Plastic Dielectric Constant Measurement using TDR and Copper Foil Tape

Neil (Bing) Hao

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http://uniteng.com

Part I: Introduction

In my article Time-domain reflectometer (TDR) theory and implementation [1], I illustrated the PCB dielectric constant measurement using TDR. The same measurement procedure can also be used for plastics such as polypropylene (PP), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), etc.

For RF design, the plastic dielectric constant control become crucial when the RF circuit does not have sufficient clearance from plastic structure. Plastic structure near the antenna causes that the resonant frequency shifts to a lower frequency about 100Mhz to 200Mhz in general [2]. This kind of situation become common due to small product dimension and flexible adhesive antenna using wildly. One way to deal with the resonant frequency shifting is wideband antenna. However, the batter solution is measuring plastic dielectric constant and then modeling the antenna with the necessary plastic structure, casing, etc. More accurate resonant frequency always can be calculated using more accurate model and the accurate dielectric constant is always required by accurate model. Therefore, it is meaningful to discuss the plastic dielectric constant measurement using TDR.

Part II: Dielectric Constant of Common Polymers

Typical Dielectric Constants:

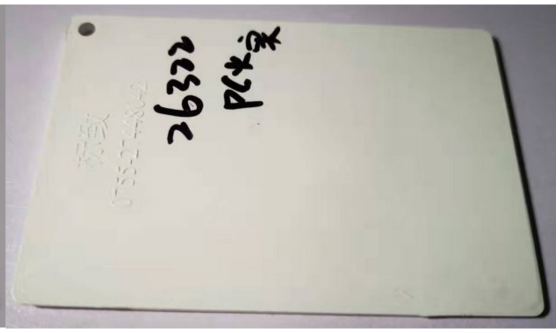
Polymer Name	**Dielectric Constant [3]**
Polycarbonate (PC) High Heat	2.8-3.8
Acrylonitrile Butadiene Styrene(ABS)	2.7- 3.2
ABS/PC Blend - Acrylonitrile Butadiene Styrene/Polycarbonate Blend	2.9-3.2

I used Panlite LN-1250G (Polycarbonate High Heat) from Teijin Chemicals Ltd. for several products, thus I had LN-1250G sample cards. Those sample cards were used in dielectric constant measurement experiment, the details are illustrated in Part III and Part IV. LN-1250G electrical properties are shown in the following form [4].

Electrical properties	Value	Unit	Test Standard
ISO Data			
Relative permittivity (100Hz)	**3.1**	-	IEC 60250
Relative permittivity (1MHz)	**3**	-	IEC 60250
Dissipation factor (100Hz)	**10**	E-4	IEC 60250
Dissipation factor (1MHz)	**90**	E-4	IEC 60250
Volume resistivity	**>1E13**	Ohm*m	IEC 60093
Surface resistivity	**>1E15**	Ohm	IEC 60093
Electric strength	**30**	kV/mm	IEC 60243-1
Comparative tracking index	**275**	-	IEC 60112

LN-1250G Sample Card:

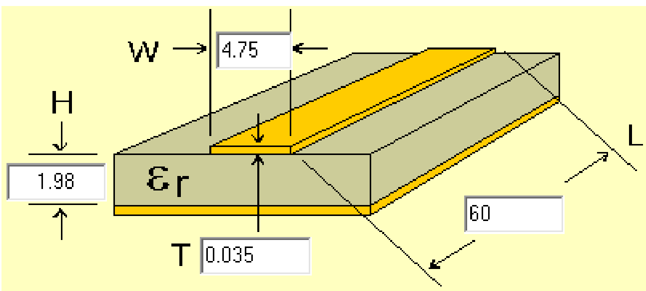
Bottom View



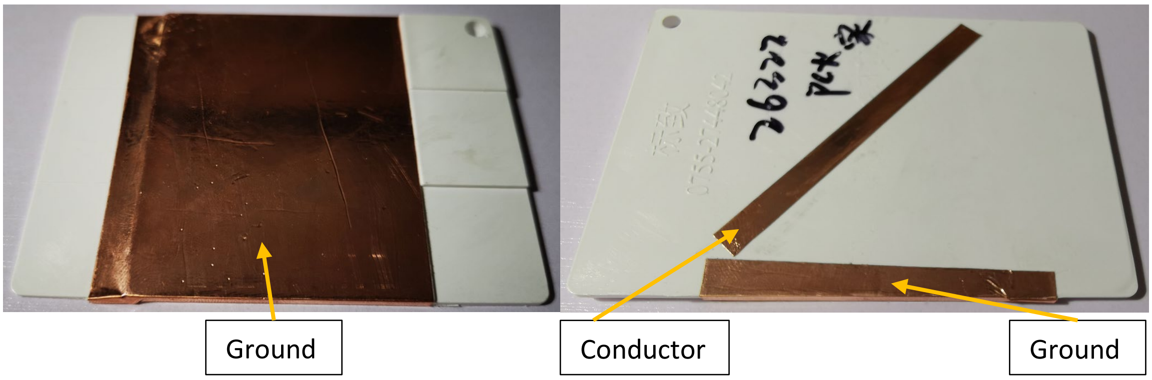
Top View

Part III: Making Microstrip from Scratch

The microstrip circuit board was made by using Panlite LN-1250G as “laminate material” and Copper Foil Tape as Conductor and Ground. The microstrip design is shown in the following diagram.

