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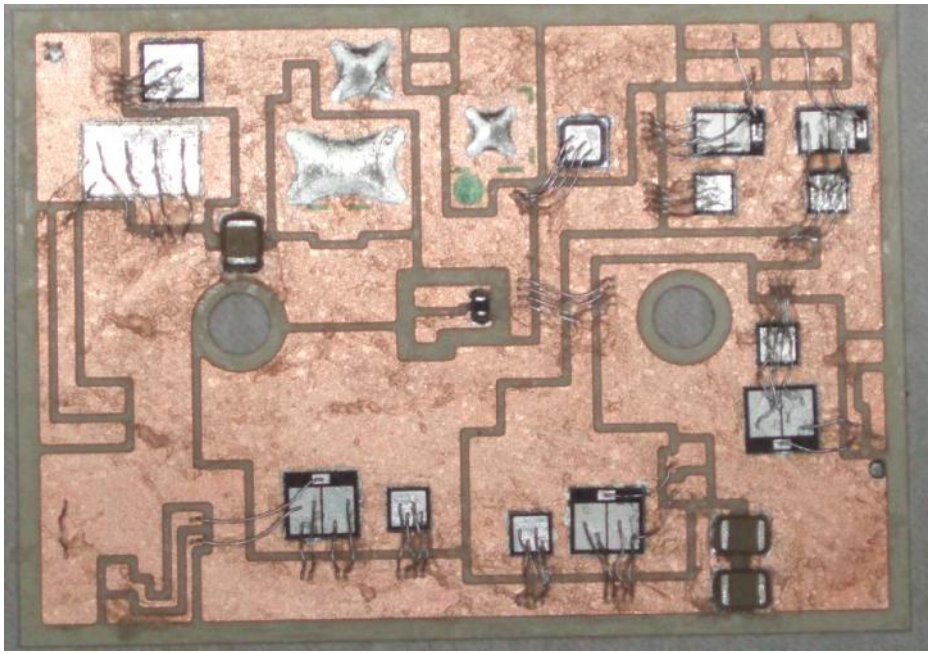
Reverse Costing analysis



Solar Inverter
Boost circuit + H bridge
Vincotech and Infineon

November 2009 - Version 1

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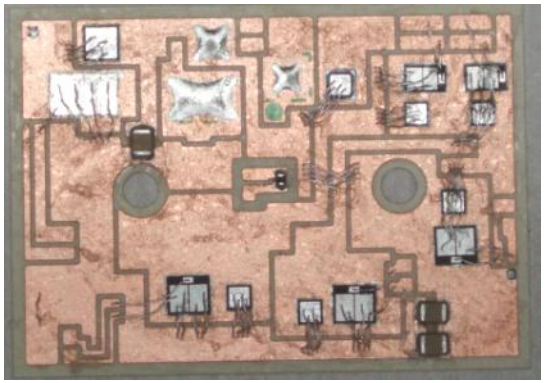
Introduction

This document is the Reverse Costing report of the **power module** included in the solar inverter **Sunny Boy 3000TL** supplied by **SMA**. The module is manufactured by **Vincotech** with diodes and IGBTs from **Infineon**. The power module integrates a H-bridge and a boost circuit (Transistor + diode). The aim of the analysis is to estimate the production cost as well as the selling price of the power module.

The device is manufactured by the German company **Vincotech** in their Hungarian factory. It is a specific module designed for SMA but it is very close to Vincotech standard inverter. It has been introduced in 2008.

The volume used to assess the production cost and the selling price of the module has been set to **30 000 units** in 2009. This quantity is based on the quantities expected for the total sales of the Sunny Boy 3000TL, 4000TL and 5000TL because the 3 models are very similar (see picture below). For the semiconductor components, the volume used is 100 000 units because Vincotech sells several standard inverters with similar characteristics.

Sunny Boy 3000TL, 4000TL and 5000TL



Vincotech Solar inverter power module

The boost circuit is constituted by one transistor and one diode. Another IGBT is associated with the boost circuit, but its function is unknown. These components are manufactured by Infineon.

The H bridge is constituted by 4 IGBT and their free wheeling diode. The 4 IGBT are manufactured by Infineon using the IGBT3 technology but the size of the transistors on the upper side differs from the ones at the lower side.

The semiconductor components are assembled on a ceramic board and a Miniskiip package is used to connect the ceramic board with the other parts of the Sunny Boy converter.

The course of the analysis

This Reverse Costing analysis has been conducted in several phases :

- **The initialization of the analysis**
  - Pictures of the power module.
  - Identification of the components.

- **The physical analysis and process flow of H bridge transistors**
  - Pictures of the transistors.
  - Identification of the physical characteristics and estimation of the process flow.
  - Creation of process flow of the studied IGBT with IGBT CoSim + software.

- **The cost calculation of H bridge transistors**
  - Simulation of the IGBT cost with IGBT CoSim+ software.
  - Estimation of the production cost & selling price.

