IEEE SW Test Workshop

Semiconductor Wafer Test Workshop

REYNAUD Vincent
MESATRONIC

Taguchi's Method applied to advanced technology probe card development

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esatronic

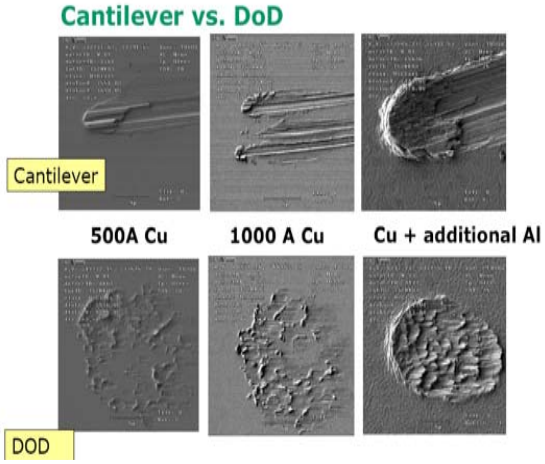
Background

- Mesatronic's R&D departement, developped a new process for manufacturing an advanced probe card based on membrane
- D.O.D. TECHNOLOGY® development project :
  - Phase 1 : "Front End" development to process the membrane
  - Phase 2 : "Back End" development to create with this membrane a probe card
  - Phase 3 : D.O.D. TECHNOLOGY® development for probe card capability (Cres, leakage, life time, cleaning, …)
  - Phase 4 : Product development (DC, RF, Parametric, …) for introduction on market

- Phase 1 and 2 were completed
- Phase 3 and 4 had to be done as quick as possible due to market pressure

Objectives

- First step on phase 3 was to control and modelize the contact resistance on aluminium with this new advanced probe card
  - Having an average value of the contact resistance as low as possible.
  - Guaranty the reliability of the contact in term of variation around the mean value and in term of opens
- Finding the best method to reduce number of experiments to save time, and cost.
- Modelization with the most important number of factors as possible

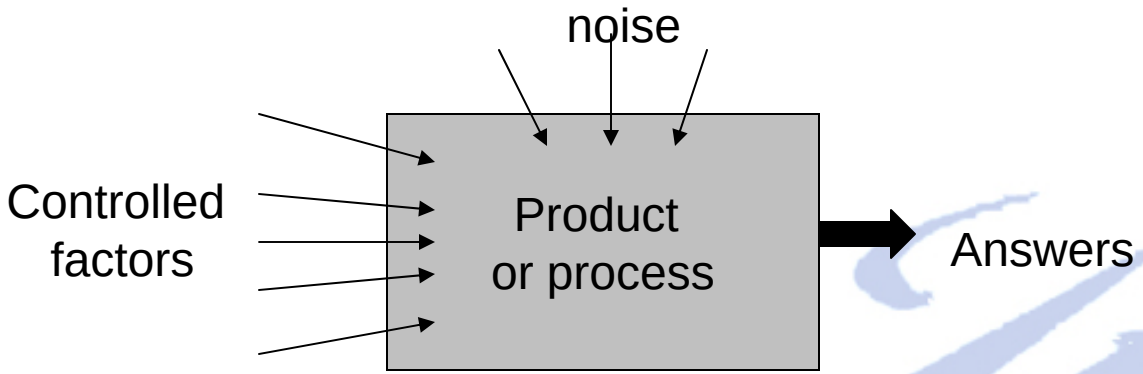


=> Taguchi's Method is the best way to achieve these goals

Taguchi's Method

- Dr Taguchi, borned in 1924 in Japan, developped several statistical methods for engineer to improve quality as "loss function" or "Signal/noise ratio".
- The Taguchi's Method came into United States in 1980's with big companies as AT & Bell Laboratories, Ford Motor Company or Xerox.
- The idea was to find a way to reduce variations during the use or the manufacturing of a product, especially due to causes difficult to control as variability of the materials, temperature, humidity, …. Usually, means to controlled these parameters create extra costs and sometime could be very expensive. The strategy of Dr Taguchi was at the opposite to find a way to minimize the influence of these existing uncontrolable parameters by better adjusting controlable parameters

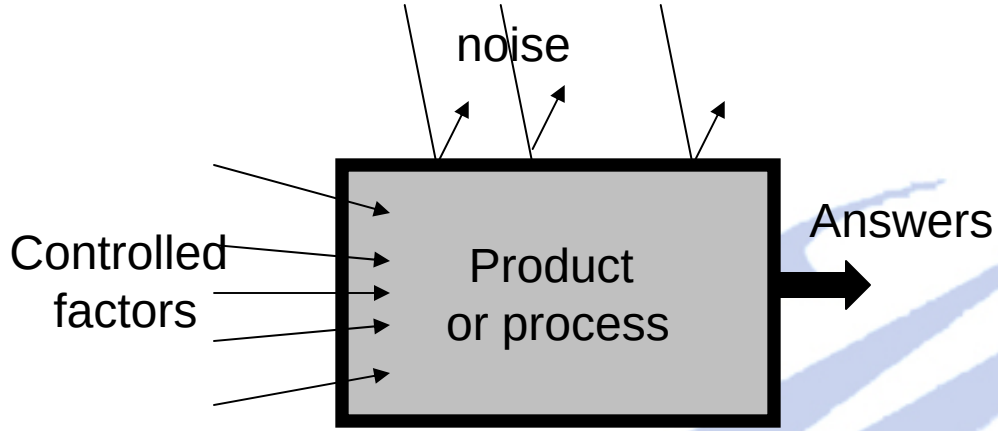
Taguchi's Method Philosophy



- Usually, to control variations we work on causes :
  - Oversized components
  - Reduced tolerances
  - Diversification of the products
  - Diversification of the user conditions
  - …….

= COSTS

Taguchi's Method Philosophy



- After experimentations, noise as causes of variations is still exist, no need to cancell these causes but better to make the system robust against this noise

The philosophy, as a joke, could be resumed as :

It is not necessary to know how a process works if this process works very well

Taguchi's Method : Orthogonal arrays plans

- Full
  - All factors are tested in combinationwith all others
  - For example 4 factors sutied at 3 levels means to make 3^4 = 81trials
- Partial
  - Only some combination of some factors at a level are efficient interm of trials
  - Based on this observation, and by « choosing » only the most efficient trials in a full array, it is possible to reduce drastically the number of trials
  - For example 4 factors sutied at 3 levels means to make 9 trials

Trial N°	Factor tried				Result of trial
	A	B	C	D	
1	1	1	1	1	R1
2	1	1	1	2	R2
3	1	1	1	3	R3
4	1	1	2	1	R4
5	1	1	2	2	R5
6	1	1	2	3	R6
7	1	2	3	1	R7
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
25	1	3	3	2	R25
26	1	3	3	3	R26
27	2	1	1	1	R27
28	2	1	1	2	R28
29	2	1	1	3	R29
30	2	1	2	1	R30
31	2	1	2	2	R31
32	2	1	2	3	R32
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
79	3	3	3	1	R79
80	3	3	3	2	R80
81	3	3	3	3	R81

Trial N°	Factor tried				Result of trial
	A	B	C	D	
1	1	1	1	1	R1
2	1	2	2	2	R2
3	1	3	3	3	R3
4	2	1	2	3	R4
5	2	2	3	1	R5
6	2	3	1	2	R6
7	3	1	3	2	R7
8	3	2	1	3	R8
9	3	3	2	1	R9