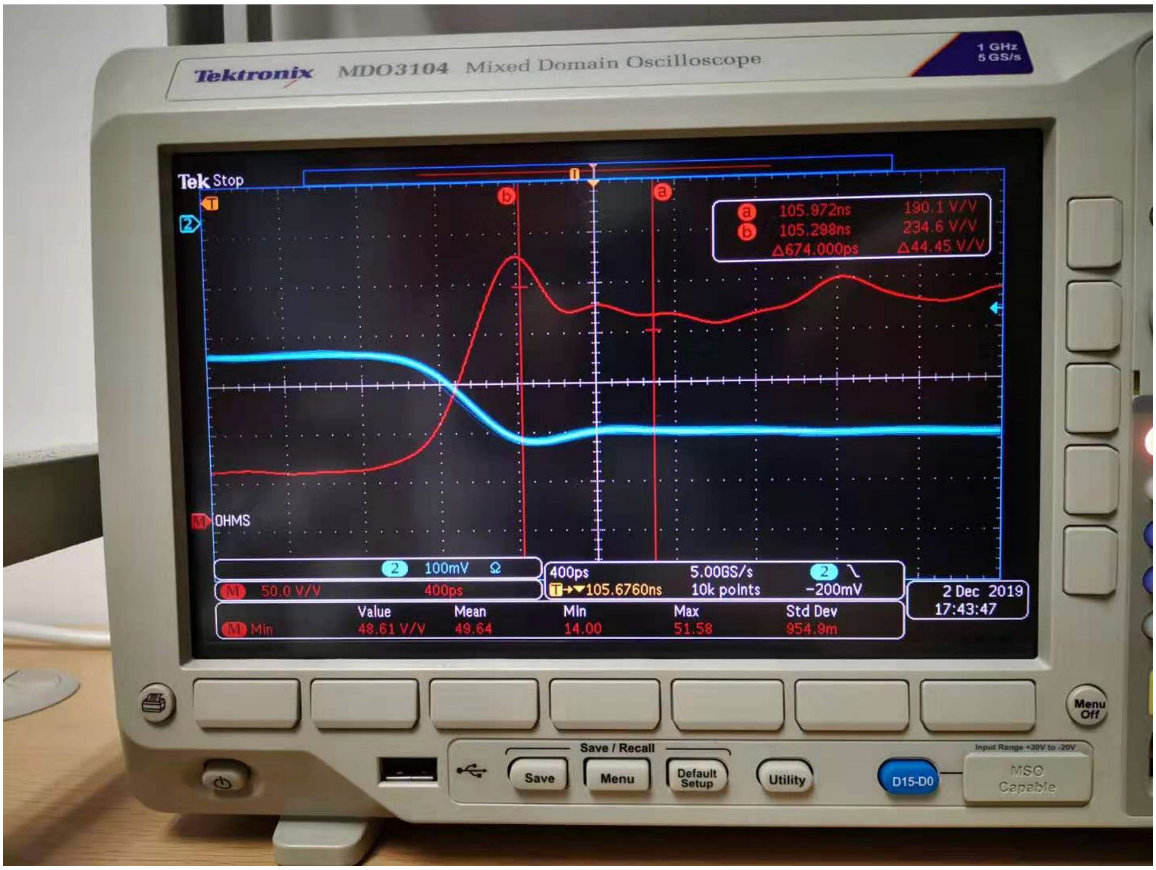


Microstrip Design (Length Units: mm)