- **The cost calculation of boost transistors**
  - Technology description and estimation of the production cost & selling price

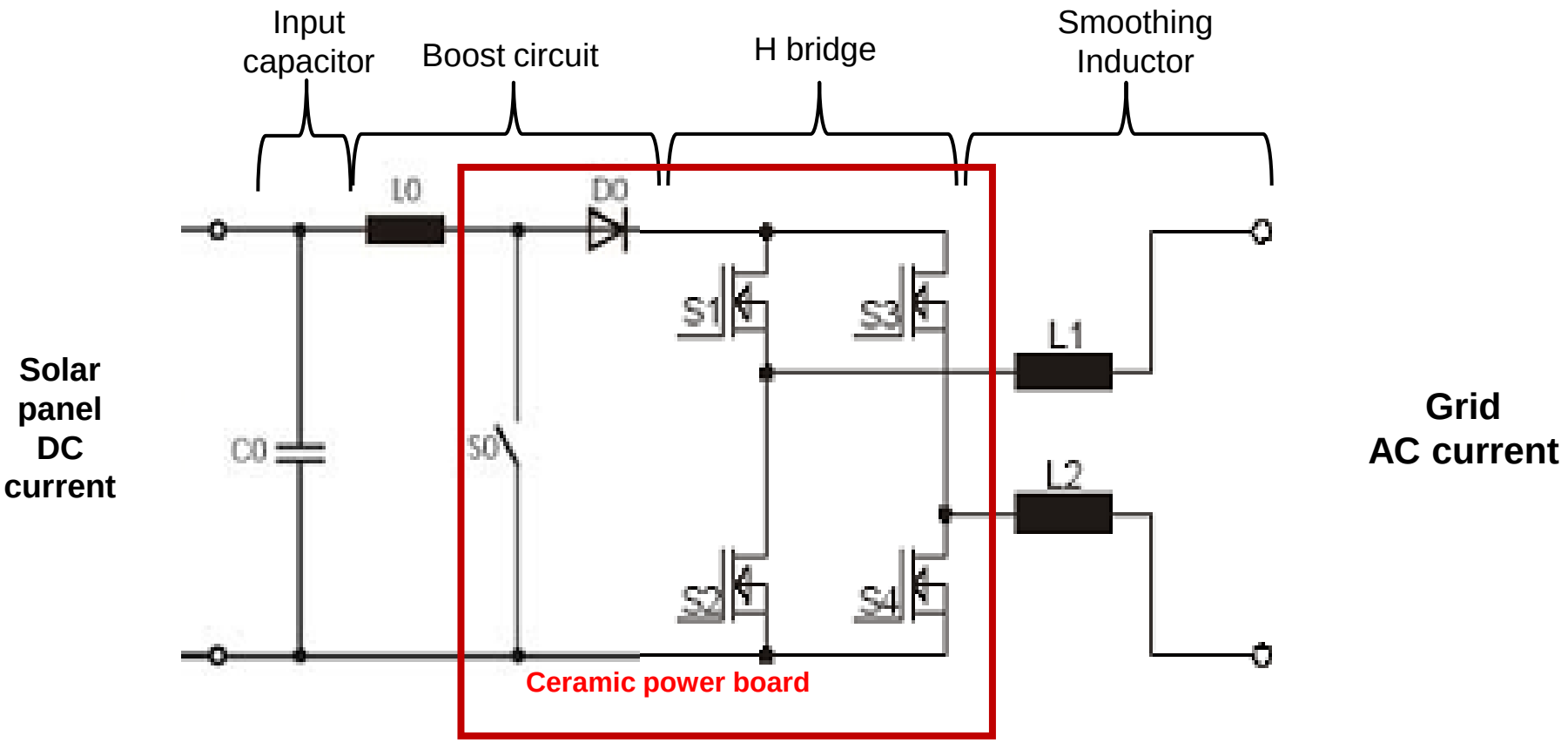
- **Description of the material in the "SYS.COST" software**
  - Creation of an "estimation project" of the studied board with SYS.COST software.
  - Construction of the Bill of Material (BOM).
  - Assessing the cost of the ceramic board and of the unaccounted references (unknown by distributors)
  - The BOM is valued with SYS.COST: price simulation according to the requested quantities.

- **Assessing the assembling and test phases**
  - Assembly and test lines are modeled with the SYS.COST software.
  - The assembly and tests costs are estimated.

- **Production cost & selling price**
  - Estimation of the production cost & selling price

SYS.COST©, is a software tool developed by SYSTEM PLUS CONSULTING to calculate the cost of electronic boards.
IGBT CoSim +©, is a software tool developed by SYSTEM PLUS CONSULTING and YOLE DEVELOPPEMENT to calculate the cost of IGBTs, diodes and power transistors. More information on the software tools can be found at www.systemplus.fr.

