Simulation-based Optimization of a Senor-Indenter System for Thin Layer Crack Detection

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INTRODUCTION

Every semiconductor device is tested for its functionality on wafer level before further processing. Therefore, metal pads on the wafer surface are mechanically contacted with elastic contact springs to provide an electrical connection to external test instruments. The ongoing shrinking of semiconductor structures has increased the risk of generating cracks in brittle layers below the contact pads by applying to much pressure.

The *Infineon Technologies AG* has invented a new method to define the contact force limits during wafer testing [1]. Cracks are generated and acoustically detected with a patented sensor-indenter system (SI system) [2] in situ.

As the released energy of sub-micron cracks is extremely small, the sensitivity of the SI system needs to be as high as possible. This is achieved by analyzing and optimizing the system with a digital twin and simulation studies. To find out the necessary sensor sensitivity, the deflections, which the indenter tip experiences during a crack, are estimated with a laser vibrometer.

SIMULATION & MEASUREMENT RESULTS

The SI system (Fig. 1a) consists of two main components – a steel indenter with a diamond tip and a piezoelectric acoustic sensor (*Vallen VS900-M*). Different to the design of the commercial sensor the indenter geometry is manufactured on custom specifications (*Synton-MDP AG*).

Fig. 1b shows a 3D simulation model of the system in ANSYS that was developed and verified by comparing measurement and simulation results. The corresponding measurement setup (Fig. 2) uses an ultrasound emitter to provide defined excitation signals and records the sensor response. With the setup the frequency characteristic and pulse response of the SI system can be analyzed.

Varying the indenter length causes a shift of the main resonance peak in the simulated frequency characteristics (Fig. 3). This peak is caused by the first longitudinal eigenmode of the indenter.

By moving the indenter peak to frequencies with the highest sensitivity of the sensor component, the SI system can be optimized. Fig. 4 shows measurement and simulation results of adjusted indenter peaks at 125kHz (10mm indenter length) and 300kHz (4.1mm indenter length).

SENSITIVITY ANALYSIS

Using the optimized 10mm indenter, cracks produce a sensor amplitude between 0.1mV and 5mV. With an ultrasound emitter (Fig. 2) similar pulse responses have been created by varying the excitation voltage in the range of 0.15V and 7.5V. Measuring the surface deflection of the ultrasound emitter with a laser vibrometer (Fig. 5) leads to values between 0.02nm and 0.68nm (Fig. 6). The deflections caused by thin brittle layer cracks are estimated to be in the same range.

CONCLUSION

With help of FEM simulation the frequency behavior of a sensor-indenter system was analyzed. The impact of the indenter length on the frequency characteristic was predicted and proven with measurement results.

The sensitivity of the system was determined using an ultrasound emitter to recreate the pulse excitation of the SI system by the semiconductor layer cracks. The emitter and thereby also the crack deflections are in the sub-nanometer range.

REFERENCES

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[2] O. Nagler, S. Bernrieder and M. Unterreitmeier, *System and Method for Examining Semiconductor Substrates*, United States Patent US 10,859,534 B2, 8 December 2018.

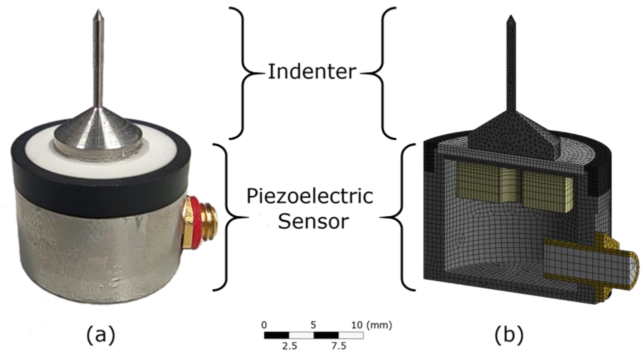

Fig. **1**. Sensor-Indenter System – (a) Real Device and (b) Simulation Model (Cut Open)

