FOR 77/79 GHZ SAFETY AND RELIABILITY APPLICATIONS THE MOST RELIABLE LAMINATES ARE USED

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Abstract

Due to the expected potential growth of 77/79 GHz ADAS (Advanced Ariver-Assistance System) several non-PTFE (Polytetra Fluoro Ethylene) laminates are trying to find their way into designs. However from electrical and mechanical reliability points of view non-reinforced PTFE/Ceramic laminates still provide a leading edge.

The high consistency of dielectric constant and loss factor of the thermoplastic material PTFE over the required operating temperature range at resonance frequency of the sensors has been recognized by the RF and microwave industry since tens of years. This is also one of the main reasons why such types of laminates are being used for every ADAS generation up to now.

For many years only one kind of such laminate was available and therefore is widely used in the industry. 2017 saw the emergence of another such type of laminate, whose tested reliability data confirm that the selection of non-reinforced PTFE laminates for 77/79 GHz is the correct one. In fact, certain features demonstrate a second generation laminate is needed in order to meet the requirements of next generation 77/79 GHz ADAS.

The market introduction of almost no profile ED (Electro-Deposited) copper foil provides an even improved insertion loss over rolled annealed copper foil, in addition to its lower cost. Only PTFE laminates result in high enough copper peel strength even at repeated rework cycles.

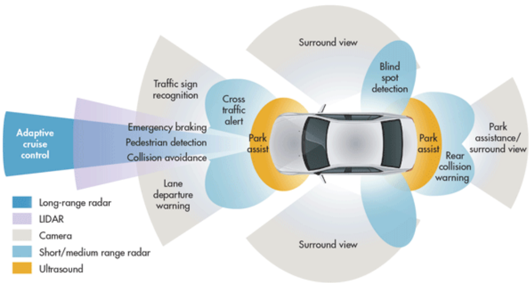

Fig 1: ADAS applications

The Case for ADAS

Why are we now so interested in 77 GHz ADAS? It has been around for some time, although in small volumes. The market acceptance is becoming quite high, and in a similar way as ABS years ago it gets cascaded down from luxury cars to almost every car. Exponential growth rates in the next few years are expected – and will happen, because all the car makers want to introduce ADAS.

Safety and reliability have become key words in the industry.

Fig. 2: 77 GHz ADAS Sensor (Courtesy of Robert Bosch GmbH)

Fig. 3: 77 GHz ADAS Sensor (courtesy of Robert Bosch GmbH)

Base Material Characteristics

The RF laminate used in the printed circuit board is required to be very stable over a very wide temperature range. PTFE laminates show a very tight DK/DK(@23C) (Dielectric Constant/Loss Factor) behaviour from -50 to +150 °C (Fig. 4):

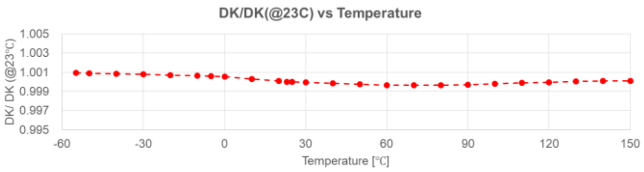

Fig. 4: PTFE laminates show a very tight DK/DK(@23C) behaviour from -50 to +150 °C

Likewise the gradient of DF over the same temperature range is very low (Fig. 5):

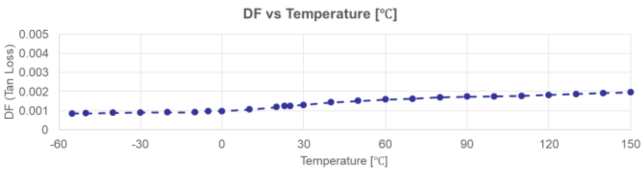

Fig. 5: DF of PTFE laminates from -50 to +150 °C

Non-PTFE organic resins are bound to have higher levels of natural electrical polarity - the Carbon-Fluorine bond in PTFE is short and not very polarizable in an electrical field, while Carbon-Oxygen bonds are naturally more polarizable. This means a lesser degree of stability over frequency

NF-30 is a non-reinforced PTFE laminate, just containing ceramic fillers. Same as the laminate being used for current 77 GHz designs, it is electrically very homogeneous in all 3 directions. A woven fiberglass reinforced resin will naturally have some electrical anisotropy due to the fiberglass weave structure, which in particular high mmWave frequencies are sensitive to. It is possible to flatten the fiberglass however the warp yarns never get flat. There will always be a higher level of anisotropy in these type of resin systems.