Taguchi's Method : Methodology

- Define objectives to achieve, cost and time borders
- Brainstorming to find all factories influent
- Choice of parameters to be studied, other are to be consider as noise
- Choice of a Taguchi Matrix
- Choice of levels of each parameters
- Preparing the experiments plan with all tool for data treatments
- Making all experiments without any change or doubt (bad results has to be found !!!!)
- Data treatments
- Results analysis and choice for validation trials
- Implementation of final changes in the process/product

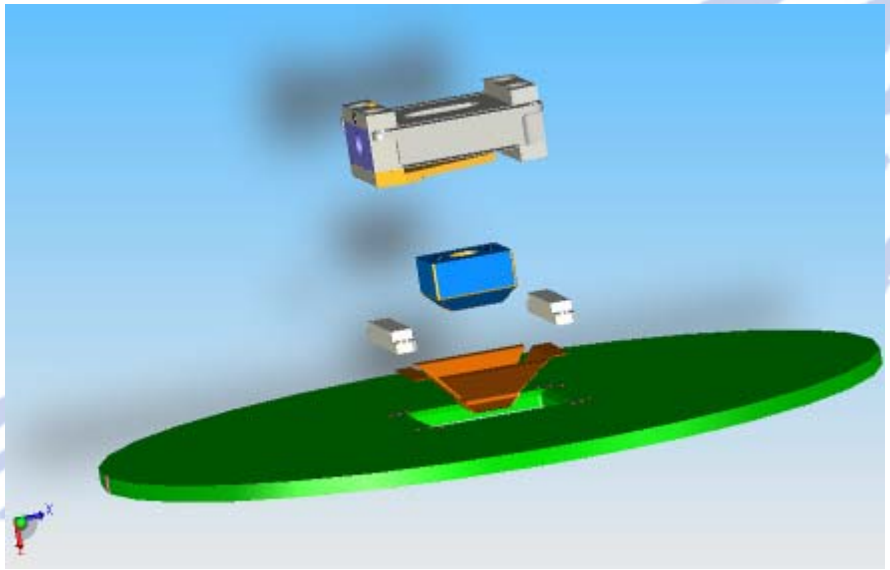
Taguchi's Method advantages

- Easy to use, don't need to be a statiscal expert to use the method at its first level
- Results are quickly obtained and have immediately an effect
- Used on a process or on a product, whatever could be this process or this product if there are any controlable parameters
- A modelization of the system is obtained, and so it is possible to know the effect of any parameter studied on the system if it is modified

All theorical bases are taken from :
« Pratique Industrielle des plans d'expériences - La qualité à moindre coût ; l'approche Taguchi»
from Jacques andt Philippe Alexis – AFNOR 1999

Concrete case

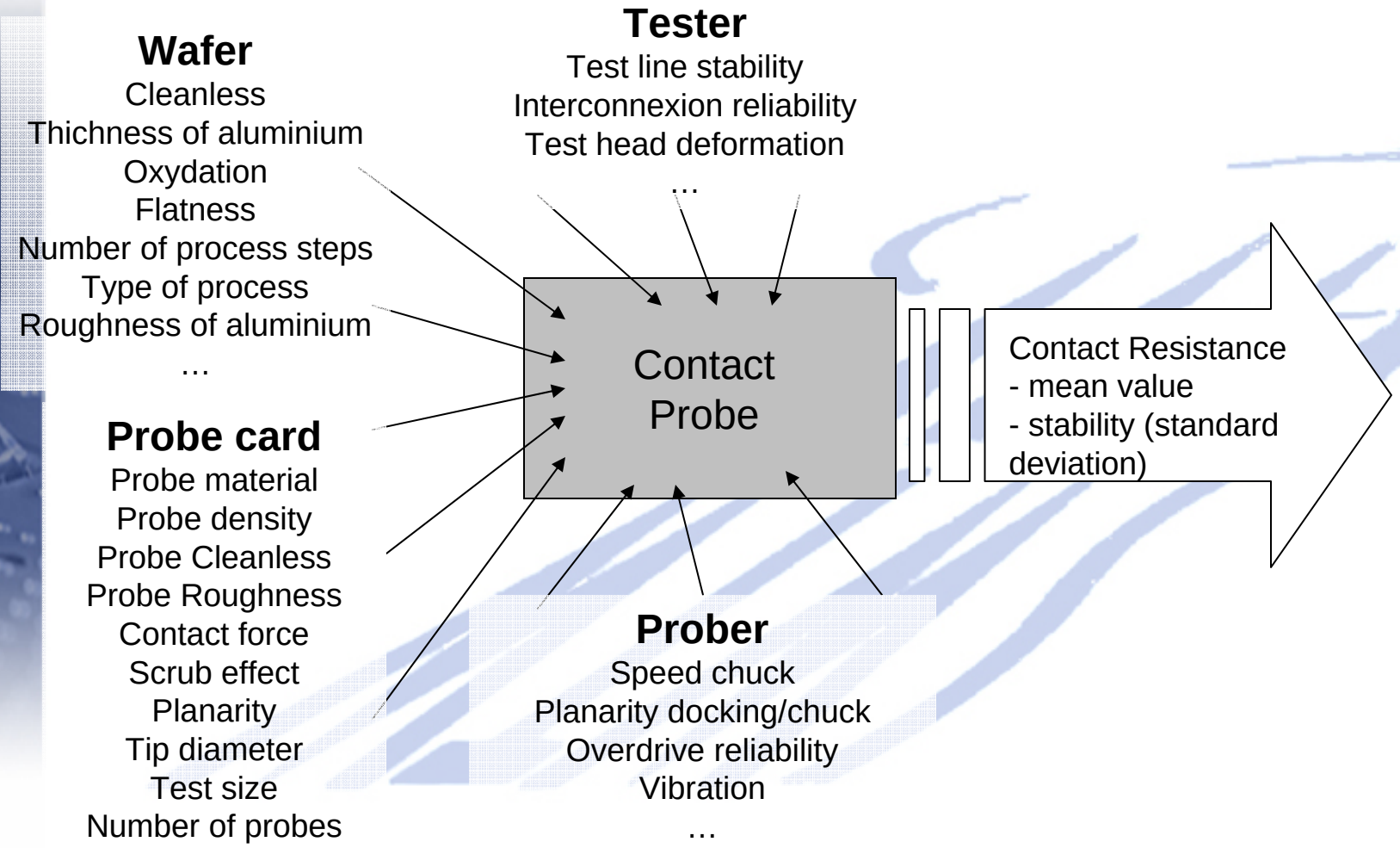
D.O.D TECHNOLOGY® DEVELOPMENTS



D.O.D. TECHNOLOGY®
Objective of Taguchi's plan

- Stabilisation of contact resistance in terme of average value (3 ohms max for the complete test line),standard deviation (0.5 ohm) and yield (<5% of open)
- 4 months
- Integration of a complete test line with prober (UF200) and test equipment (Agilent 400 I/O ohm-meter)