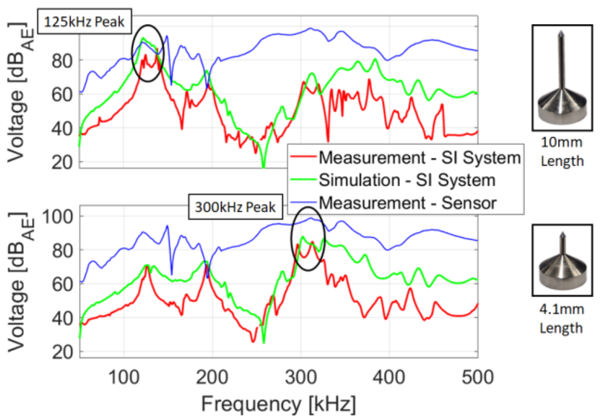

Fig. 4. Comparison between Simulated and Measured Frequency Characteristics with Adjusted Indenter Length

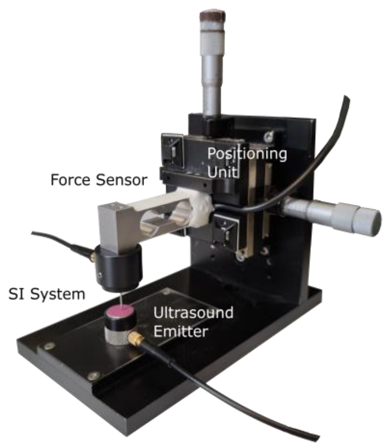

Fig. 2. Measurement Setup with Ultrasound Emitter for SI System Characterization

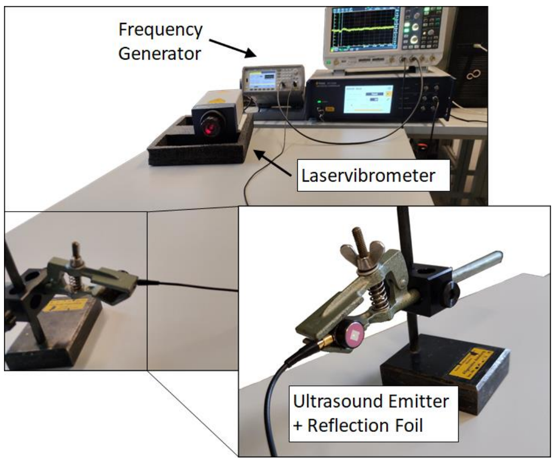

Fig. 5. Laser Vibrometer Setup to Analyze the Ultrasound Emitter Deflection

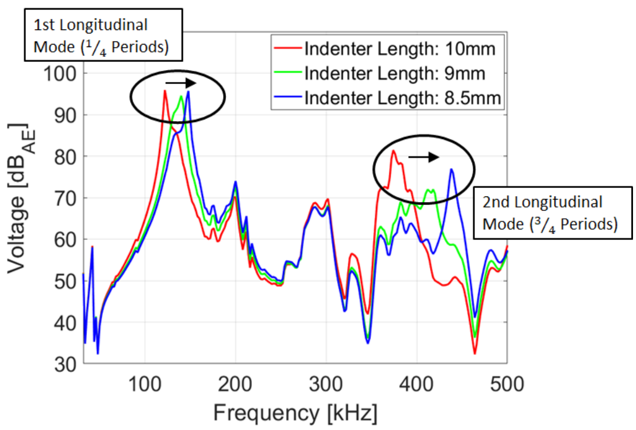

Fig. 3. Simulated Frequency Characteristics of the SI System with Varied Indenter Length

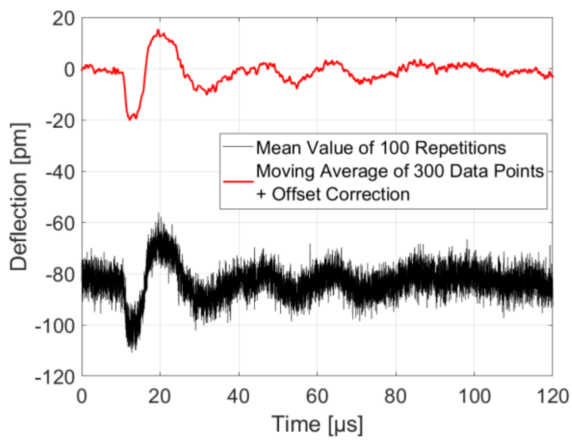

Fig. 6. Measured Ultrasound Emitter Deflection for 180mV excitation voltage (625MHz Sample Rate)