Signal Propagation Properties of Anisotropic Conducting Polymers up to 110 GHz and their Applicability in Test Fixtures

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Abstract — Over the past decades data rates and hence frequencies rose continuously. Extrapolating this trend into the future leads to challenges with temporary microwave interconnects used in test adapters. Existing test socket concepts are going to reach their applicability limit. Most promising candidates to meet the requirements of the emerging challenges in microwave device interfacing are thin, anisotropic conducting polymers. This paper focuses on newly developed measurement methods for evaluating the microwave characteristics of anisotropic conducting polymers up to 110 GHz.

I. INTRODUCTION

During IC-test and testing of subassemblies, temporary contacting is required. To achieve test interconnects, e.g. rigid contacts and spring loaded pins are utilized [1,2]. Due to increasing frequencies the size of those structures is in the order of a wavelength, causing parasitics and finally limiting test bandwidth.

To further increase maximum test frequency the contact element between impedance matched printed circuit board (PCB) and device under test (DUT) should be as short as possible. To this purpose, thin, flexible sheets of anisotropic conducting polymers are promising candidates [3].

Anisotropic polymers only show conductivity in the direction normal to the material plane, which allows perpendicular interconnects without shorting adjacent pins [4]. This behavior is achieved by an internal metal structure which varies depending on technology and vendor. For example, there are the so-called BallWire® [5] or ZebraStripes™ [4] technologies as shown in Fig 1 and Fig 2 respectively.

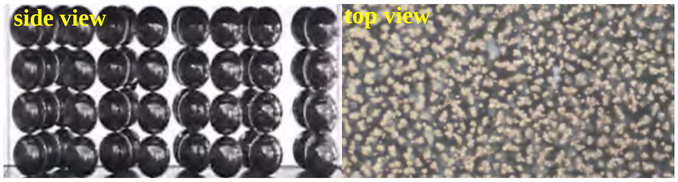

Fig.1: Anisotropic conducting polymer with BallWire® technology to achieve conductivity in vertical direction only, side view (left, image of side view from www.paricon-tech.com) and top view (right)

These polymers have to be characterized in terms of their impact on signal propagation, like loss, parasitic reactance, contact resistance and resulting possible impedance mismatch at microwave frequencies.

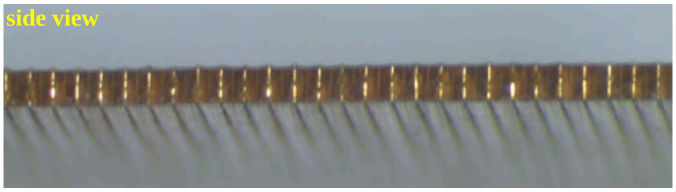

Fig.2: Photograph of an anisotropic conducting polymer with ZebraStripes™ technology to achieve conductivity in vertical direction only

Therefore, a coaxial measurement assembly was developed to precisely measure insertion loss up to 110 GHz. Moreover, a microstrip assembly and a dummy chip with ball grid array (BGA) package were connected by a polymer to a PCB board in order to obtain results comparable to later application.

II. MEASUREMENT ASSEMBLY AND RESULTS

A. 2.4 mm Coaxial Assembly

A simple but very accurate characterization method is to insert the conductive polymer between the faces of a sexless coaxial connector pair, e.g. PC-7. As these faces are calibration reference planes at the same time, only the properties of the polymer are measured. As the frequency range of PC-7 extends to only 18 GHz, a similar interface was realized by modifying a 2.4 mm inter series connector which can be used up to 50 GHz (Fig 3).