D.O.D. TECHNOLOGY®
Parameters for Contact Resistance



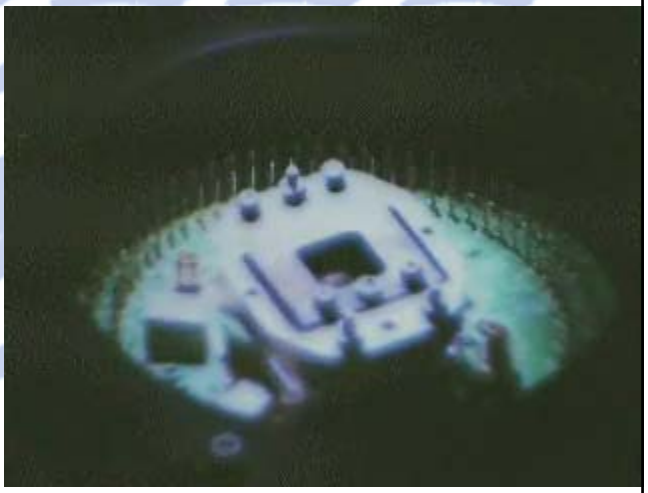
D.O.D. TECHNOLOGY®
Taguchi's array

- L9(3)4, 4 combined factors with 3 levels of test to have at least 10 parameters under control during this plan
- 27 trials in 3 runs of 9 trials with 1000 measurements of contact resistance on 32 or 180 chanels of 2 probes
- Time and cost of trials reduced, with an large base of measurments results which guarantee the good statistical end treatment

N° Trial	Probe force and overtravel	Tip size and material of probe	cleanless	Planarity and tip shape
1	**1**	**1**	**1**	**1**
2	**1**	**2**	**2**	**2**
3	**1**	**3**	**3**	**3**
4	**2**	**1**	**2**	**3**
5	**2**	**2**	**3**	**1**
6	**2**	**3**	**1**	**2**
7	**3**	**1**	**3**	**2**
8	**3**	**2**	**1**	**3**
9	**3**	**3**	**2**	**1**

D.O.D. TECHNOLOGY®
Treatment tools

- $1.7x10^6$ values to analyse
- Excel sheet base
- Statisical treatment of results possible following 6 axis, time, average, standard deviation, ligne (all the probe card) and column (chanel by chanel)
- Need to double checkdata loss in the statistical process treatment
- Test request form with all experiments configurations saved
- Backup of all data to make advanced treatment later in a continuous improvement process



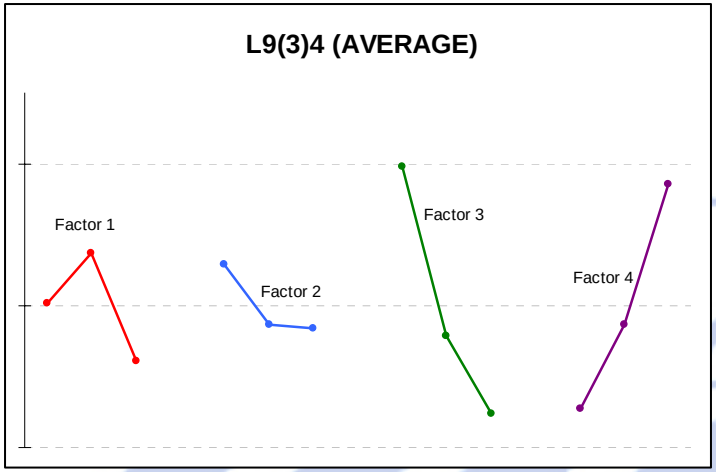
D.O.D. TECHNOLOGY® Results

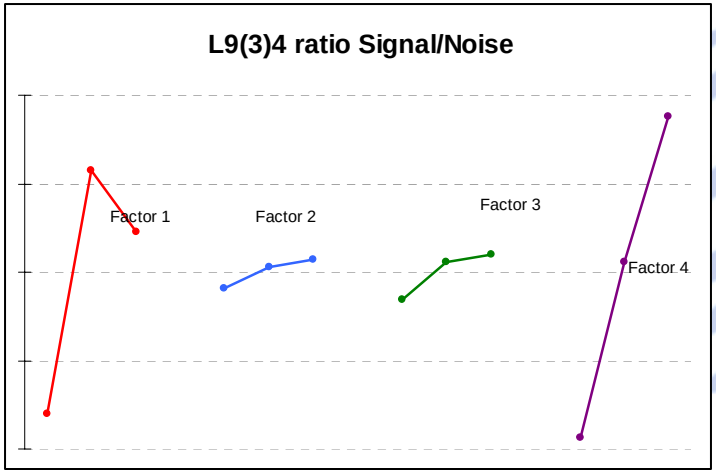
- Data from trials

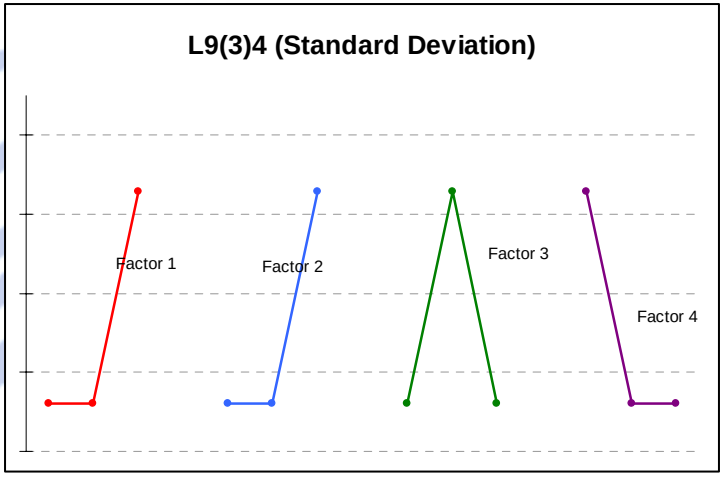
N° Trial	Probe force and overtravel	Tip size and material of probe	cleanless	Planarity and tip shape	Run 1	Average	Standard deviation	Ratio Signal/noise	Run 2	Average	Standard deviation	Ratio Signal/noise	Run 3	Average	Standard deviation
1	1	1	1	1	li		2,1	10,4	li	7,3	1,4	14,7	li	6,6	1,7
					co	7,3	1,6	14,7	co	6,8	1,6	11,3	co	7,2	1,5
2	1	2	2	2	li	7,5	1,9	12,2	li	7,5	1,9	12,2	li		2,2
					co	10,2	1,5	16,9	co	7,5	2,3	10,1	co	8,1	1,7
3	1	3	3	3	li	7,1	1,3	14,6	li	6,0	1,2	13,9	li	6,0	1,1
					co	1,4	14,4		co	1,1	16,8	34,8	co	1,1	17,0
4	2	1	2	3	li	7,8	1,0	17,2	li	7,4	1,5	13,9	li	7,9	1,3
					co		15,7	8,4	co	1,3	16,1	16,7	co	0,9	17,6
5	2	2	3	1	li	7,1	2,4	9,5	li	7,2	2,2		li	5,0	1,0
					co	8,1	1,3	17,4	co	7,3		14,1	co	5,0	
6	2	3	1	2	li	6,8	1,5	13,5	li	7,7	1,4	15,1	li	7,9	1,3
					co	7,0	1,3	12,8	co	7,5	1,6	13,3	co	7,8	1,5
7	3	1	3	2	li	7,2	2,0	11,1	li		1,3	18,6	li	5,7	1,8
					co	7,2		11,3	co	10,3	1,2	19,2	co	5,8	1,2
8	3	2	1	3	li	7,8	1,4	15,3	li	7,9	1,3	15,6	li	7,7	1,3
					co	1,1	17,7	31,7	co		16,8	12,3	co	1,2	16,8
9	3	3	2	1	li	5,2	2,0	8,3	li	4,9	1,0	14,3	li	4,6	0,8
					co	5,6	1,0	17,2	co	4,9	0,4	24,5	co	4,6	0,5

