UNLOCKING THE TRUE POWER OF ADDITIVE MANUFACTURING FOR EMI SHIELDING

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DO YOU REMEMBER THIS NOISE BEFORE ELECTRO MAGNETIC INTERFERENCE (EMI) SHIELIDING BECAME STATE OF THE ART?

AGENDA

1 **State-of-the-art package level shielding**
- Sample and testing characteristics
- Shielding effectiveness Cu sputtering

2 **Ag MOD inkjet printing**
- Sample preparation
- Sample characterization

3 **EMI shielding from Ag layers**
- Shielding performance
- Reference vs. State-of-the-art

4 **Closing and outlook**
- Proposal for an adjusted specification

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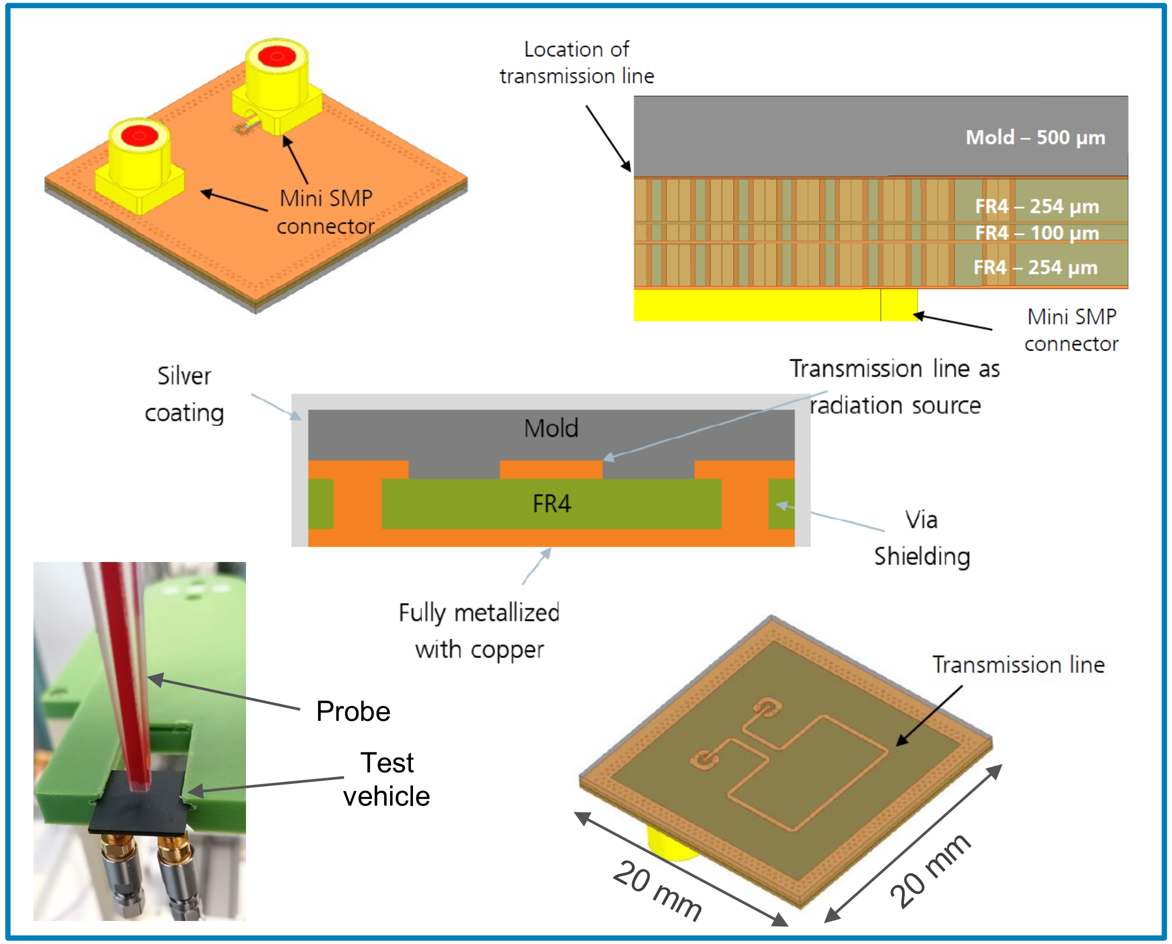
SHIELDING TEST VEHICLE: ACTIVE EMITTER PACKAGE