Simplified Block Diagram

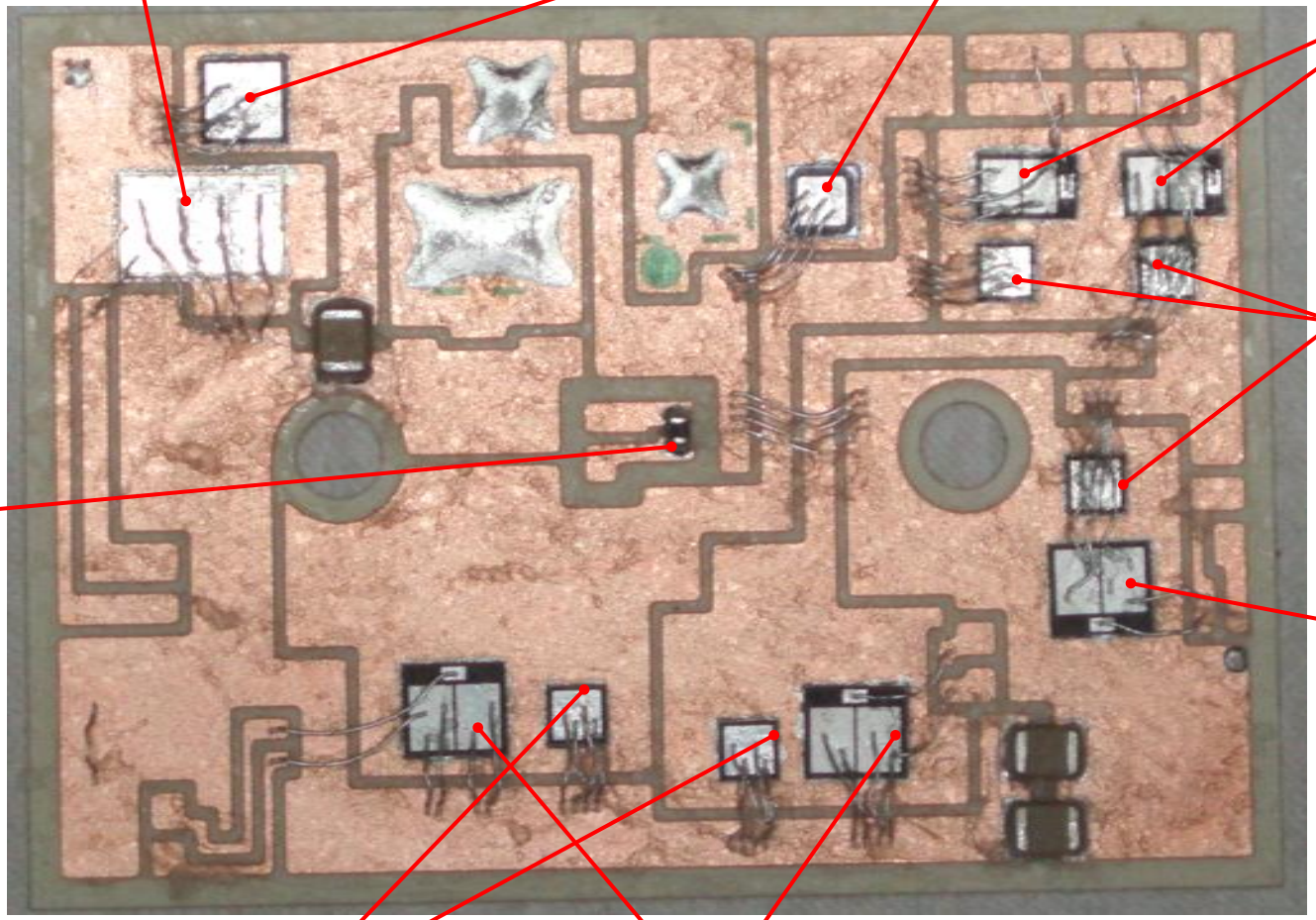


The ceramic power board integrates a H bridge with the 4 IGBTs and their free wheel diodes and a boost circuit. The magnetic components and the input capacitor are assembled directly in the solar inverter.

Note : This simplified block diagram is based on the observation of the product implementation, manufacturer's data sheets where available and engineering judgment.
Some details could not been reflected in this block diagram.
Partitioning and connectivity are speculative.

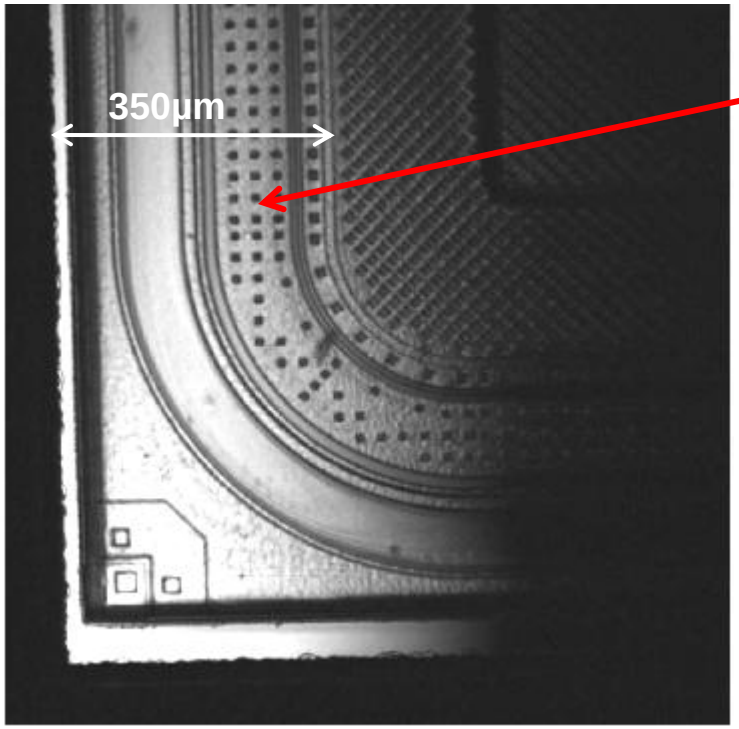
Vincotech is a specialist of electronic power systems. It designs and manufactures several inverter ranges which are optimized for solar inverters. It manufactures the Ceramic Power Board. This board is not a standard reference.