D.O.D. TECHNOLOGY® Results

- Treatment and analysis of effect of each factor on contact resistance average value, standard deviation value and ratio signal/noise
- This is also the comportemental model of the probe card with these factors



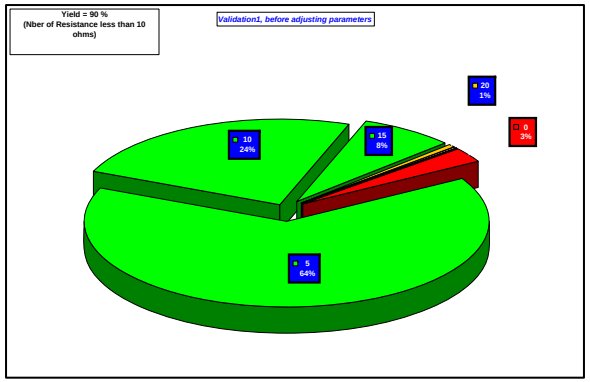


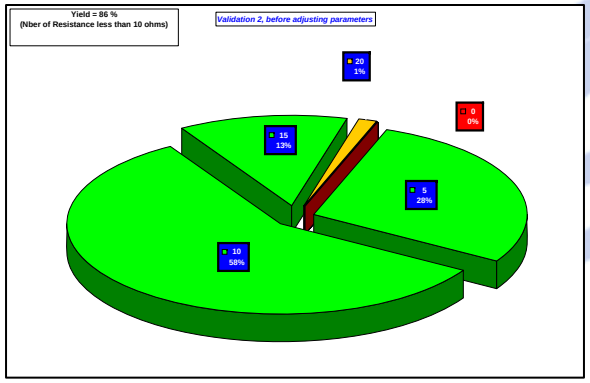


D.O.D. TECHNOLOGY®
Validation trials

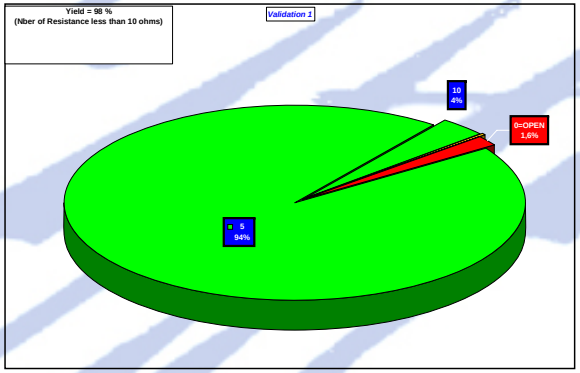
- Validation trials are here to confirm that statistical results obtained in the plan are correct and that the goal is achieved

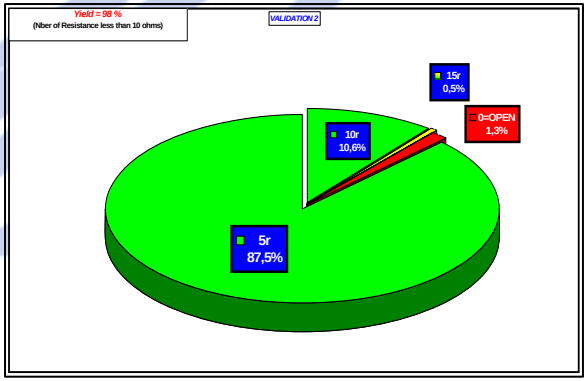
Before experiments plan





After modifiying paramaters accordingly to results of plan

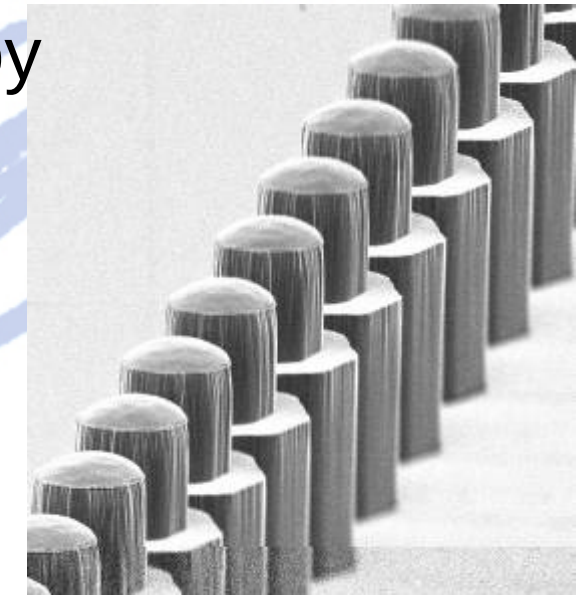




D.O.D. TECHNOLOGY® PRODUCT IMPACT

Contact probes shape

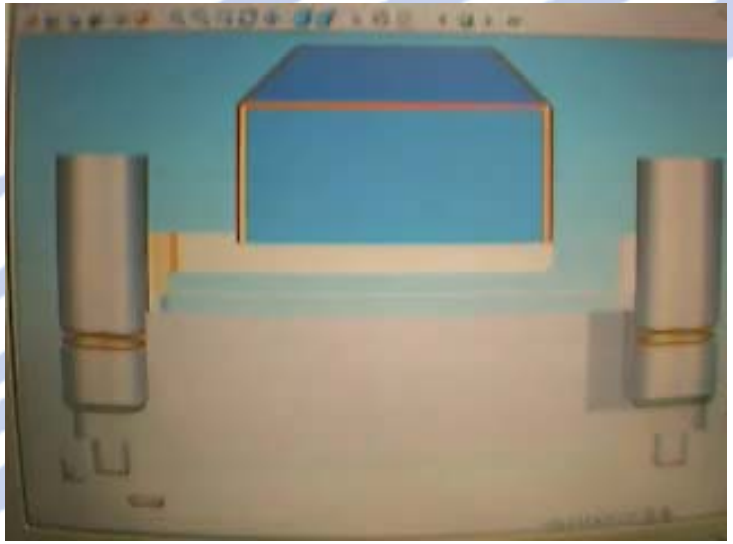
- Shape : Mesatower
- Typical dimension
  - Base diameter : 30 to 50 µm
  - Typical Contact diameter : 23 µm
  - Typical Overall height : 50 µm
- Material : Hard Nickel alloy
- Shear resistante probes



D.O.D. TECHNOLOGY® PRODUCT IMPACT

Overdrive / Probe force

- Field adjustable probe force
- No alignement variation during Z movement
- Overdrive :
  - 50µm +/-5 for a
- Probe Force range
  - 2.3-2.7 g

