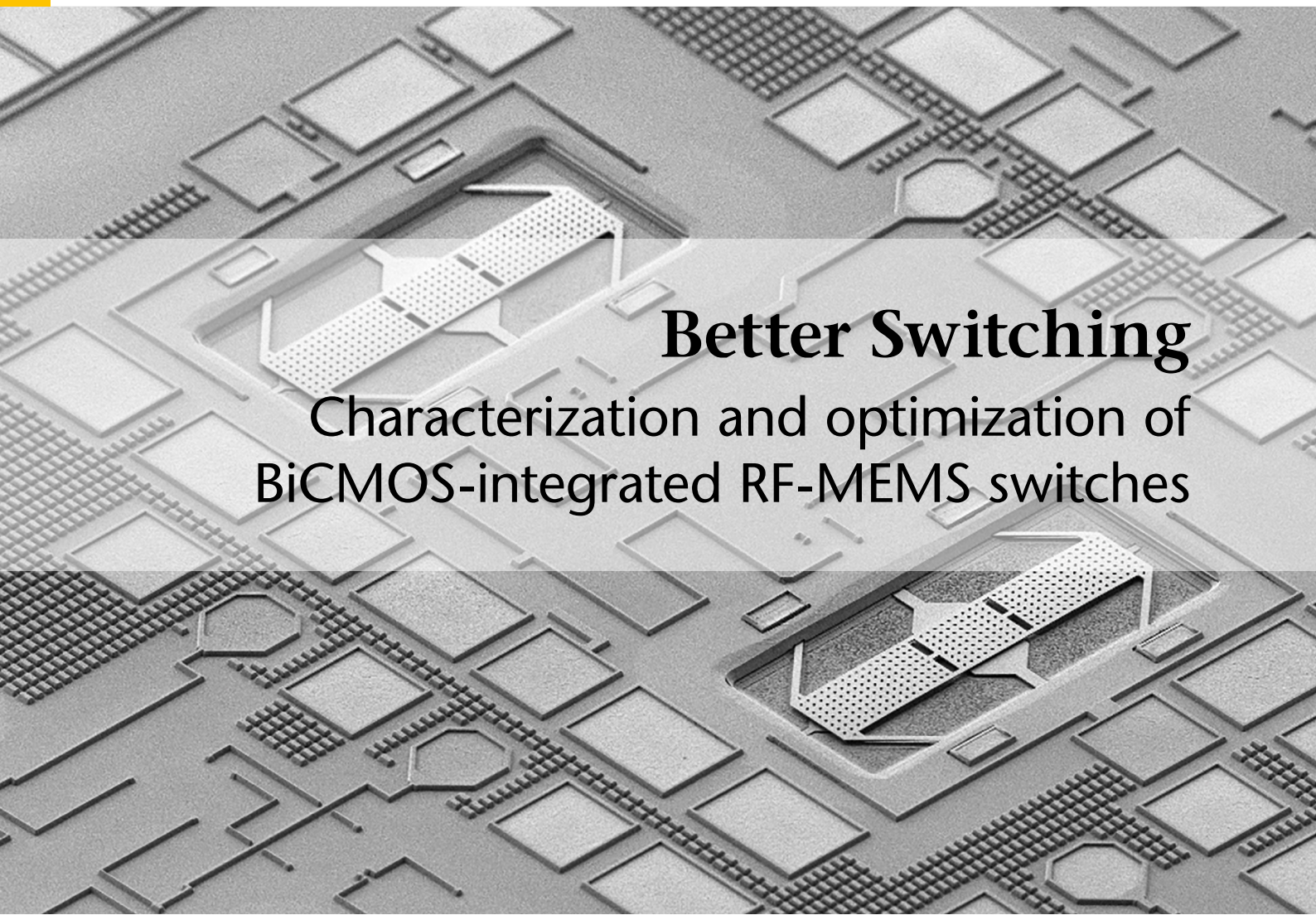

Better Switching

Characterization and optimization of BiCMOS-integrated RF-MEMS switches

The monolithic integration of RF-MEMS into a SiGe-BiCMOS technology enables the development of cost-effective and highly-integrated circuits for future radar and imaging systems. Laser Doppler vibrometry (LDV) and coherence scanning interferometry (WLI) have enabled the development of RF-MEMS switches with excellent performance and reliability.

BICMOS RF-MEMS SWITCH INTEGRATION

SiGe-BiCMOS technologies are becoming more and more interesting for mm-wave applications such as WLAN, radar and imaging. These applications frequently require reconfigurable integrated circuits (IC) for different frequency bands, switches to control the signal path between transmitter, receiver and antenna as well as phased-array systems, which can be realized using RF-MEMS and benefit from their improved RF-performance (Figure 1).

The capacitive-type RF-MEMS switch is monolithically integrated into the backend-of-line (BEOL) of IHPs SiGe-BiCMOS technology (Figure 2). Therefore the shortest interconnections between transistors and MEMS can be achieved, minimizing or preventing high frequency parasitic effects.

The switch is realized in the first three BEOL metallization layers. The high-voltage electrodes for electrostatic actuation are produced in metal 1, metal 2 is used as the RF-signal line and the suspended membrane is located in metal 3. By applying a voltage to the electrodes, the position of the membrane can be modified, hence the capacitive coupling between the signal line and suspended membrane changes leading to efficient switching of high-frequency signals.