Ceramic Power Board - Vincotech



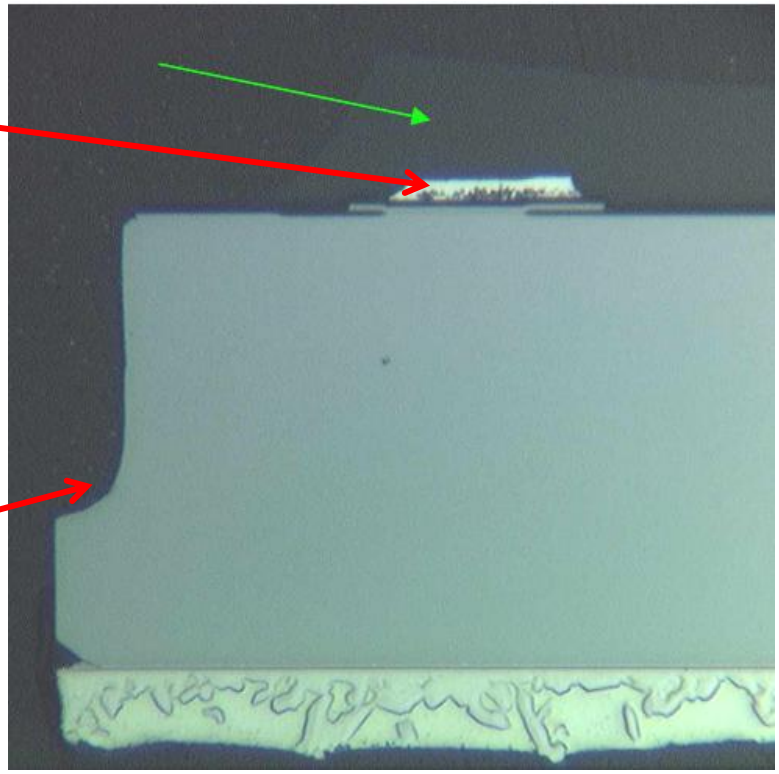
Guard Ring

Guard Ring : the guard ring prevents from leakage current.



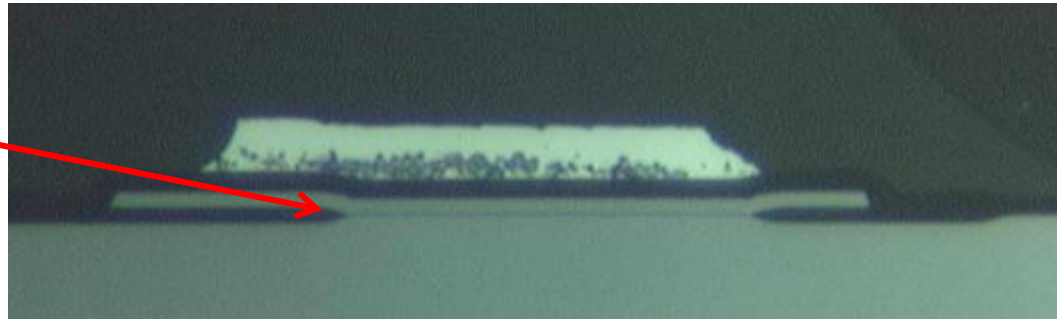
Metal ring

Polyimide passivation



The wafers are pre-sawn and cleaved.

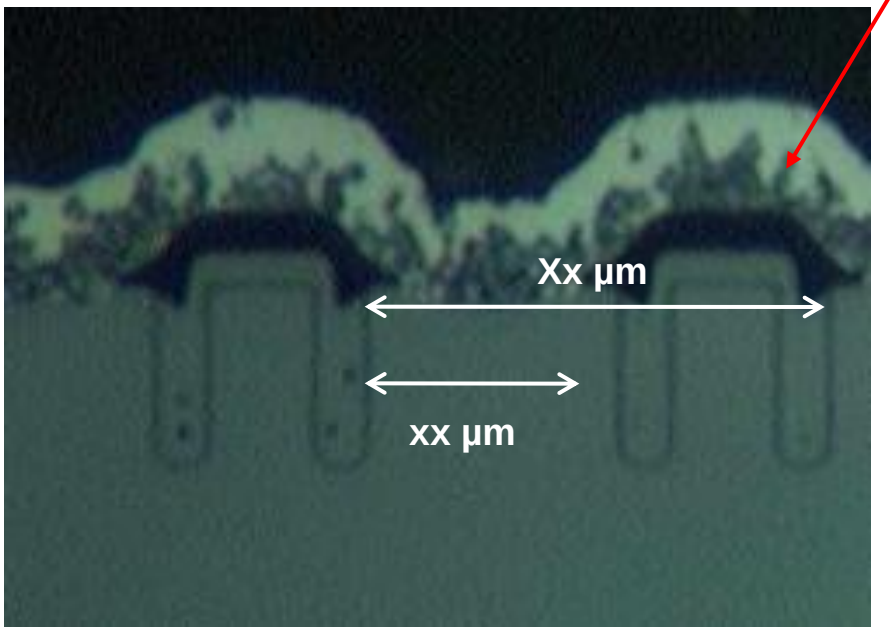
Detail of edge seal. LOCOS structure.