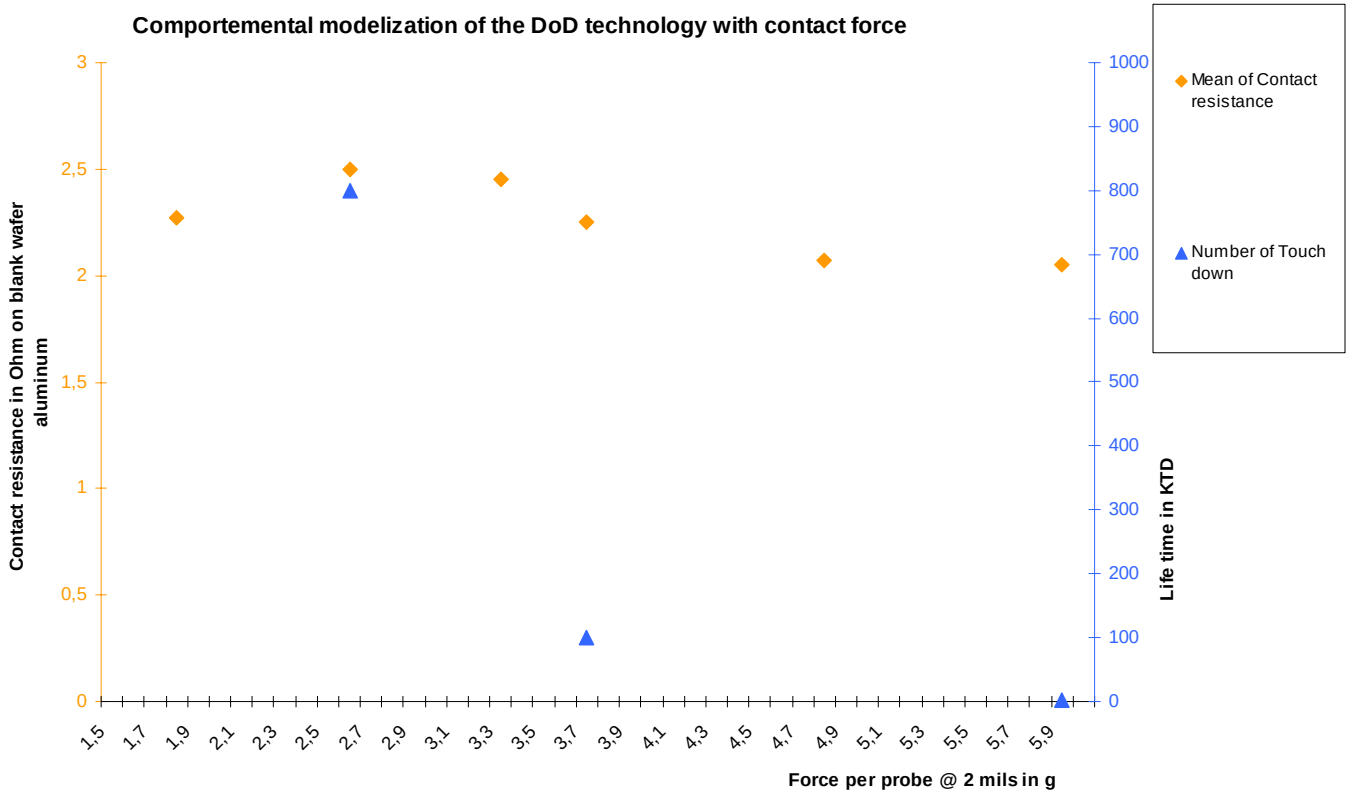


D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental model

Cres / life time vs probe force/overdrive

- Yellow : Cres vs Probe force(=f(overdrive))
- Blue : Life Time vs Probe force(=f(overdrive))