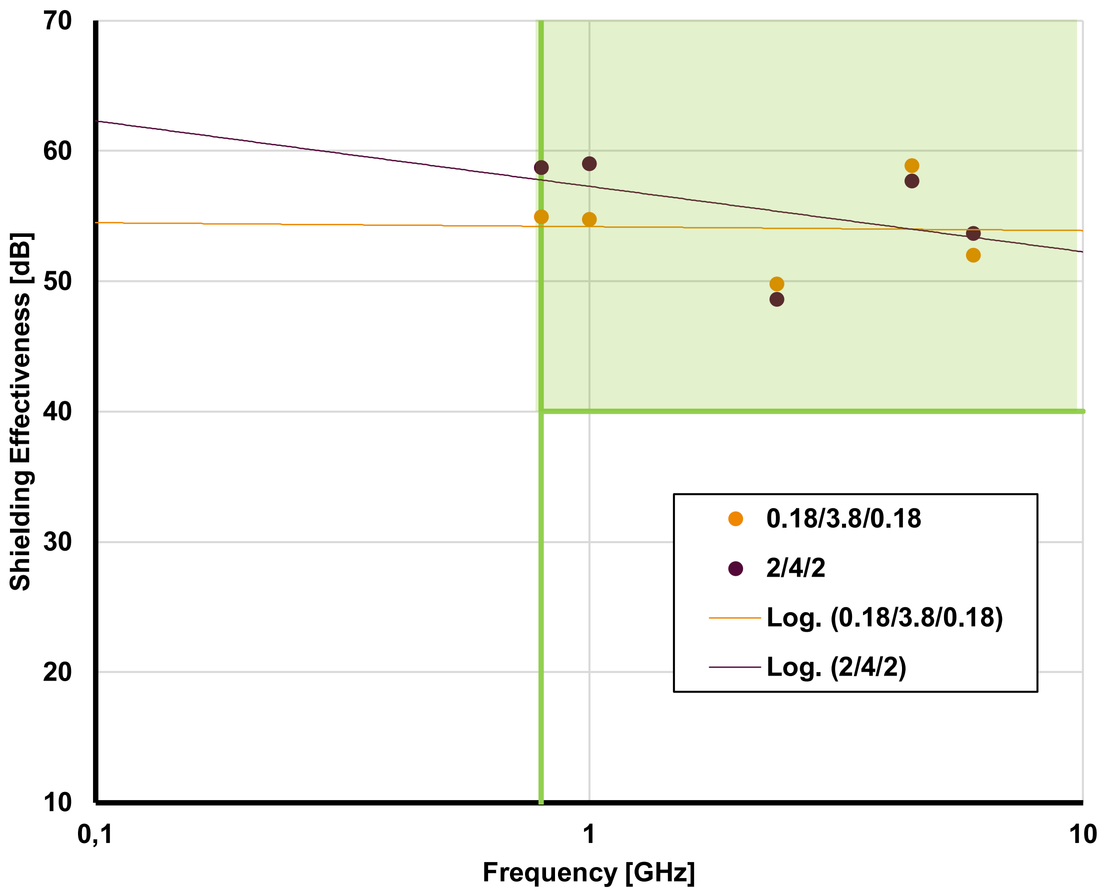
Transmission line package design

- Transmission line emitter package is fully shielded from the bottom
- 608 µm FR4 substrate with vias and grounding structures
- 500 µm EMC mold cap
- Topside fully shielded by conformal coating (Sputter vs. Ag)
- Transmission line excitation by Mini SMP connectors
- 2 units tested per shielding layer thickness
- Backside radiation requires a short probe to sample surface distance of 1 mm for frequencies of 6 GHz

Fraunhofer IZM

Source: Study with Fraunhofer IZM, Berlin, 2022.

SHIELDING EFFECTIVENESS OF STATE-OF-THE-ART CU SPUTTERING



Shielding performance

- Shielding using typical stacks of
  - Steel using Stainless (SuS) for adhesion
  - Cu for shielding
  - SuS for surface oxidation prevention
- Constant shielding between 50 to 60 dB
- No trend between to layer stacks indicates no influence from SuS layer thickness on shielding
- Shielding performance of both stacks significantly higher then typical shielding requirments

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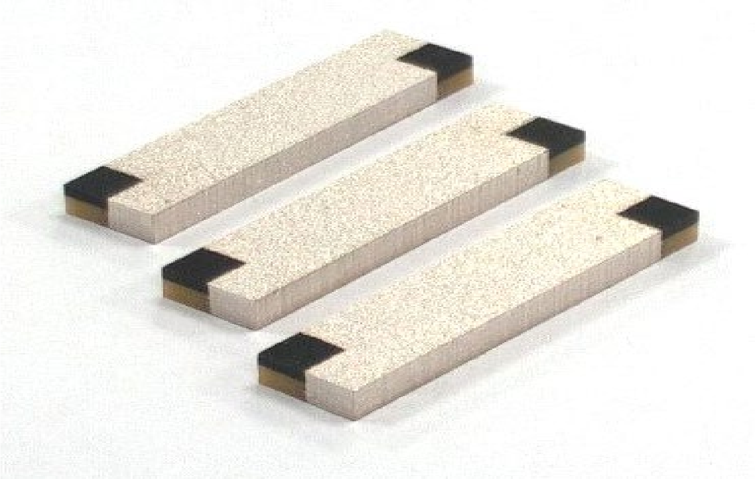
HERAEUS INKJET PRINTING ENABLES SELECTIVE PRINTING