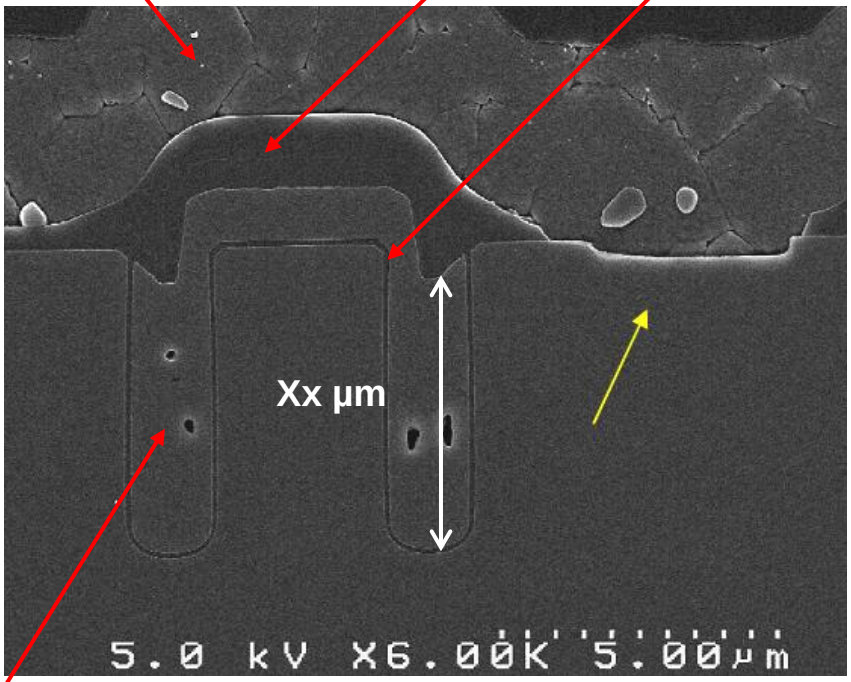


Trench IGBT

The aluminum metal layer is the IGBT source. The source covers the whole area except the pads for the gate.

We measure a pitch of x µm between two gates.