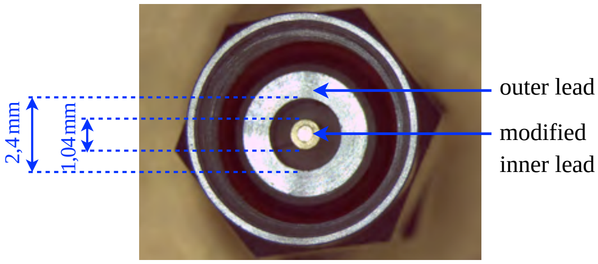

Fig.3: Modified 2.4 mm connector to measure polymer properties up to 50 GHz

Since the polymer would be punctured by the pin of the male connector, the connector had to be modified for those measurements. The inner lead was cut flush with the outer lead, so that the inner and outer lead are in the same plane.

Additionally this plane is identical to the reference plane of the 2.4 mm series connector. Calibration with an unmodified connector of the same type then assures that the polymer surfaces lie on the reference plane for s-parameter measurements. The advantage of this methodology is, that solely the polymer is measured, i.e. all disturbing influences from cables and connectors are eliminated.

The measured insertion loss up to 40 GHz of four anisotropic conducting polymers of different technology is shown in Fig 4 in comparison to the response of the empty connector without polymer.

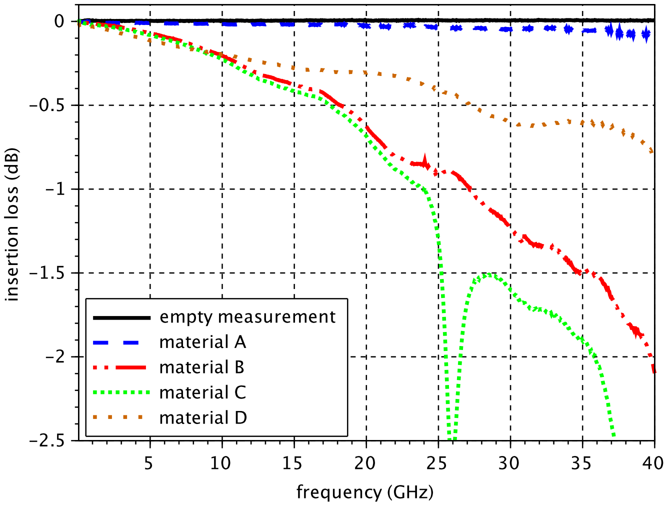

Fig.4: Insertion loss of different conducting polymers

The polymers show very different insertion loss characteristics over the frequency range. At 40 GHz the obtained figures are 0.08 (A), 0.8 (D), 2.1 (B) and 4 dB (C) respectively.

After inserting the polymer into the modified connectors, the screwcaps were always tightened with the same low torque to ensure comparability. Two of the tested polymers, material C and D, however, did not well cope with repeated contact cycles. Therefore, those material are not suitable for use in test fixtures. From the remaining materials, polymer A was further examined because of its superior electrical performance.

B. *1.0 mm Coaxial Assembly*

To further increase measurement frequencies up to 110 GHz a 1.0 mm through standard from a calibration kit instead of a modified 2.4 mm inter series connector was adapted in the same way as described above. The modified sexless contacts are shown in Fig 5.

Due to the dimensions of the 1.0 mm connectors, the contact area of the inner lead is so small, that the spring fingers of the jack had to be plugged in order to increase the contact area.

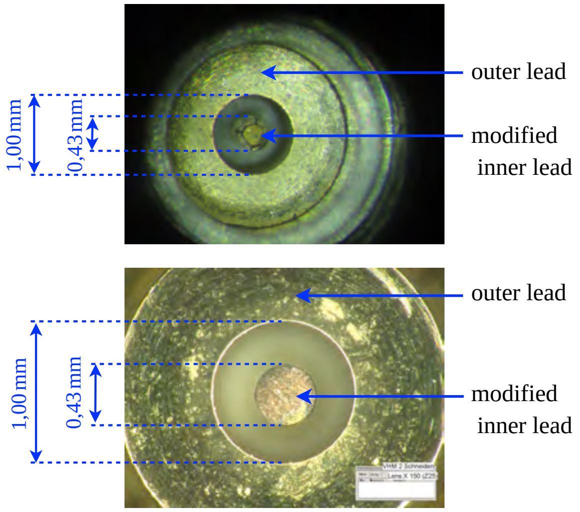

Fig.5: Modified 1.0 mm calibration kit (through) to measure polymer properties up to 110 GHz

This ensures, that enough vertical metal structures in the polymer are in contact with the inner lead in order to achieve low DC resistance.

