible for ESD protection, is the homogenization of the current flow during the ESD pulse. We have studied the trigger dynamics and instabilities causing pulse-to-pulse (PTP) variations in the triggering place along the width of different types of ESD protection devices fabricated by a smart power technology. Backside laser interferometry was used allowing the investigation of thermal dynamics during a single ESD event with a ns time scale resolution.

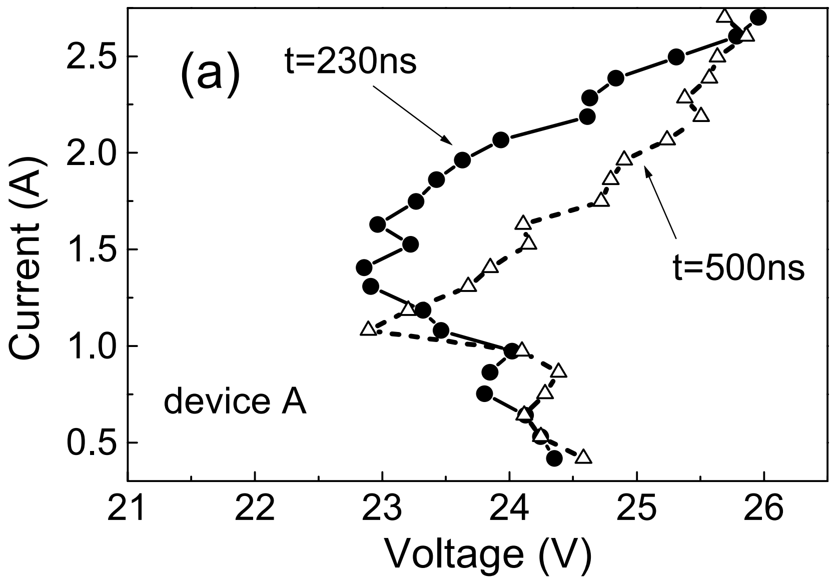


Fig. 1: IV characteristics of the ESD protection device recorded at two time instants. The NDR can be seen up to the stress current of 1.5A.

The studied protection devices are npn transistors with breakdown and sustaining voltages of 44 V and 24 V, respectively. The measured phase shift represents, in the first approximation, the 2D-lateral density of thermal energy in the silicon. The devices were stressed by rectangular current pulses using a DMOS switch (duration 170 – 500 ns). In order to study the PTP variation in the phase shift dynamics, ten to fifty ESD pulses were applied at each position of the device during a scanning procedure.

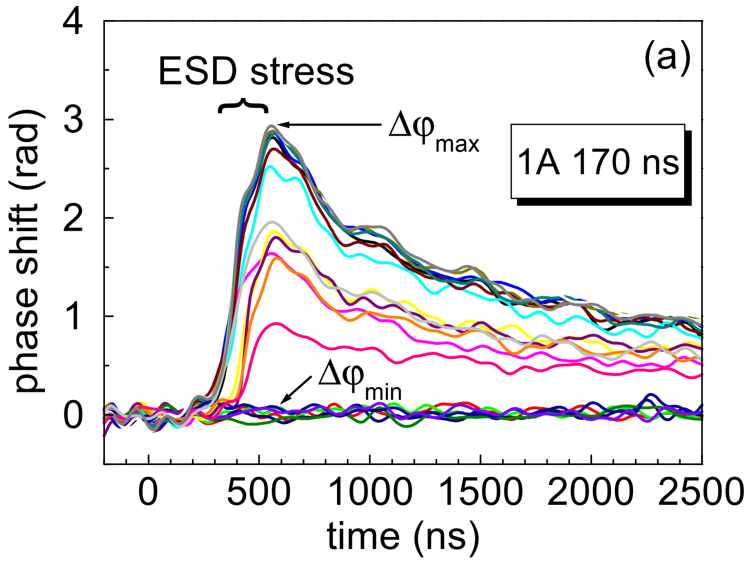


Fig. 2: Typical pulse to pulse variations in the phase evolution demonstrating the instabilities in the current flow from pulse to pulse.

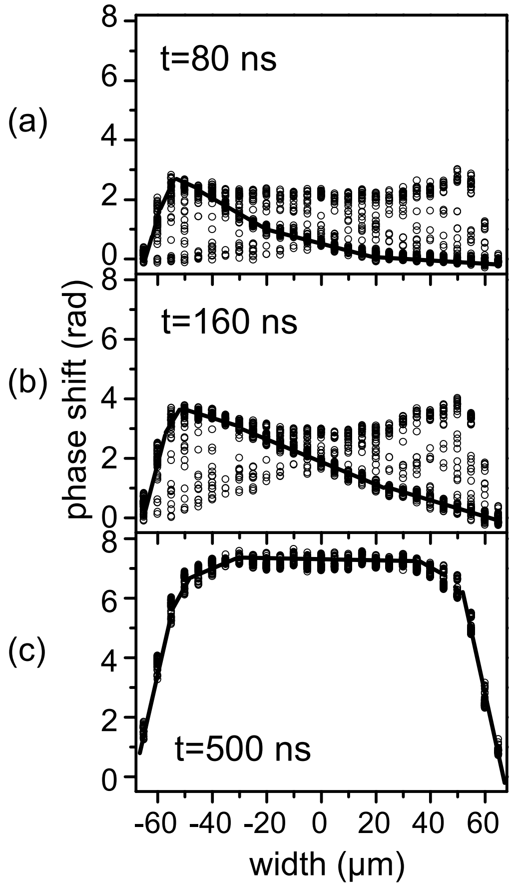


Fig. 3: Phase shift distribution along the device width at three time instants during the stress pulse of $I = 2$ A. At each position 50 phase shift values are given. The envelopes (solid lines) indicate the heat energy for the case when the device triggers in the left part.

Large PTP variations in the local phase shift value have been observed in the studied devices (see Fig. 1). They occur only in devices exhibiting a NDR region in the IV characteristics (see Fig. 2). The scattered data of phase shift along the device width can be grouped into two distributions forming envelopes, which are symmetrical to each other around the middle of the device (see Fig. 3). These envelopes represent two different possible thermal energy distributions (heated regions) during a stress pulse. It means that, from pulse to pulse, the device triggers either in one or another half of its width, forming thus a large current filament. The origin of the current filamentation is attributed to the NDR in the IV curves. The heated region increases with progressing time during the pulse. This indicates a spreading of the current distribution with time. The increase in the stress current magnitude has the same effect on the current spreading, leading to a current flow homogenization. The spreading effect is attributed to a negative feedback from the local temperature increase due to the self-heating effect. The increasing temperature causes a decrease in the impact ionization coefficient. In a result the current flow tends to move to a cooler region, leading to the current flow homogenization. The observed increase of the holding voltage with time (see. Fig. 1) supports this hypothesis. The current homogenization with time and stress current explains the high ESD robustness of this device (>8 kV Human Body model stress type).