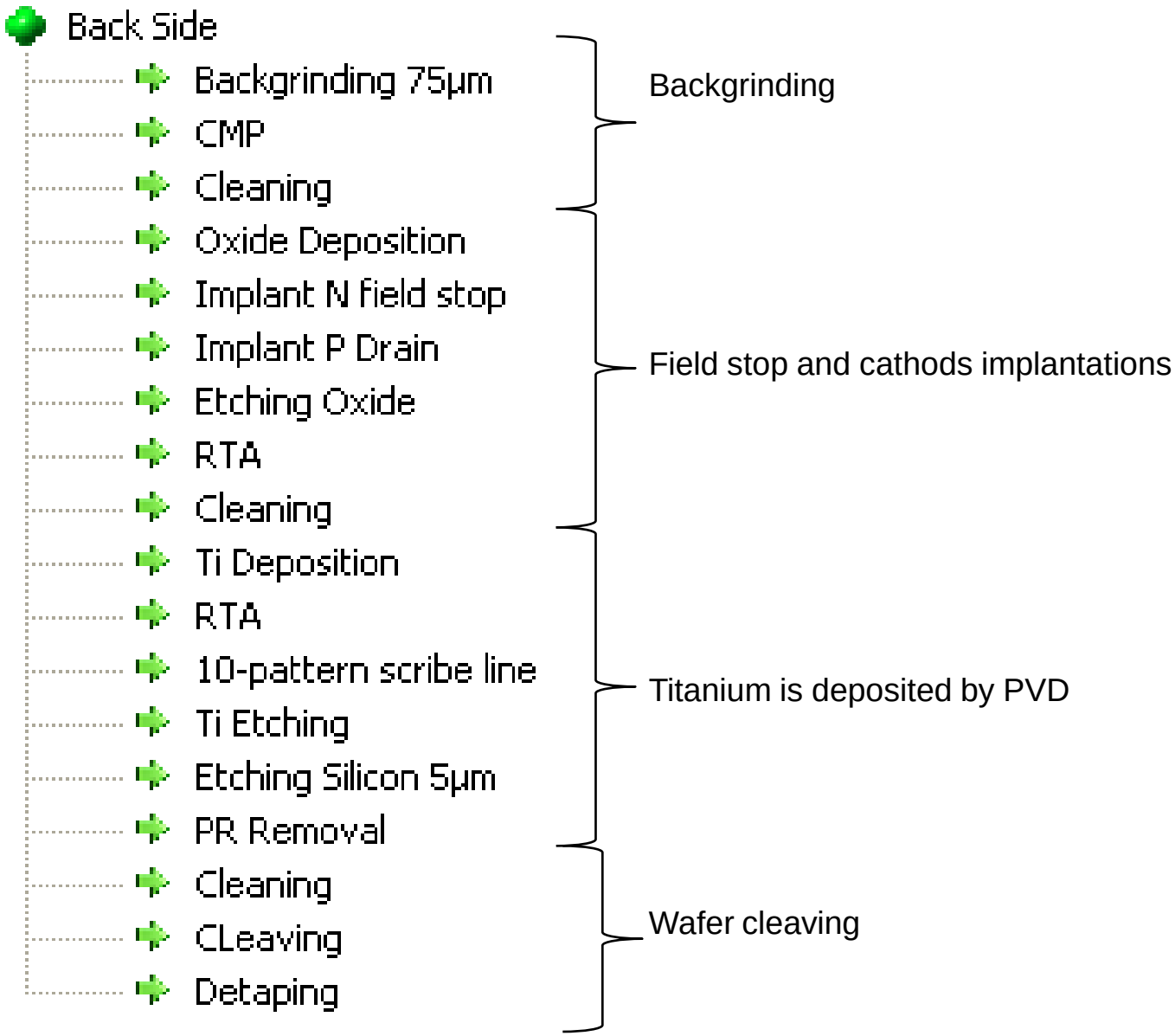




Poly-silicon filled trench

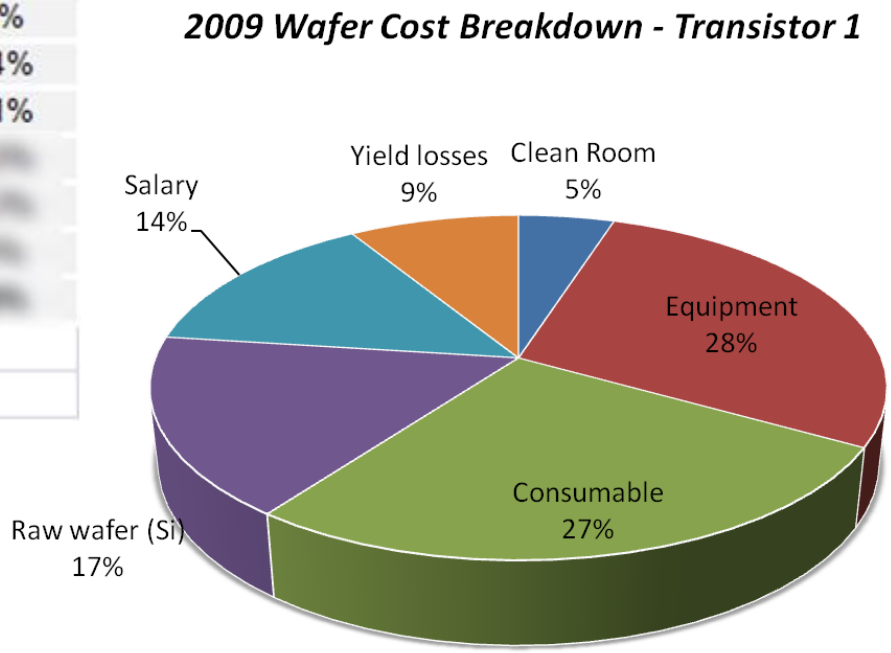
The silicon is recessed in contact area

Back Side Process Flow



Wafer Cost – Transistors 1 & 2

2009	Transistor 1		transistor 2	
	Cost	Breakdown	Cost	Breakdown
Clean Room	$16,74	5,0%	$16,74	5,0%
Equipment	$95,35	28,2%	$95,35	28,4%
Consumable	$91,11	27,0%	$91,11	27,1%
Raw wafer (Si)	[illegible]	[illegible]	[illegible]	[illegible]
Salary	[illegible]	[illegible]	[illegible]	[illegible]
Yield losses	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL COST	[illegible]	[illegible]	[illegible]	[illegible]
Fab Yield	91,2%		91,7%	



- The wafer cost is $xxx in 2009.

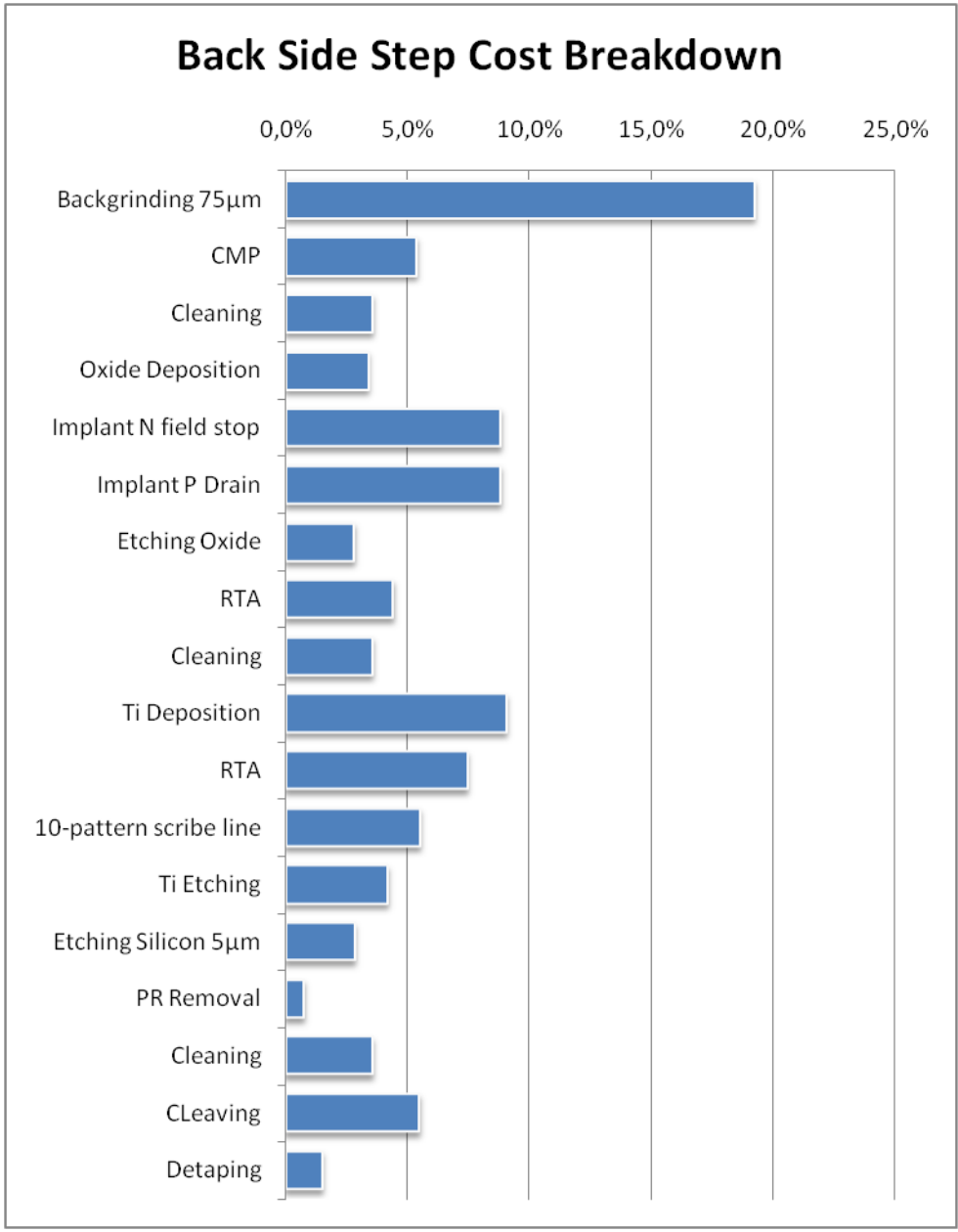
- The main part of the wafer cost is due to the consumables (27%). The salary part is high (14%) because the location of the wafer fabrication unit is Austria.