EXPERIMENTAL SETUP

The development of RF-MEMS switches requires several methods for mechanical, electrical and RF-characterization. The analysis of electromechanical performance is of utmost importance because RF-performance is strongly influenced by this. Optical characterization methods are preferred because measurements are possible with the highest resolution and with zero influence on the ▶

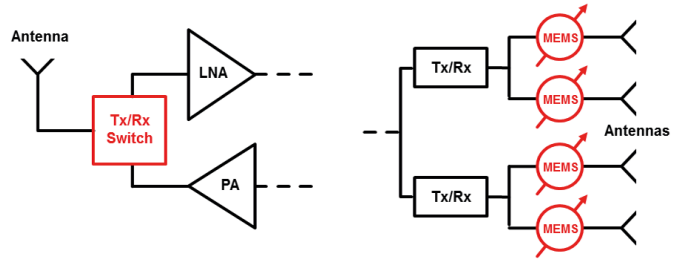

Figure 1: RF-MEMS switch used as Tx/Rx-switch (left) or phase-shifter (right).

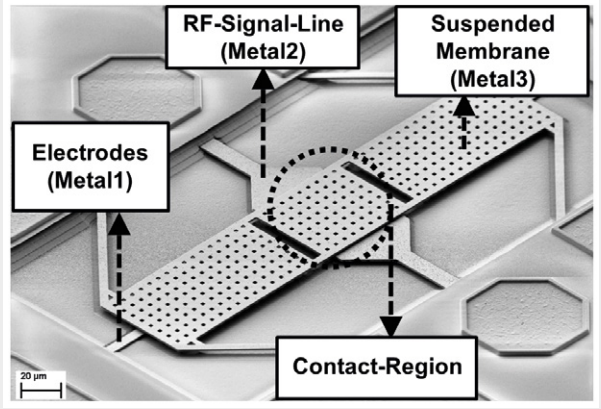

Figure 2: Scanning electron microscopy picture of RF-MEMS switch.

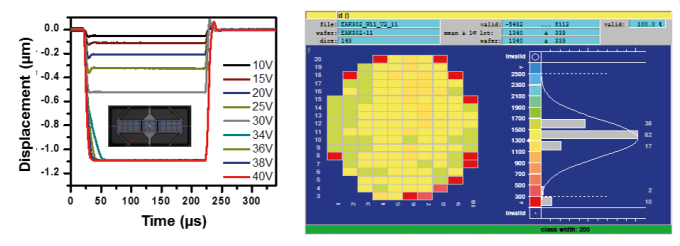

Figure 3: LDV-measurement shows membrane displacement with different actuation voltages (left) and wafer-level homogenity (right).

behavior of the device. The MSA-500's LDV is used for automated 200mm wafer-level electromechanical motion characterization of the RF-MEMS switches, and WLI for analyzing the static deformation. LDV is an outstanding measurement method for process-control due to its ability to detect "out-of-plane" motions with nm-range displacement resolution and µm spatial resolution.

RESULTS

Parameters such as pull-in voltage and switching-time can be extracted by applying different actuation voltages. Very good uniformity can be achieved for the demonstrated RF-MEMS switch technology (Figure 3).

Conclusions on the mechanical spring constant and the influence of residual stress can be drawn from the membrane displacement. The latter significantly influences the mechanical, electrical and RF-performance, therefore requiring regular detection (Figure 4).

Reliability is a major obstacle for the successful application of RF-MEMS because charging and fatigue can lead to device failure. LDV can be useful for reliability detection, leading to design improvement, because several switches can be tested in parallel resulting in fast and very cost-effective analysis over billions of switching cycles (Figure 5).

CONCLUSION AND OUTLOOK

In recent years, the monolithic integration of RF-MEMS switches has progressed in terms of performance, process stability, yield and reliability, not least because of the application of LDV and WLI. These characterization methods provide fast and cost-efficient detection of electromechanical performance at the wafer-level for developing reliable mm-wave systems. For example, an intelligent antenna-array with integrated RF-MEMS switches has been developed (Figure 6). ■

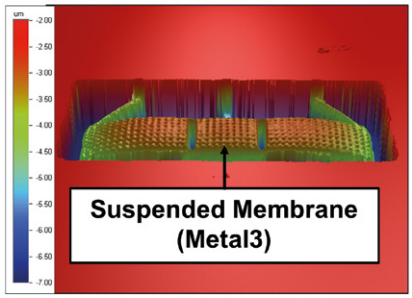

Figure 4: WLI of an RF-MEMS switch shows the influence of residual stress inside the thin layers.

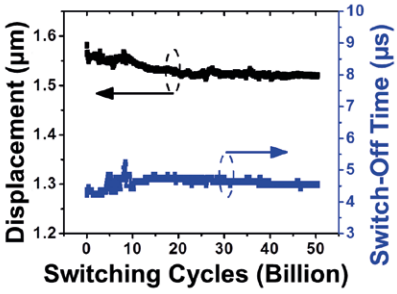

Figure 5: RF-MEMS switch reliability test using LDV

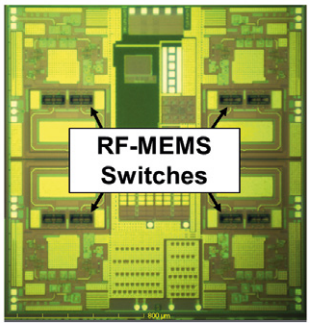

Figure 6: Transceiver quad-chip for intelligent antenna-arrays.

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