Selective Printing

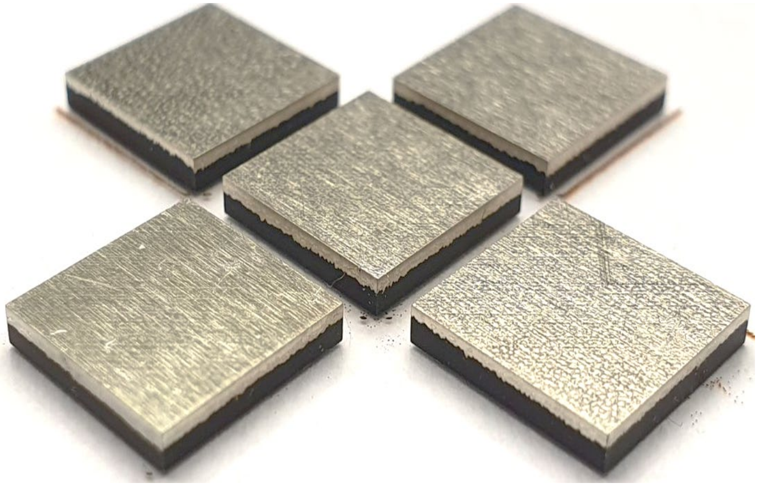


- Selective printing without additional masking or etching process
- Different stand-offs possible by tailored print data generation

Example 1

- Selective printing on topside
- Possibility to print markings

Example 2



- Sidewall stand-off printing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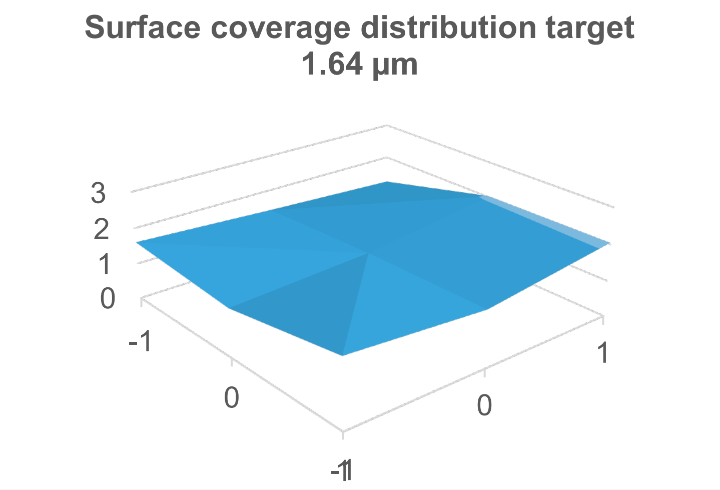
MEASURED TOPSIDE AVERAGE AG THICKNESS IS ON TARGET (XRF)



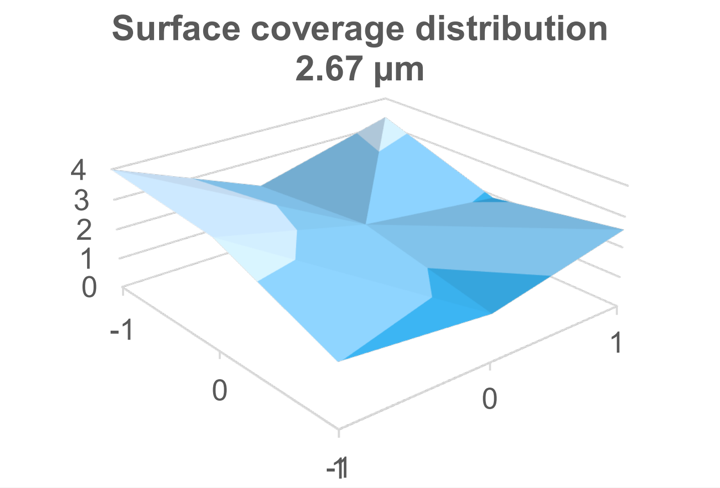
Surface coverage distribution target
1.64 µm

- Homogenous layer coating, no defect at edges or corners
- No trend in layer thickness

1.64 µm				
	[µm]	Position x		
		-1	0	1
Position y	-1	1.605	1.330	1.858
	0	1.405	1.535	1.563
	1	1.227	2.027	2.046
Average	[µm]	1.622		
STDV	[µm]	0.279		
Dev.	[%]	25%		
Target	[µm]	1.64		

- Total thickness variation of 0.28 µm = 25%
- Good match between target and average