- The manufacturing yield is 91.2% for the transistor 1 and 91.7% for the transistor 2. The thin wafer and the steps on the backside explains this low value of manufacturing yield.

Breakdown per process step - Back End

Back Side	Cost	Breakdown
Backgrinding 75µm	$15,44	19,2%
CMP	$4,31	5,4%
Cleaning	$2,85	3,5%
Oxide Deposition	$2,71	3,4%
Implant N field stop	$7,07	8,8%
Implant P Drain	$7,07	8,8%
Etching Oxide	$2,24	2,8%
RTA	$3,53	4,4%
Cleaning	$2,85	3,5%
Ti Deposition	$7,27	9,0%
RTA	$5,97	7,4%
10-pattern scribe line	$4,41	5,5%
Ti Etching	$3,35	4,2%
Etching Silicon 5µm	$2,26	2,8%
PR Removal	$0,58	0,7%
Cleaning	$2,85	3,5%
CLeaving	$4,39	5,5%
Detaping	$1,19	1,5%
TOTAL	$80,33	100,0%

Results of IGBT CoSIM + Software

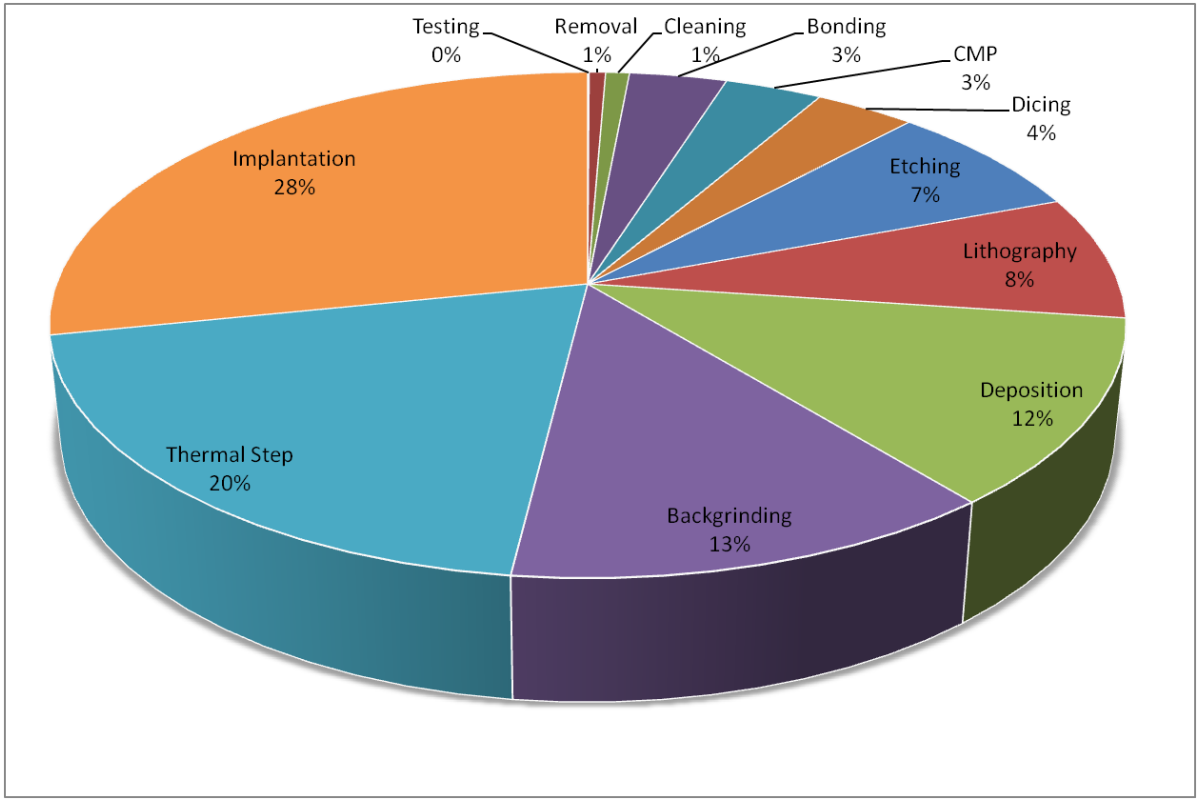


Breakdown per equipment Family

Equipment Family	Cost / Wafer
Testing	0,05 $/wafer
Removal	0,55 $/wafer
Cleaning	0,80 $/wafer
Bonding	3,26 $/wafer
CMP	3,26 $/wafer
Dicing	3,37 $/wafer
Etching	7,06 $/wafer
Lithography	7,55 $/wafer
Deposition	11,40 $/wafer
Backgrinding	12,23 $/wafer
Thermal Step	18,92 $/wafer
Implantation	26,91 $/wafer
TOTAL	95,35 $/wafer