Fig 6 shows measured insertion loss of material A. The polymer causes very low loss of about Δ IL=1 dB at 110 GHz. To confirm the measured loss figures with regard to repeatability the measurement was repeated after complete disassembly.

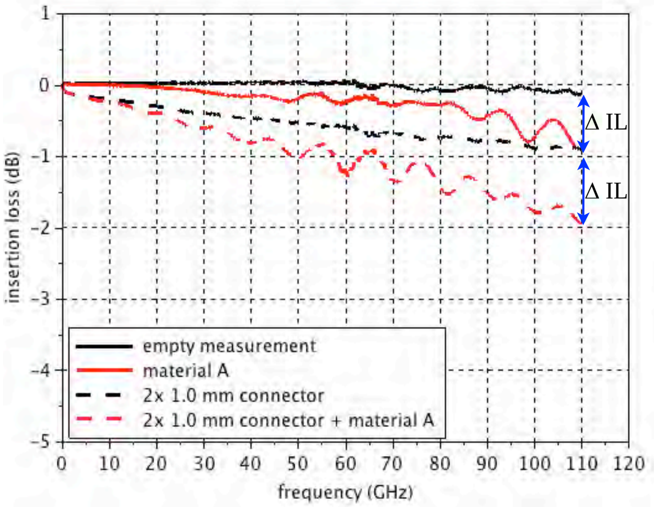

Fig.6: Insertion loss of material A measured with different reference planes

During the second measurement (dashed lines), the assembly was calibrated with reference planes shifted behind the connectors like sketched in Fig 7.

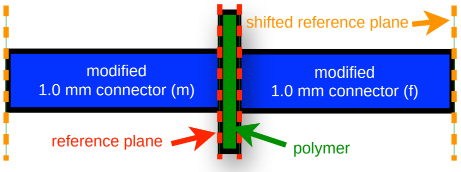

Fig.7: Positions of the reference planes during measurements

The measurement with shifted reference planes confirms the loss figures found before, since the difference between the insertion loss obtained with the empty specimen holder and the insertion loss measured with polymer delivers nearly the same figures over the entire frequency range. This also justifies the described calibration routine utilizing unmodified connectors.

C. *Microstrip-to-Microstrip Transition*

To create a situation comparable to later application, a microstrip-to-microstrip transition as shown in Fig 8 was used instead of sexless contacts.

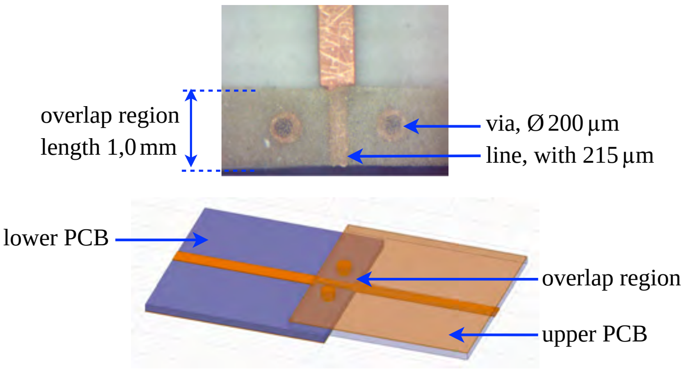

Fig.8: Microstrip-to-microstrip transition connected with conducting polymer

The transition is formed by two identical PCBs with microstrips on top. One of them is turned upside down and overlapped with the other. The traces are narrowed in the overlap region to ensure an impedance of 50 Ω. The impedance profile of this assembly, obtained by frequency domain reflectometry, is shown in Fig 9.