Recent developments in copper foil technology have resulted in the introduction of a so-called "Almost No Profile" ED copper foil [Taconic grade name for 0.5 oz is ULPH] (Fig. 6). Compared with a traditional Very Low Profile copper foil this foil leads to better defined and much steeper sidewalls of traces due to less copper treatment which has to get etched out of the substrate; in other words, finer features with tighter tolerances are possible.

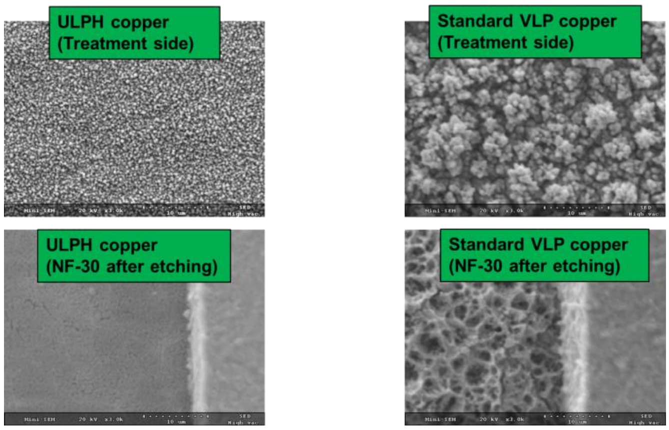

Fig. 6: Comparison VLP copper foil with ULPH copper foil (courtesy of Circuit Foil Luxembourg Sàrl)

And what's of significance is that the insertion loss gets improved considerably – the higher the frequency the better the insertion loss (Fig 7.):

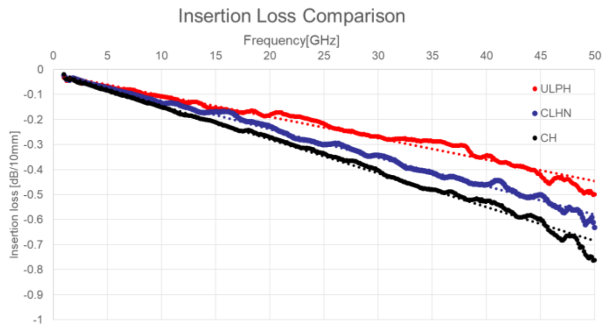

Fig. 7: NF-30 Insertion Loss Comparison of 0.5 oz "Almost No Profile" copper foil (ULPH), reverse treatment copper foil (CLHN), and Very Low Profile copper foil (CH)

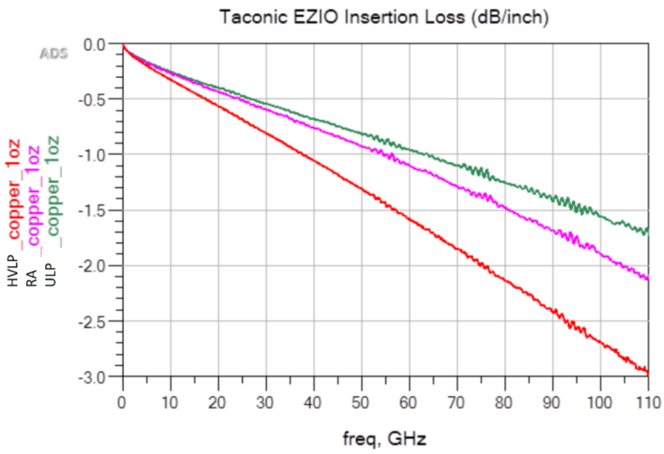

Fig. 8: Insertion Loss Comparison of 1 oz "Almost No Profile" copper foil (ULP), Rolled Annealed copper foil (RA), and Flat Profile copper foil (HVLP) on a different substrate, measured up to 110 GHz

Insertion Loss Comparison of 1 oz “Almost No Profile” ED copper foil (ULP), Rolled Annealed copper foil (RA), and Flat Profile ED copper foil (HVLP) on a different substrate, measured up to 110 GHz shows that the improvement gap widens even more compared with RA copper foil (Fig. 8).

A major advantage of a thermoplastic substrate, such as PTFE, lies in the high copper foil peel strength even after repeated IR reflows, irrespective whether an organic surface protection (PSR) is used or just immersion tin. Measured peel strength values are in the same range as of standard Very Low Profile copper foil (Fig. 9).