Results of IGBT CoSIM + Software

Cost of equipment for Front End and BackEnd process steps is $95.35



Details of the Ceramic Board AV Cost

Operation	Linked Labour	Equip Time	Labour Time	Net Operation Time	Brut Operation Time	Cumulative Yield	Equip Cost	Labour Cost	Entity Cost	Full Labour Cost by Op	Operation Total Cost	Currer
screenprinting soldering paste - Se	☐	0,9000	0,9000	0,9000	0,9000	100,00%	0,0032	0,0012	0,0000	0,0000	0,0044	USD
Panel loading/unloading	☑	0,0000	0,0000	0,0000	15,0000	100,00%	0,0528	0,0201	0,0000	0,0000	0,0729	USD
Screenprinting soldering paste	☑	0,0000	0,0000	0,0000	15,0000	100,00%	0,0528	0,0201	0,0000	0,0000	0,0729	USD
Pick and place Chips	☑	1,4400	0,0000	1,4400	1,7391	100,00%	0,0152	0,0023	0,0000	0,0013	0,0188	USD
Pick and place SMT- Setup	☑	0,9000	0,9000	0,9000	0,9000	100,00%	0,0079	0,0012	0,0000	0,0000	0,0091	USD
Panel loading/unloading	☑	0,0000	0,0000	0,0000	0,0000	100,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Pick and place Bare die	☑	23,4000	0,0000	23,4000	28,2609	100,00%	0,2472	0,0378	0,0000	0,0204	0,3054	USD
Reflow - Setup	☑	0,9000	0,9000	0,9000	0,9000	100,00%	0,0010	0,0012	0,0000	0,0000	0,0022	USD
Panel loading/unloading	☑	0,0000	0,0000	0,0000	0,0000	100,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Reflow	☑	30,0000	0,0000	30,0000	30,0000	100,00%	0,0327	0,0402	0,0000	0,0262	0,0991	USD
Storage	☐	0,0000	0,0000	0,0000	0,0000	100,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Reflow - Setup	☑	0,9000	0,9000	0,9000	0,9000	100,00%	0,0032	0,0012	0,0000	0,0000	0,0044	USD
Panel loading/unloading	☑	0,0000	0,0000	0,0000	0,0000	100,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Wire bonding	☑	40,0000	0,0000	40,0000	40,0000	100,00%	0,1443	0,0536	0,0000	0,0349	0,2328	USD
Stockage	☑	0,0000	0,0000	0,0000	0,0000	100,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
In circuit test - Setup	☐	0,9000	0,9000	0,9000	0,9000	99,00%	0,0032	0,0040	0,0000	0,0000	0,0072	USD
Panel loading/unloading	☑	0,0000	0,0000	0,0000	0,0000	99,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
In circuit test	☑	5,0000	5,0000	5,0000	5,0000	99,00%	0,0177	0,0223	0,0000	0,0044	0,0532	USD
Stockage	☑	0,0000	0,0000	0,0000	0,0000	99,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Depaneling	☑	30,0000	30,0000	30,0000	30,0000	99,00%	0,0243	0,0397	0,0000	0,0262	0,0902	USD
Stockage	☑	0,0000	0,0000	0,0000	0,0000	99,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Rework	☑	0,6000	0,6000	0,6000	0,6000	99,00%	0,0004	0,0016	0,0000	0,0005	0,0025	USD
Stockage	☑	0,0000	0,0000	0,0000	0,0000	99,00%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Hot Temperature Test - Setup	☐	0,9000	0,0040	0,9000	0,9000	95,04%	0,0005	0,0000	0,0000	0,0000	0,0005	USD
Hot Temperature Test	☑	90,0000	90,0000	90,0000	90,0000	95,04%	0,0460	0,0402	0,0000	0,0785	0,2122	USD
Storage	☐	0,0000	0,0000	0,0000	0,0000	95,04%	0,0000	0,0000	0,0000	0,0000	0,0000	USD
Board conditioning	☐	0,0000	10,0000	10,0000	10,0000	95,04%	0,0058	0,0265	0,0000	0,0087	0,0410	USD
	Board production time :	239,2000		Cycle time :	90,00	95,04%	0,6582	0,3132	0,0000	0,2009	1,2288	

The total Manufacturing and Test time is close to **xx seconds**.
The assembly is assumed to be done in **Hungary** and its cost is **$xx**

- Labor Cost : Direct Labor or Operators and line Technicians, which equals to **$xx**, **25%** of the Added Value.
- Indirect Labor : Line Managers and Engineers which equal to **$0.xx**, **54%** of the Added Value.
- Equipment Cost : Equipment, consumables, floor space and energy which equals to **$0.xx, 16%** of the Added Value.

The total cost takes into account a cumulative yield of **xx%** with none rejected items.

Conclusion

- **Reverse costing analysis represents the best cost/price evaluation given the publically available data, completed with industry expert estimates.**

- **These results are open for discussion. We can re-evaluate this circuit with your information. Please contact us:**