$$Dev = \frac{Max - Min}{2\ x\ Average}$$



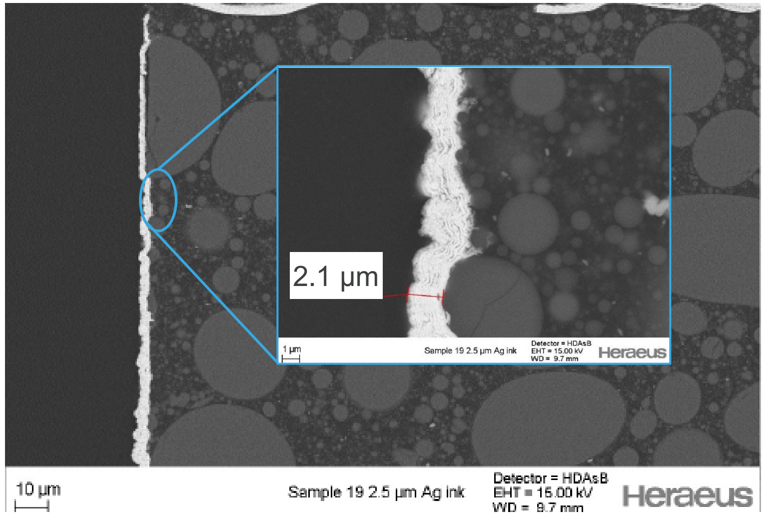
Surface coverage distribution
2.67 µm

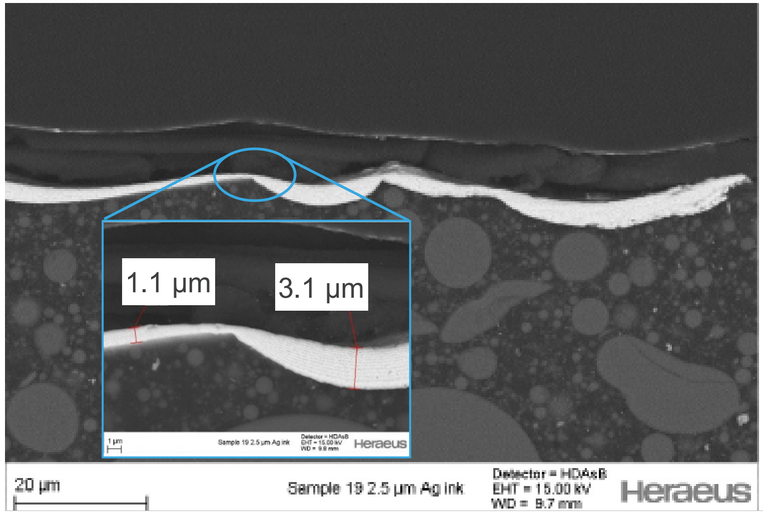
- Homogenous layer coating, no defect at edges or corners
- Lowest thickness at single edge

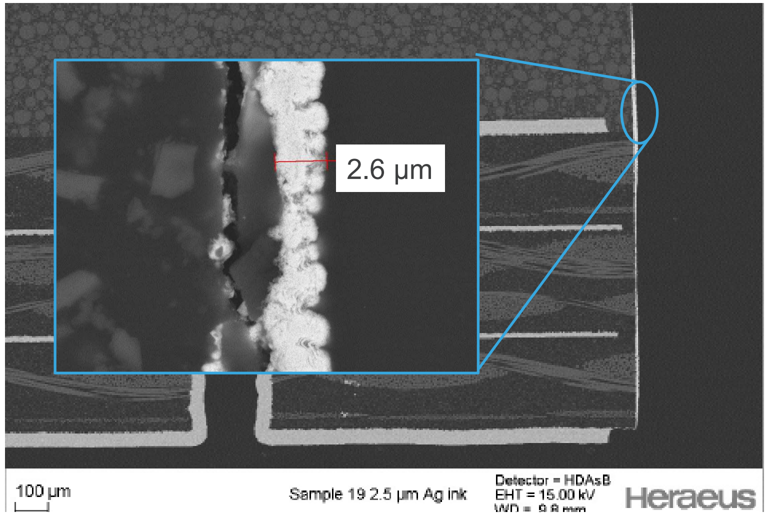
2.67 µm				
	[µm]	Position x		
		-1	0	1
Position y	-1	3.993	3.600	2.012
	0	2.061	2.461	1.560
	1	3.298	1.903	2.579
Average	[µm]	2.607		
STDV	[µm]	0.792		
Dev.	[%]	47%		
Target	[µm]	2.67		

- Total thickness variation of 0.79 µm = 47%
- Good match between target and average

THICKNESS VARIATION DOES NOT AFFECT THE TOTAL SHIELDING AT 2.67 µm







Side wall left

- No thickness trend along sidewall
- Representative thickness measured at 2.1 µm