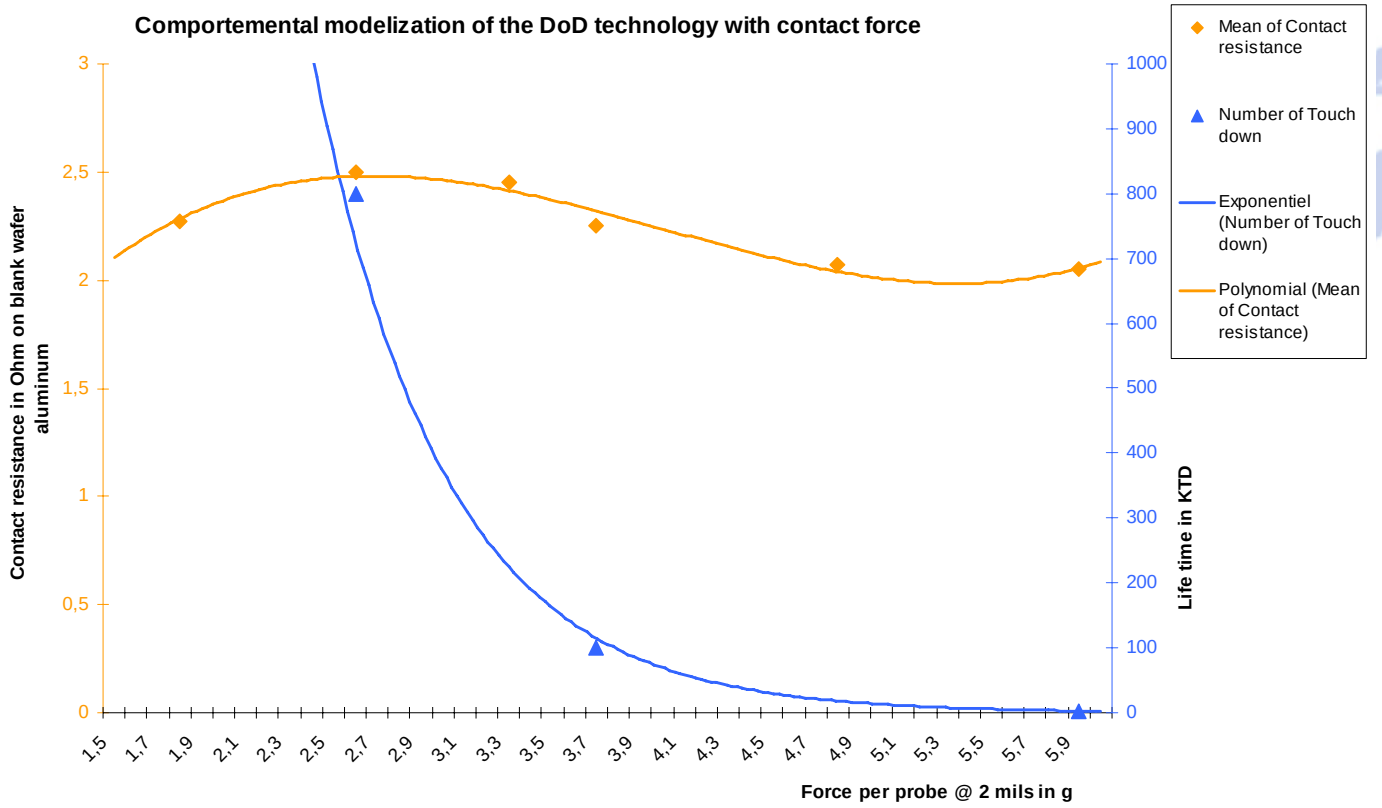


D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental model

Cres / life time vs probe force/overdrive

- Polynomial and exponential modelisation

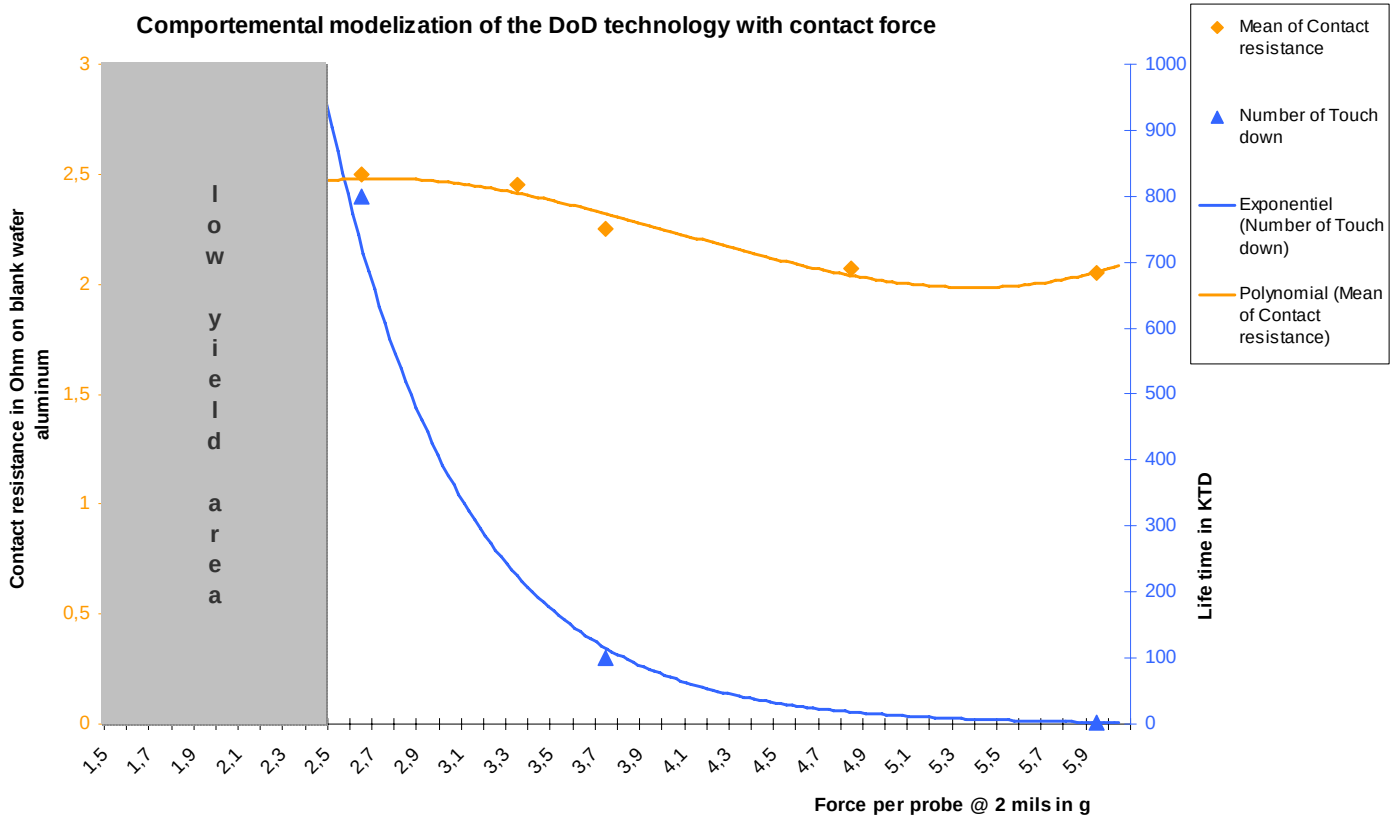


D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental model

Cres / life time vs probe force/overdrive

- Removing too low yield area

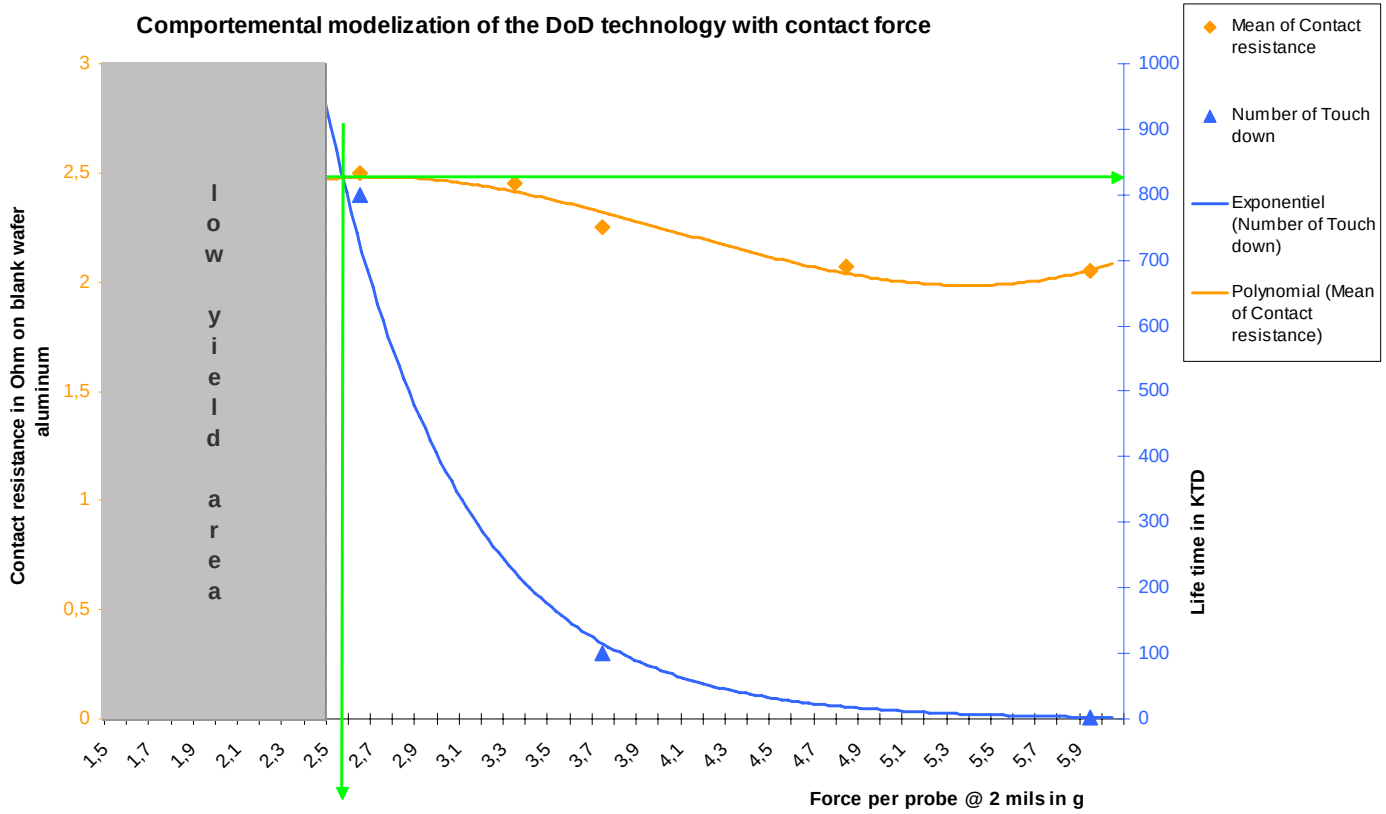