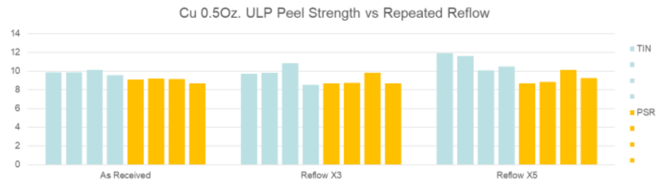

Fig. 9: Copper Peel Strength of 0.5 oz “Almost No Profile” copper foil (ULP) after 3x and 5x IR reflow

mmWave Measurements

All theory is fine, however the proof is in the pudding when doing actual DK and Insertion Loss tests at 77 GHz. Microstrip ring resonator test method using waveguide connectors is applied for DK measurements, whereas strip lines of different lengths are used for Insertion Loss (Fig. 10).

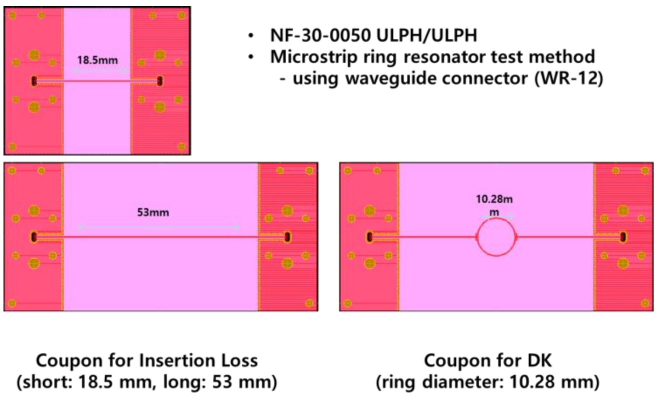

Fig 10: Microstrip ring resonator test coupons for DK and Insertion Loss measurement

Although the Almost No Profile copper foil improves the insertion loss, it also leads to a DK shift to a 0.1 lower value for design purposes at 77 GHz (Fig. 11).

NF-30-0050					
Freq.	DK ULPH	Freq.	DK CLH	Freq.	DK CH
10.011	2.885	9.881	2.973	9.866	2.983
20.118	2.854	19.765	2.972	19.765	2.972
30.055	2.880	29.481	3.010	29.481	3.010
40.032	2.887	39.465	2.983	39.465	2.983
49.962	2.897	49.204	3.001	49.051	3.022

Product	Expected Frequency Shift near 77GHz [GHz]	
NF-30-0050-CH	0.460	0.000
NF-30-0050-CLH	0.696	0.236
NF-30-0050-ULPH	1.863	1.403

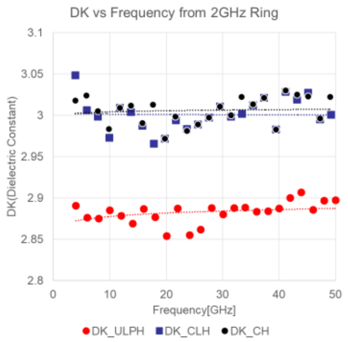

Fig. 11: NF-30 DK shift at frequencies, depending on type of copper foil used

This observed effect is due to the actual profile structure of this copper foil, and can easily be incorporated into any design through simulation software.

S21 of ring resonators measured at -40°C and at +125°C show a quite small frequency drift (Fig. 12):

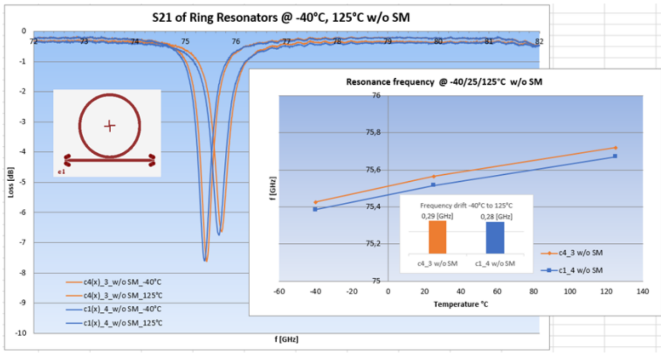

Fig. 12: S21 of ring resonators measured at -40°C and at +125°C: Frequency shift (courtesy of Robert Bosch GmbH)

Also the observed loss in the frequency range between 78 and 80 GHz shows an acceptable increase (Fig. 13):