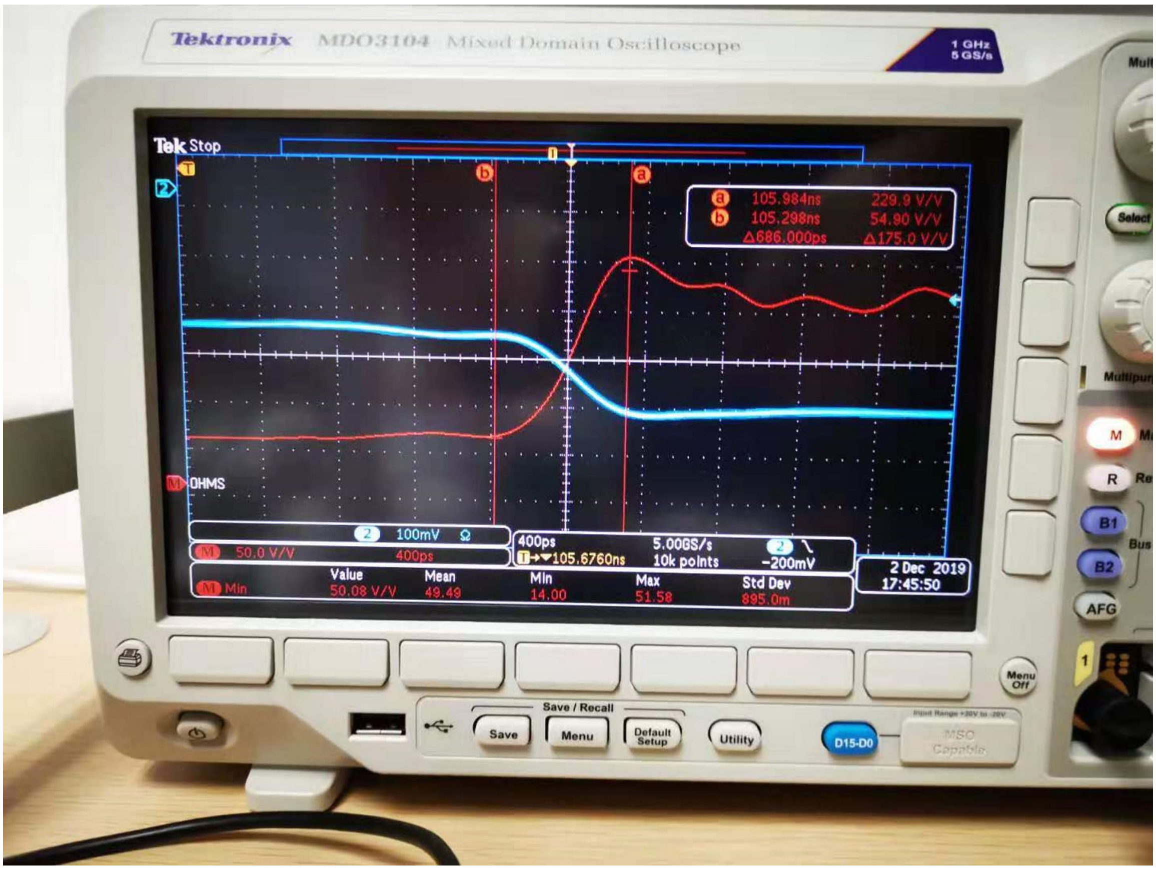
Bottom View　　　　　　　　Top View

Part IV: Plastic Dielectric Constant Measurement



TDR result without DUT

The point at cursor “b” is the starting point for the round way trip of the falling edge.



TDR result with DUT

The point at cursor “a” is the ending point for the round way trip of the falling edge.

According to the microstrip design in Part III:

Round Way Time = 686ps = $0.686 * 10^{-9}$ s

The Length is 0.06 m

Thus,

$$Dk = \frac{2.25 * 10^{16} * (Round\ Way\ Time\ in\ Second)^2}{(Length\ in\ Meter)^2}$$

$$= \frac{2.25*10^{16}*(0.686*10^{-9})^2}{(6*10^{-2})^2}$$

$$= 2.941225$$

Part V: Conclusion

According to the dielectric constant (Dk=2.941225) which was measured in the Part IV and the dielectric constant (Dk=3@1Mhz) which was indicated in the Panlite LN-1250G datasheet [4]. The experimental result matched the data from datasheet. Therefore, plastic dielectric constant can be accurately measured using TDR and Copper Foil Tape.

Part VI: References

[1] Neil (Bing) Hao. Time-domain reflectometer (TDR) theory and implementation. Retrieved Dec 03, 2019, from http://uniteng.com/wp-content/uploads/2019/11/Time-domain-reflectometer-TDR-theory-and-implementation-Neil-Hao.pdf

[2] Neil (Bing) Hao. The Considerations of Antenna Design for IOT and Wearable Devices. Retrieved Dec 03, 2019, from http://uniteng.com/wp-content/uploads/2019/11/The-Considerations-of-Antenna-Design-for-IOT-and-Wearable-Devices.pdf

[3] Dielectric Constant Values of Several Plastics. Retrieved Dec 03, 2019, from https://omnexus.specialchem.com/polymer-properties/properties/dielectric-constant

[4] Teijin Chemicals Ltd. Panlite LN-1250G. Retrieved Dec 03, 2019, from http://www.fredixinternational.com/wp-content/uploads/2016/02/PC-LN-1250G.pdf