D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental model

Cres / life time vs probe force/overdrive

- Recommanded working zone

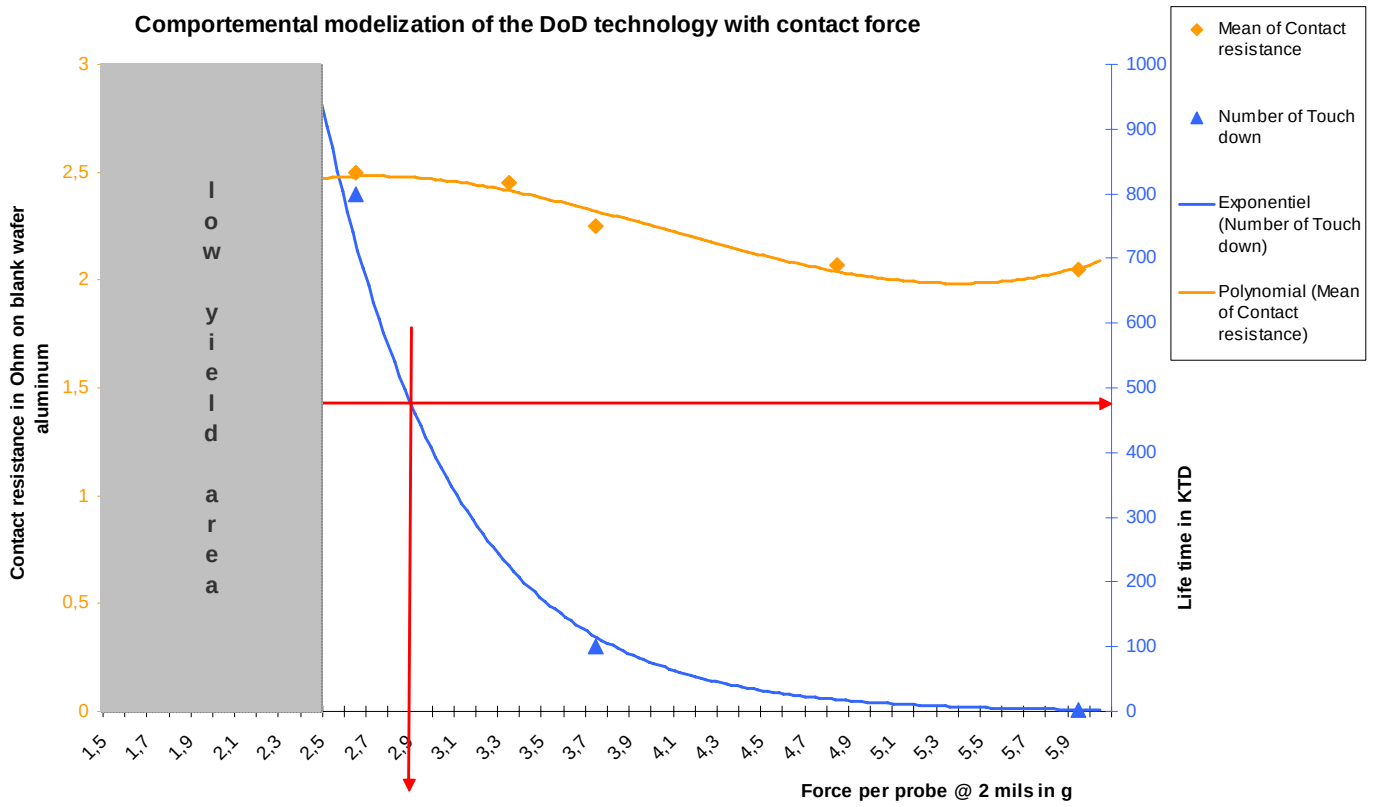


D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental model

Cres / life time vs probe force/overdrive

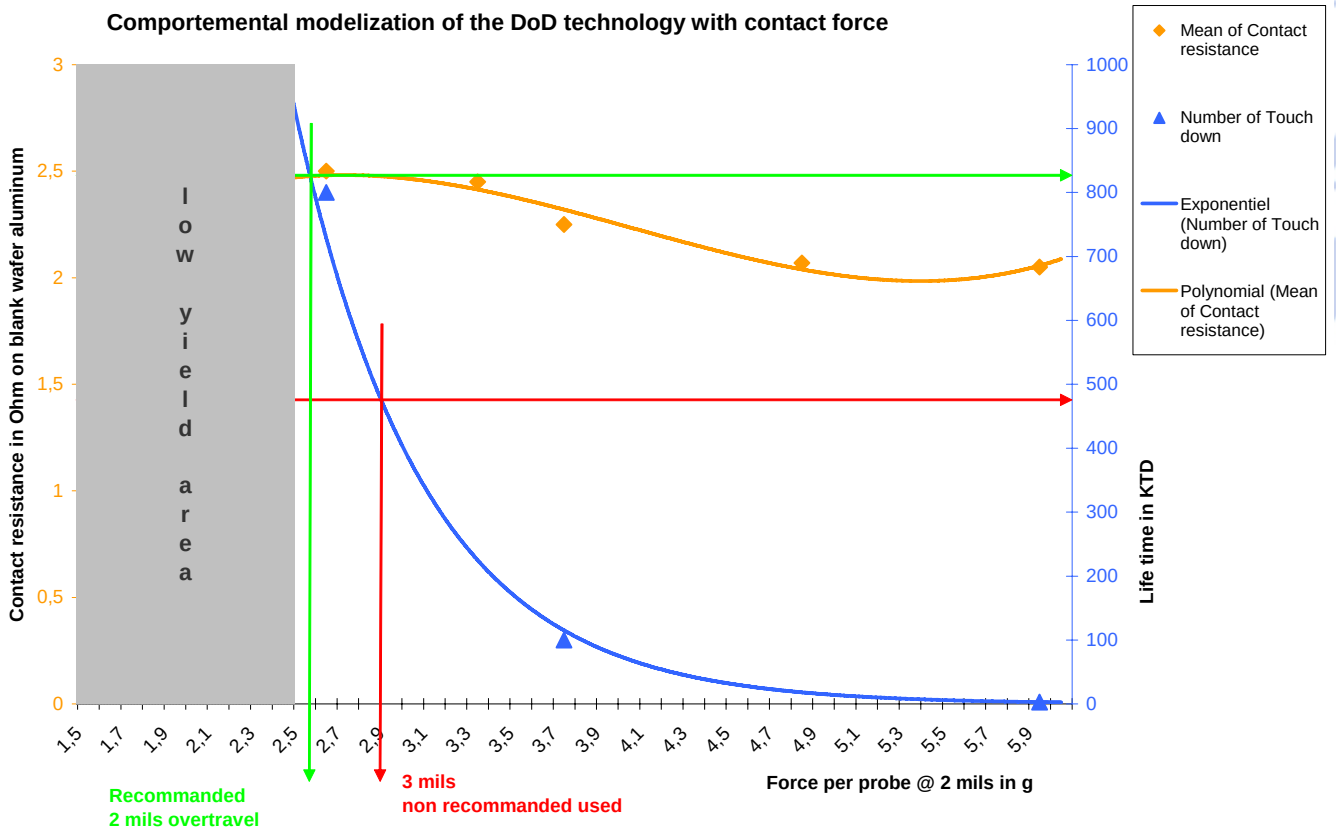
- If using 3 mils overtravel, reducing life time down to 25%