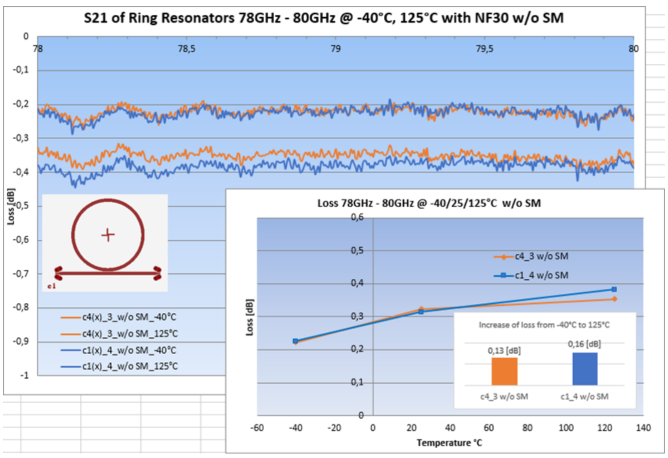

Fig. 13: S21 of ring resonators measured at -40°C and at +125°C: Insertion Loss Printed Circuit Board (courtesy of Robert Bosch GmbH)

Most 77/79 GHz ADAS pcbs are hybrid multilayer pcbs, where only layers 1 and 2 are PTFE laminate.

Aforementioned high reliability of PTFE laminates can easily get demonstrated during 288 °C solder float (Fig. 14 a-c):

Fig. 14a: NF-30 before solder float at 288 °C

Fig. 14b: NF-30 during solder float at 288 °C

Fig. 14c: NF-30 after 30 minutes solder float at 288 °C: no blistering, no delamination!

Taking the unusual step of using rather thick 20 and 60 mil NF-30 to demonstrate via drilling, hole wall desmearing and pth, it is obvious that it is of no issue for this no glass containing PTFE laminate (Fig. 15)

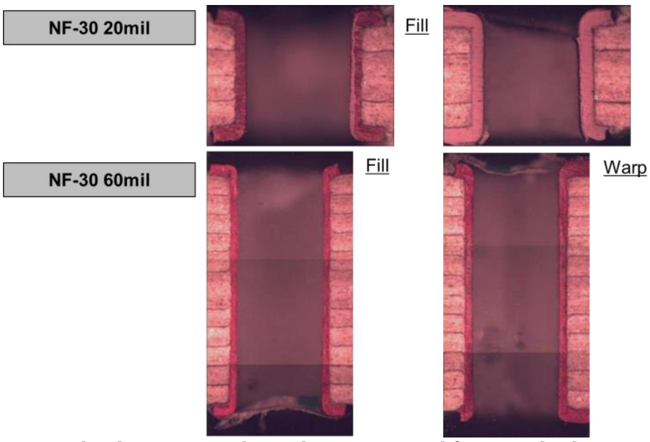

Fig. 15: plated vias in 20 and 60 mil NF-30, viewed from x and y direction

The biggest challenge is thermal cycling of the hybrid multilayer - 1,000 cycles from -40°C to + 140°C (Fig. 16, 17)

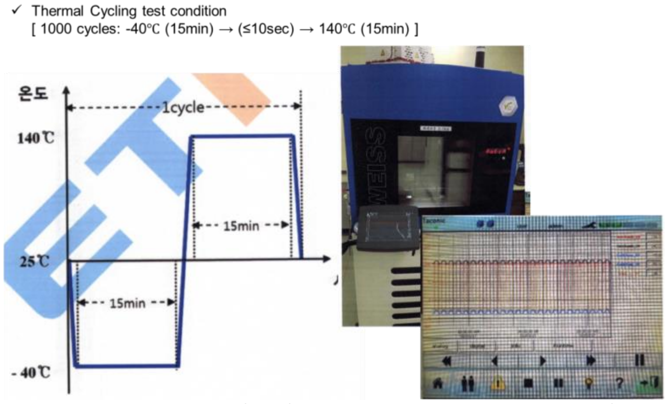

Fig 16: Thermal cycling profile of the hybrid multilayer - 1,000 cycles from -40°C to + 140°C

However the hybrid multilayer survives this test without any issues:

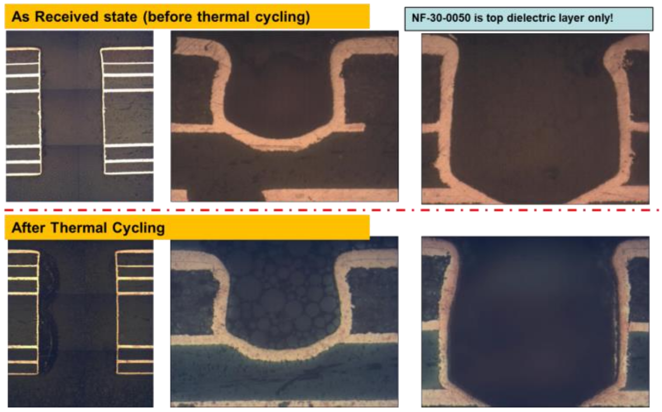

Fig 17: microsectioning of NF-30 hybrid multilyer – entire multilayer and also blind via in NF-30; before and after thermal cycling

And even after 50x solder float (10 s at 288 °C) the hybrid multilayer shows its superior quality (Fig. 18)

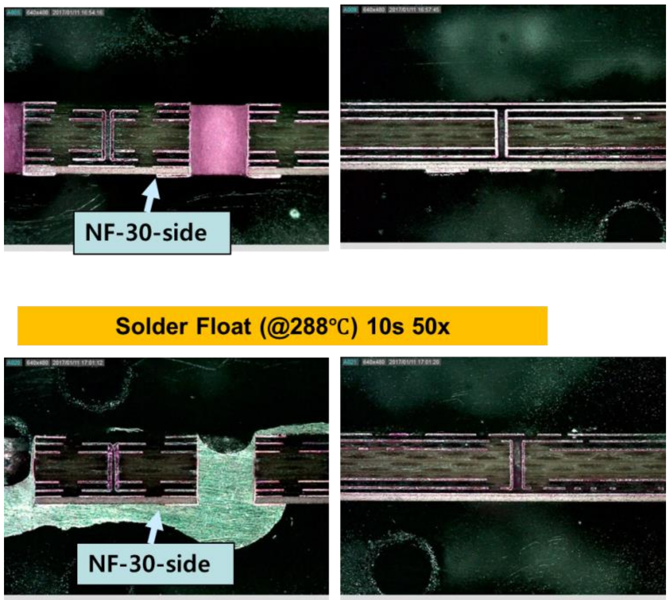

Fig. 18: NF-30 hybrid multilayer after 50x solder float (10 s at 288 °C)

Reliability and electrical performance needs dielectric consistency from laminate production through to field deployment. A known concern with ceramic filled dielectrics is process chemistry absorption during the PCB fabrication steps. Observations in one popular laminate of cosmetic changes, as well as some measured shifts in electrical properties at 77/79GHz. It is much preferred to have finished PCBs with no contamination and NF-30 is constructed to minimize penetration and interaction of most common PCB chemistry. Fig 19 shows tests of machined NF-30 dielectric. This is achieved through care in ceramic filler selection and mixing, leading to better cosmetic results after etching in the PCB production process.

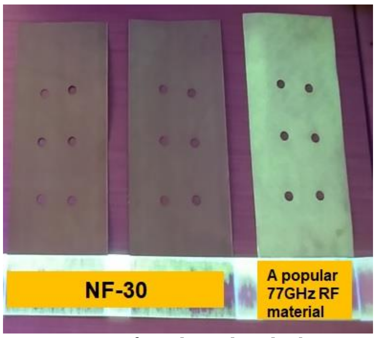

Fig. 19: significantly reduced chemistry absorption of NF-30 vs other materials

Conclusion

NF-30 is truly a high reliability RF base material, suitable for 77/79 GHz ASAS hybrid multilayer printed circuit boards, all-RF multilayer printed circuit boards, as well as double-sided printed circuit boards. The combination of non-reinforced PTFE laminates with Almost No Profile copper foil is the ideal solution – providing the supply chain with a safe knowledge of long term reliability in operation.

References

Except where specific references were made all other information is Taconic internal test information

Biography

Dipl.-Ing. Manfred Huschka spent his entire professional career in the printed circuit board industry: After graduation he was manufacturing printed circuit boards (Braun Ireland Ltd). Thereafter manufacturing FR4 base materials (AlliedSignal Laminate Systems), with his final position being Director Technology Europe. Since 1997 Manfred is with Taconic, manufacturing PTFE base materials. In those more than 20 years he was in charge of the Irish manufacturing plant for more than 10 years, and is Vice President Global Sales.

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