Top side

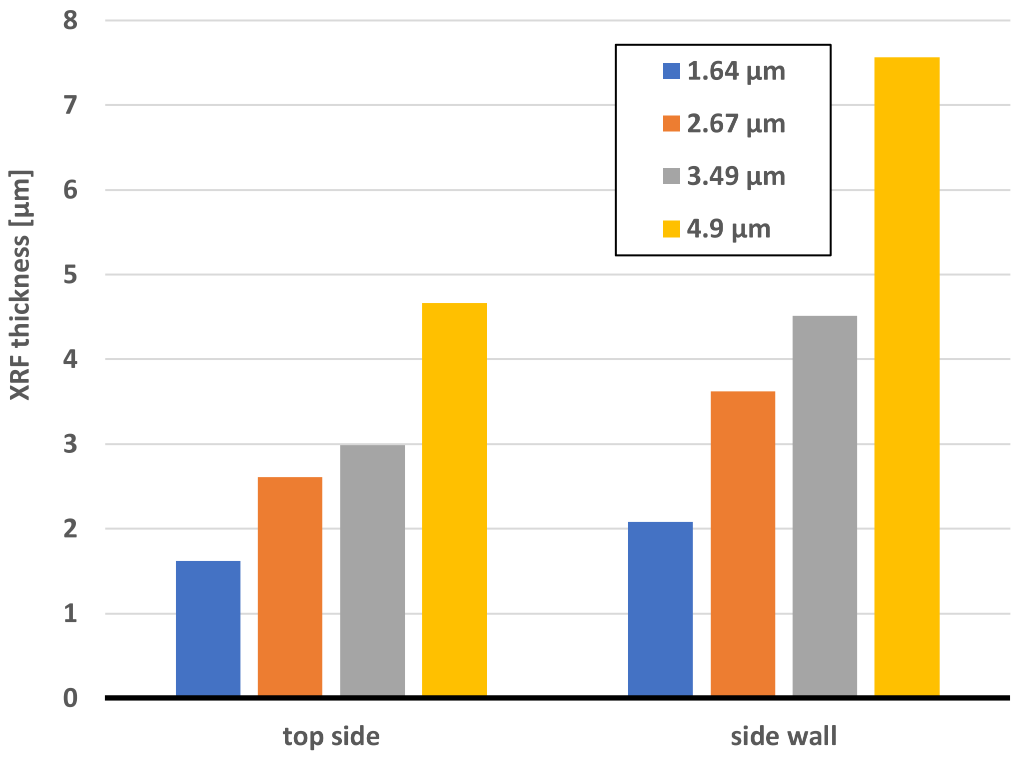
- Thickness variation according to substrate surface roughness
- Variation between 3.1 - 1.1 µm found

Side wall right

- Thickness variations on side walls observable
- Conformal coating over the whole sidewall