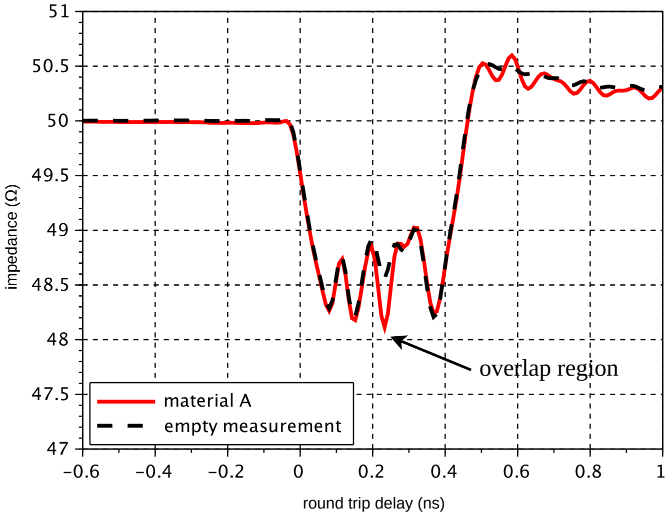

Fig.9: Impedance profile of the microstrip-to-microstrip transition

The impedance of the microstrip line is about 48.5 Ω due to production tolerances. The dashed black line shows the impedance profile of the assembly without polymer inserted. The impedance profile is slightly changed in the contact region by inserting a polymer, leading to a capacitive drop between 0.2 and 0.3 ns. This capacitive behavior in the transition region can mainly be attributed to the geometry change due to the additional polymer thickness of 60 µm.

D. *Transition from PCB to Chip with BGA grid*

A possible test fixture to temporarily contact an IC with BGA grid is shown in Fig 10. It consists of a PCB board designed for the footprint of a BGA package (0.8 mm pitch), which also carries the socket for mechanical fixturing of the DUT. The feed lines are microstrip lines with contact pads for probe tips at the other end.

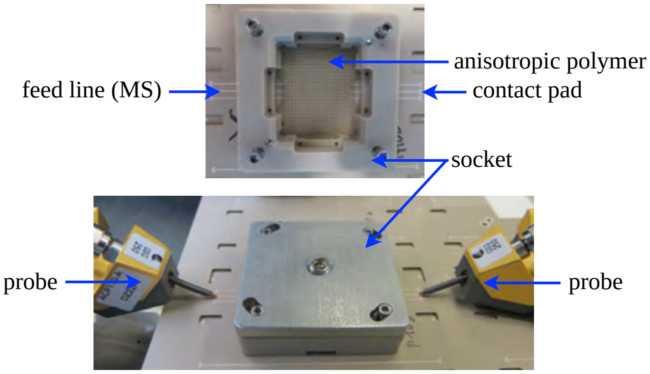

Fig.10: PCB to chip transition with test socket

As DUT, a dummy chip was used that contained only trough lines in an inner layer and was made of the same material as the PCB. The measured impedance profile is plotted in Fig 11.

