Guided terahertz pulsed reflectometry simulation with near field probe

M. Pan[1], J.P. Guillet[1], F. Fauquet[1], D. Lewis[1] and P. Mounaix[1]
[1]Bordeaux University, IMS, UMR CNRS, 351 cours de la libération 33405, France

***Abstract*—Guided terahertz pulse reflectometry is a failure analysis method applied to detect and locate open circuits or impedance fluctuations in the advanced 3D packages. In this article. We propose use near field microprobe to test some transmission lines and defective circuits in the different level of the packaging. We do some finite element simulations of various types of terahertz waveguides by combining defects with different sizes and positions, in order to predict the different orders of magnitude of the awaited signal after propagation trough several interconnections. We could finally deal with the detectability of several defects by this new technique.**

I. INTRODUCTION

GUIDED Terahertz reflectometry is a setup topology with a source which injects a signal in a waveguide to a probe. Then, this signal is reflected back to a detector. It be can used for near field imaging with continuous wave source[1]. In the case of a pulse source, guided terahertz pulsed reflectometry (GTPR) allows open circuit detection and localization in waveguides or 3D packages interconnections. It can be used to detect through silicon via (TSV) delamination [1], characterize open in solder bumps [2] and locate an open in a daisy chain [3] or even a crack in a layer of an integrated circuit [4].

In this work, we propose to interpret electromagnetic simulations and to predict orders of magnitude of the signals that can be obtained with this method for several components. We can finally discuss the detectability of typical failures in 3D packages.

II. EXPERIMENTAL SETUP

GTPR (scheme in figure 1and photography in figure 2) is based on photoconductive antennas excited by femtosecond pulse laser. A first antenna emits a THz wave which is coupled to a waveguide. Then, this pulse is guided to the device under test (DUT) and reflected back to the sensor. This retro-propagating signal is detected by a second antenna.

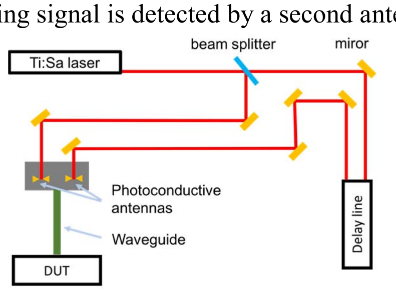


Fig. 1. Scheme of the experimental setup. DUT : Dispositive under test.

This measurement is performed with a time sampling using a delay line which allows to measure the signal for different delays and thus to reconstruct the variation of the signal as a function of the time (photoconductive sampling).

III. FINITE DIFFERENCE TIME DOMAIN SIMULATION

We employ a finite difference time domain (FDTD) simulation software (CST Microwave Studio) to simulate the near field probe *TR.5* from *Protemics GmbH* (represented in Fig.2). This probe has two photoconductive antennas and resonator avoiding probe-internal reflections signals. We performed typical simulations with a sheet at different distances from the probe. We obtain in Fig.2 (left) two signal with delays corresponding to distance between probe and sample.

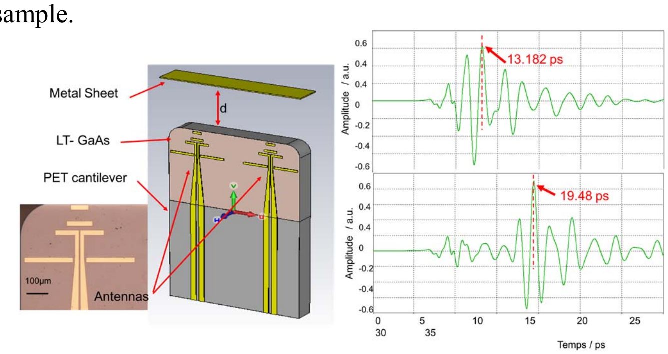
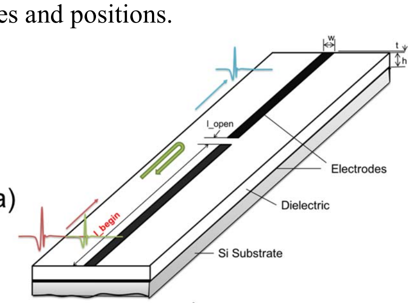


Fig. 2. (left): Photography and scheme of the probe. **(right)**: Signal simulated in the detection antenna for two different distances between the near field probe and the metal sheet.

Then, we simulate several waveguides that can be used in the millimeter-wave frequencies like coplanar, microstrip lines and single wire. We used an experimentally measured typical time domain signal as a simulation signal source and propagated it into the waveguides which contain defects varying in sizes and positions.