Average XRF aspect ratio is confirmed in the cross section

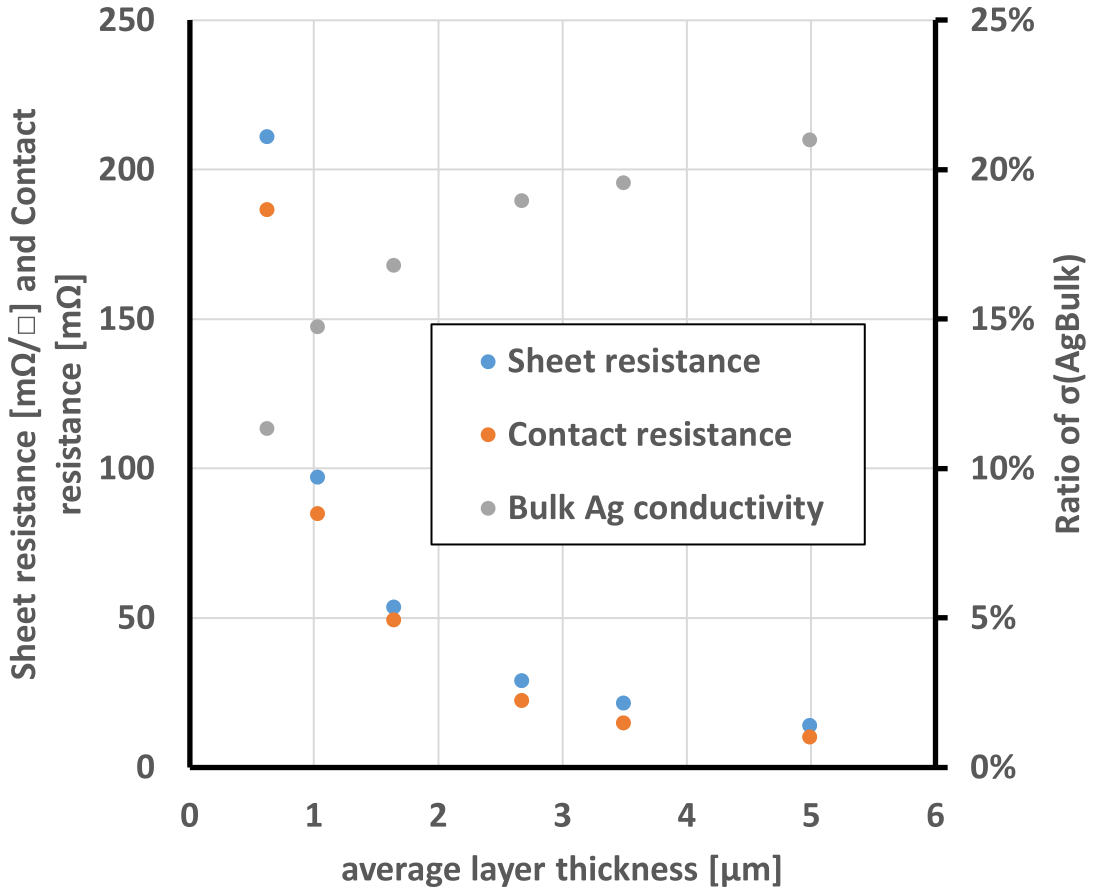
ASPECT RATIO OF 1:1 IS POSSIBLE WITH AG INKJET TECHNOLOGY



Individual samples

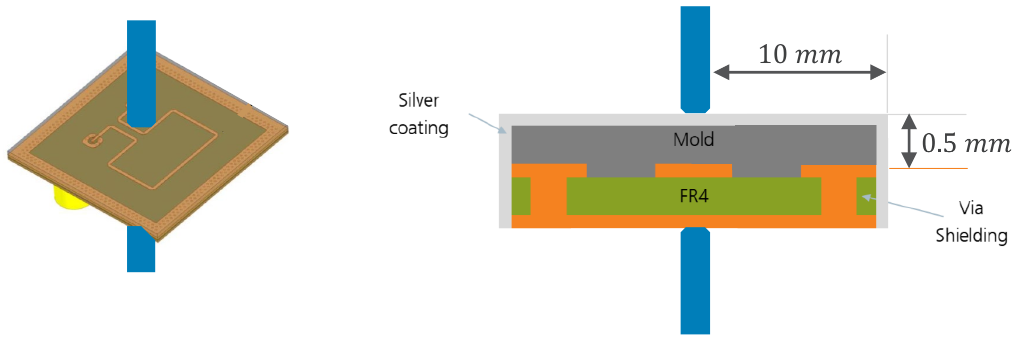
- Each average sidewall is thicker than top side
- Thickness determined by XRF on multiple spots

TRANSFER LAYER THICKNESS INTO A CONTACT RESISTANCE SPEC



Conductivity influence

- Sheet resistance determined by 4-point probe declining resistance with layer thickness
- Contact resistance measured for 10.5 mm over Ag surface
- Identical trend of sheet- and contact resistance
- Bulk Ag conductivity ratio reaches plateau of > 17 % with 180 °C maximum curing temperature at 1.64µm or thicker



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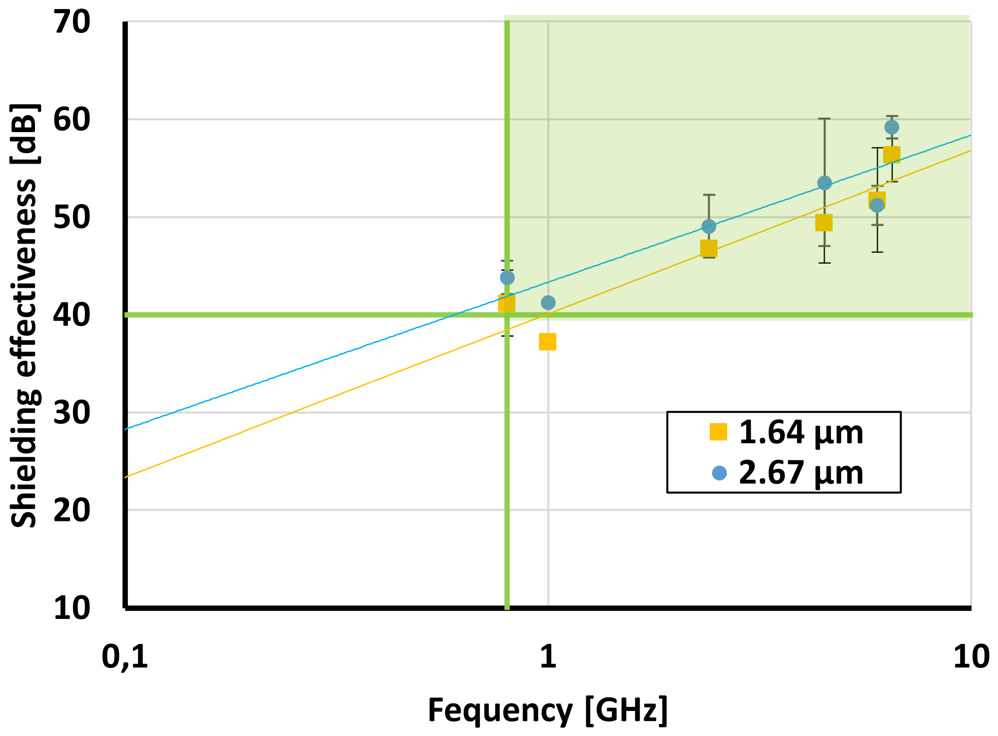
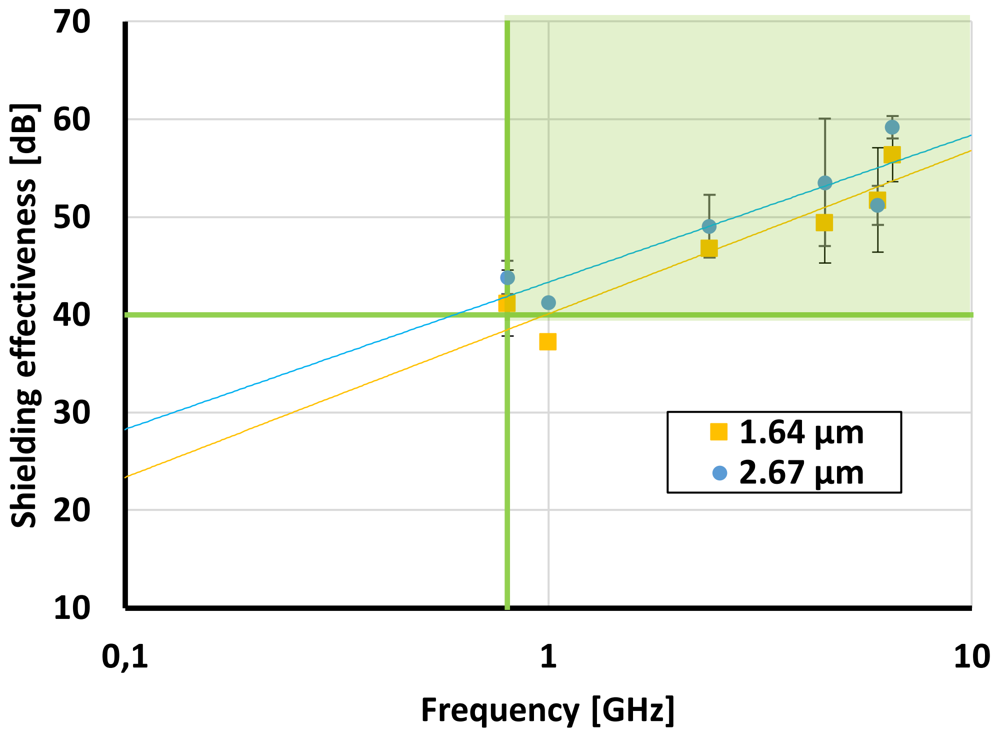
SHIELDING EFFECTIVENESS ON AG PRINTED LAYERS