D.O.D. TECHNOLOGY® PRODUCT IMPACT

Comportemental modelisation vs probe force/overdrive

- Typical values on blank aluminum wafer

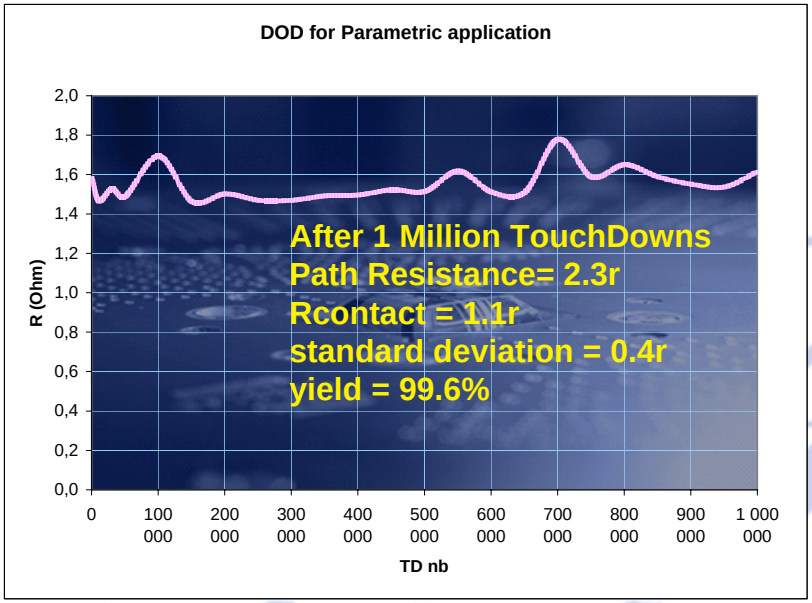


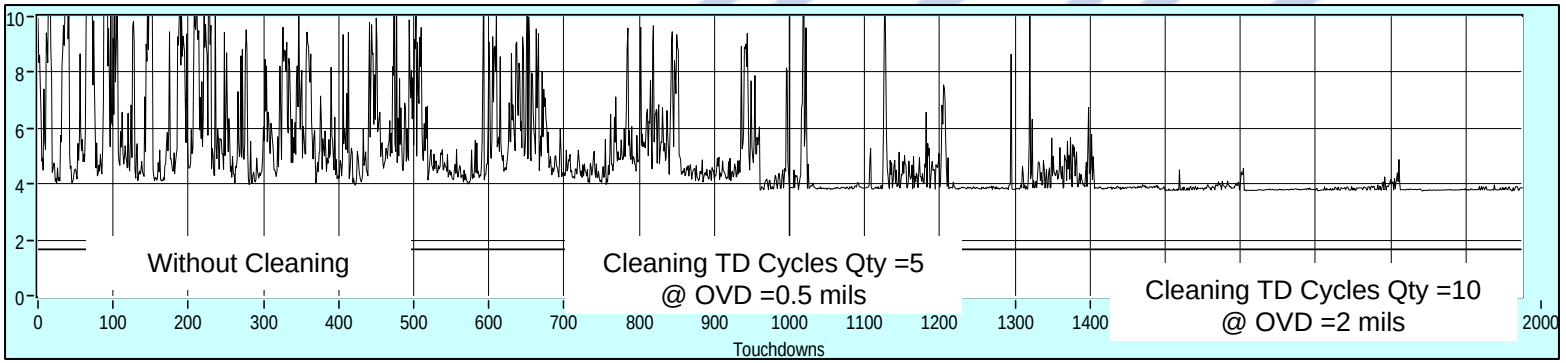
Conclusion

- Powerful method which given expected results in term of
  - Time
  - Cost
  - Results
- Modelisations used for customer support and prediction for future R&D development results
- Easy to use and adaptable on many aspects as process controls or product improvements

Follow On work

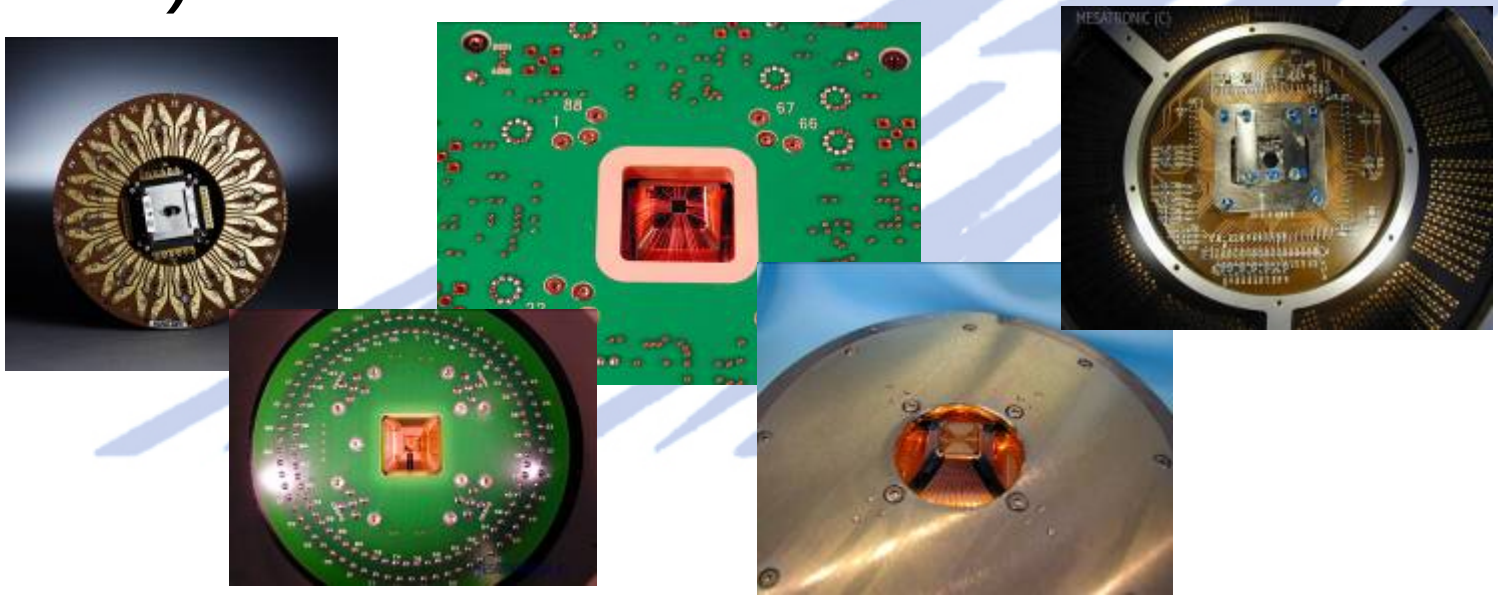
- After contact resistance modelisation we worked on
  - Life time
  - On line cleaning





Follow On work

- Next steps is, based on this knowledge, to develop products and applications to answer to needs of markets (RF, parametric, Fine pitch, …)



Acknowledgement

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  - Laetitia Castagne
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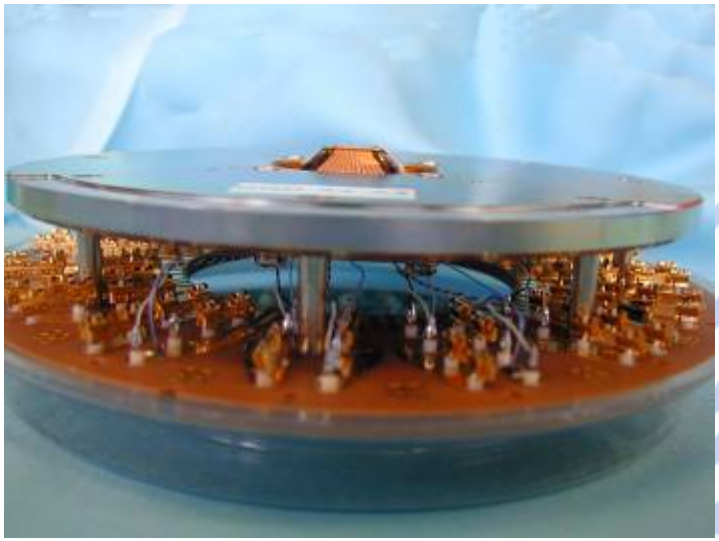
- For support
  - Michel Gondran
  - Aissa Joulali
  - Daniel Vervier



I personnally would like to thank the SWTW audience for its attention and the wonderful organisation team

MERCI !!!!!

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