(a)



(b)

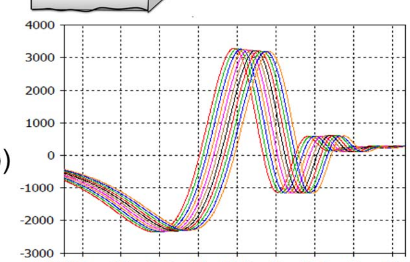


Fig. 3 : (a) Microstrip waveguide with an open in the center. (b) . Reflected signal as a function of time for different positions

Pulse duration is lying in the picosecond range, corresponding to frequencies ranging from 10 GHz to 1.7 THz. We illustrated the potential of the technique with a typical example on a microstrip waveguide represented in Figure 3(a). The signal propagated on the line and is reflected with a delay depending on the position. We can observe on Figure 3(b) that we easily discriminate sub ps delay, corresponding to a localization with a ±20 µm accuracy, which is in same range than results obtained with *EOTPR2000*™ setup from *Teraview* Company [2-5].

After analysis of waveguides, we utilized this method to localize open circuit in a BGA (ball grid array) package, a TSV and a daisy chain. We draw in figure 4, an example of simulated structure corresponding to a BGA and a via.

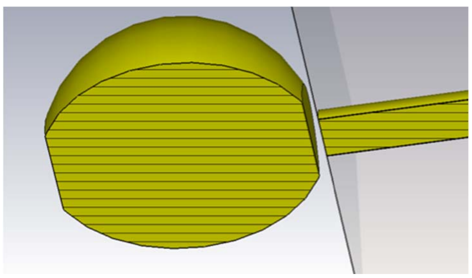


Fig. 4 : BGA ball with an open. A space was added between the ball and the via.

We performed simulations with and without a space between the ball and the via. Signal with an open is given in figure 5(a) and correctly connected in figure 5(b).

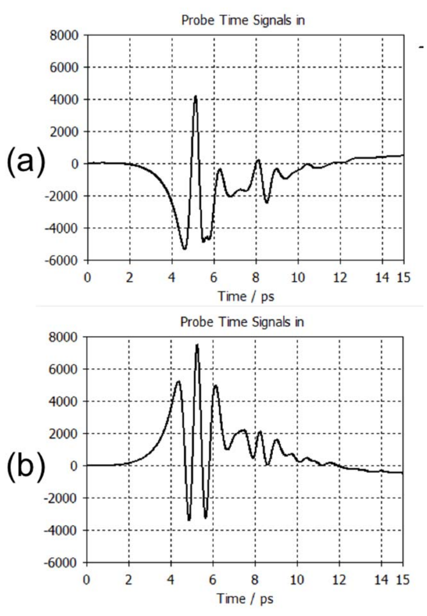


Fig 5 : (a) Signal with open (b) correctly connected.

We report an inversion of the phase field and a substantial shape difference around 7ps. This inversion is typical presence of an open in the circuit. Since localization is limited to 20µm due to pulse duration, we can detect defects with size under localization resolution. Moreover, detectability of such a defect depends on the distance of the two components. It was demonstrated that we can detect an open after up to 12 mm propagation in a daisy chain [4].

IV. Summary

GTPR is an emerging technique for non destructive testing of packages and terahertz waveguides. We show how FDTD simulation can be used to predict signal from typical failures found in microelectronic industry. Current work is now focused on experiments with the near field probe and a waveguide.

Acknowledgements

We thank *Dassault CST Microwave Studio*, *Protemics GmbH* and *Teraview LTD* for their cooperation and support.

References

[1] Guillet, J.-P., Chusseau, L., Adam, R., Grosjean, T., Penarier, A., Baida, F. and Charraut, D. (2011), “Continuous-wave scanning terahertz near-field microscope”. Microw. Opt. Technol. Lett., 53: 580–582. doi:10.1002/mop.25754

[2] E. Kowalczuk, A. Bhattacharya, K. C. Lee, J. Alton, M. Igarashi, et S. Barbeau, “ Fault Localisation of defects using ElectroOptical Terahertz Pulse Reflectometry and 3D EM modelling with Virtual Known Good Device “, *Proc. IEEE 3D Syst. Integr. Conf. 2014*, p. 14, 2014.

[3] D. P. Vallett, D. A. Bader, V. V Talanov, J. Gaudestad, N. Gagliolo, et A. Orozco, « Localization of dead open in a solder bump by space domain reflectometry », in *Proc Int Symp Lest, Fail Anal (ISLFA)*, 2012, p. 1720.

[4] A. Reverdy, M. Marchetti, A. Fudoli, A. Pagani, V. Goubier, M. Cason, J. Alton, M. Igarashi, et G. Gibbons, « Electro Optical Terahertz Pulse Reflectometry, a non destructive technique to localize defects on various type of package », *Microelectron. Reliab.*, vol. 54, nº 910, p. 20752080, 2014.

[5] J. Alton et M. Igarashi, « Non-destructive fault localization in advanced IC packages using electro optical terahertz pulse reflectometry », *Microelectron. Packag. Conf. , 2013 Eur.*, p. 14, 2013.