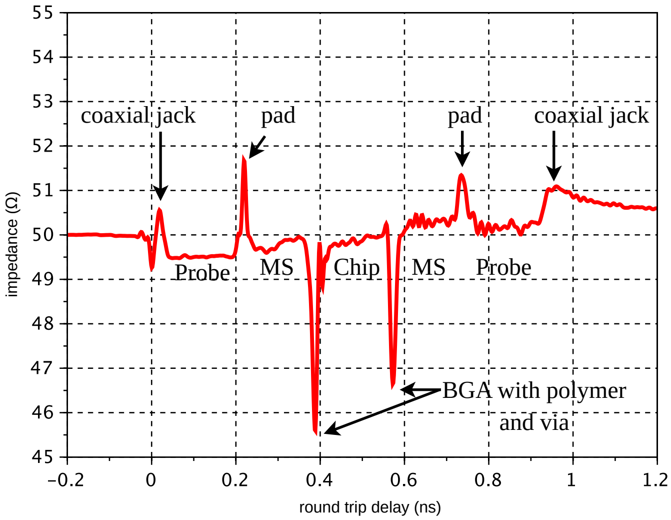

Fig.11: Impedance profile with transitions from PCB to BGA chip

Since a coaxial calibration was utilized, the reference planes were located at the connectors of the measurement cables and the first spike is due to the coaxial connector of the probe. The next occurs at the transition from probe tip to the PCB pad.

After a short microstrip (MS) section, the polymer supported contact can be recognized by its parasitic capacitive behavior at about 0.4 ns. From the center of the dummy chip at 0.5 ns, the symmetry of the structure causes the following, reversed sequence spikes.

This test fixture allows to characterize respectively resolve structures in the DUT as can be seen between 0.4 and 0.6 ns. In this case, for test purposes, it is simply a 50 Ω stripline.

Note that the capacitive mismatch at the transition to the DUT is mainly caused by the BGA layout and directly following, mismatched through-connection (via) to the inner layer. The polymer hardly has any impact on the response shown in Fig11, as it was already stated in section C (Fig 9).

For completeness, the insertion and return loss are shown in Fig 12 up to 40 GHz. Keep in mind that the responses are measured end to end from coaxial reference plane.

In total, this means, a PCB with the footprint of the DUT combined with a suitable conducting polymer and a simple mechanical fixture can be utilized as test fixture for microwave frequencies.

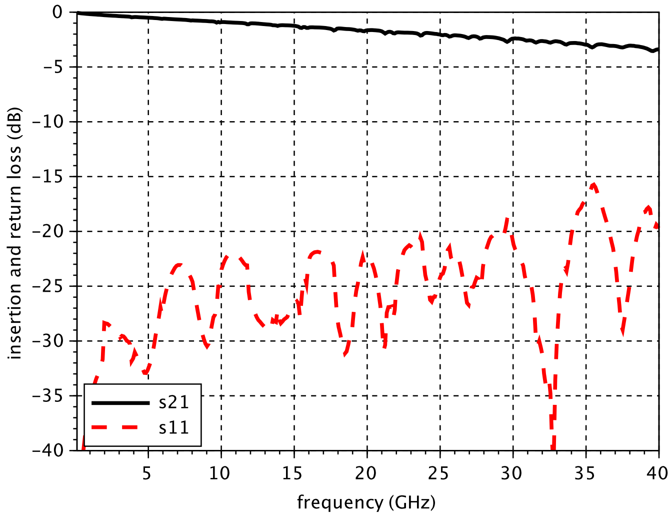

Fig.12: Return and insertion loss in dB measured end to end

Limiting factors are the footprint dimensions as well as via transitions rather than the polymer, as long as the surface area is large enough to contact a sufficient number of vertical conducting structures and thus to prevent noticeable series resistance.

III. CONCLUSION

Some anisotropic conductive polymers are very sensitive to contact force, so that they are damaged after one connection. Those materials are not suitable for test fixtures aimed at many contact cycles.

Basically, the signal paths established by coductive polymers are very short compared to state of the art technology like spring loaded pins. Therefore they are appropriate candidates for this purpose.

Nevertheless, there are huge differences in their electrical performance as was be measured with modified 2.4 mm and 1.0 mm sexless assemblies up to 110 GHz. Some of the examined polymers show very low loss up to 110 GHz. In application, it should be taken care to have sufficient contact area in order to avoid an increased series resistance.

The geometry of an interconnect is crucial for obtaining impedance matched signal paths. The chosen polymer itself has hardly an effect on this discontinuity.

The performance of temporary microwave interconnects can be considerably improved by thin conductive polymers. A test fixture can be developed by combining a simple PCB with the footprint of the DUT, the polymer itself and a mechanical mounting.

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