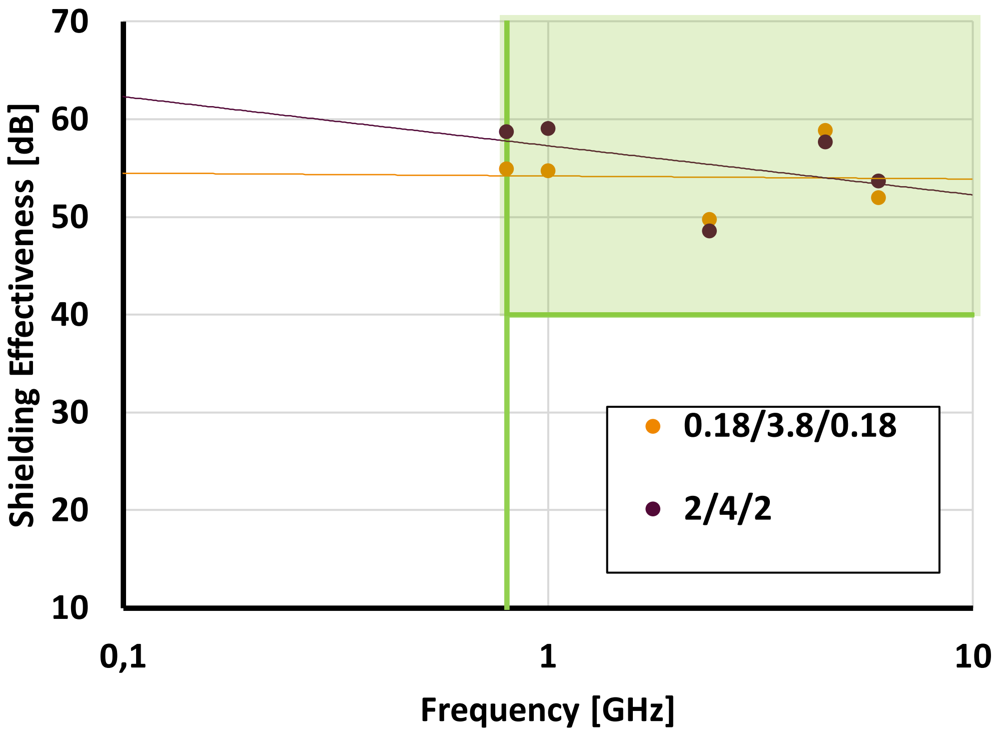


SE vs. *f*

- Linear trend of shielding effectiveness on frequency (*f*, logarithmic)
- Lowest value at *f* = 1 GHz within measurement error of 800 MHz value

SHIELDING EFFECTIVENESS OF AG PRINTING AGAINST CU SPUTTERING



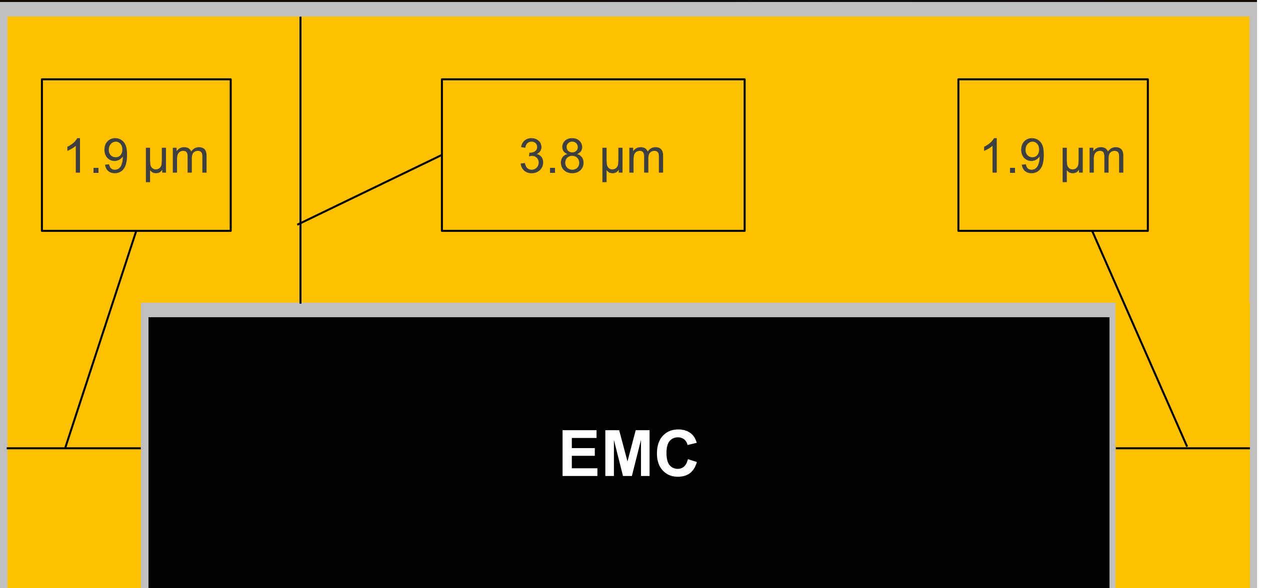


Ag inkjet

- No difference at f ≥ 2.4 GHz within coating thickness
- Low frequencies 1 ≤ GHz shielding achieved with layers between 1.64 – 2.67 µm

Sputter

- No difference between both layer stacks
- Shielding performance exceeding typical requirements indicate overcoating



WHY IS 4 µm THICK SPUTTER COATING A STANDARD ?

Sputter aspect ratio of side wall / top side ~ 0.46 - 0.5[1]

To guarantee 1.9 µm on the side wall, 3.8 µm is required on the top side

Thinner side wall → oversizing of sputter thickness on the top side

[1]: Tango Systems: Equipment capability for EMI conformal package shielding

CONCLUSION AG COATING

Shielding at frequencies > 2.4 GHz is independent of the Ag layer thickness (≥ 1.6 µm) and in the same range like 4 µm sputter

Contact resistance serves as an inspection criteria for the shielding target of a specific package (e.g. 27 mΩ for 40 dB at f_{min} = 800 MHz)

We propose an Ag coating with 2 µm average thickness and an aspect ratio of 1:1 as an equivalent to 4 µm sputter

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LET INNOVATION PROGRESS

Sputtering allows for high shielding performance, however topsides are overcoated

Selectively applied Ag layers from inkjet printing match the performance already at thinner coating thickness

Correlations of contact resistance with shielding effectiveness allow to define the perfect coating

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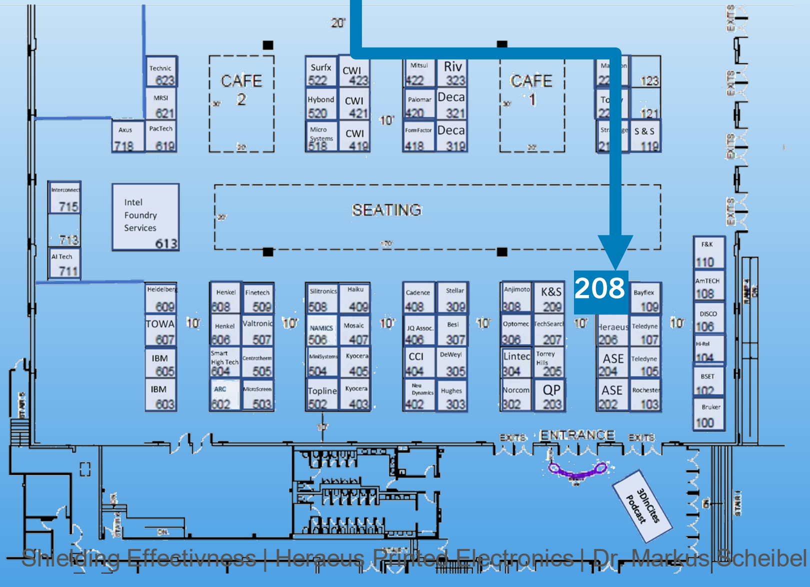

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