

Success Factor Proven Reliability of PV Modules and Systems

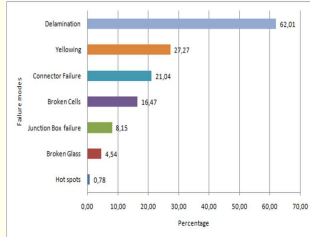
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Quality Management “nice to have?”

❑ Problem:

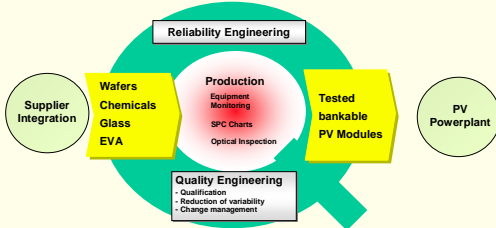
- Early failures of PV Modules
- Root causes:
 - deficient control of material and/or process
 - insufficient awareness for the importance of Quality Engineering for reliability



from Master Thesis A. Asfaw, Jacobs University Bremen, 2016

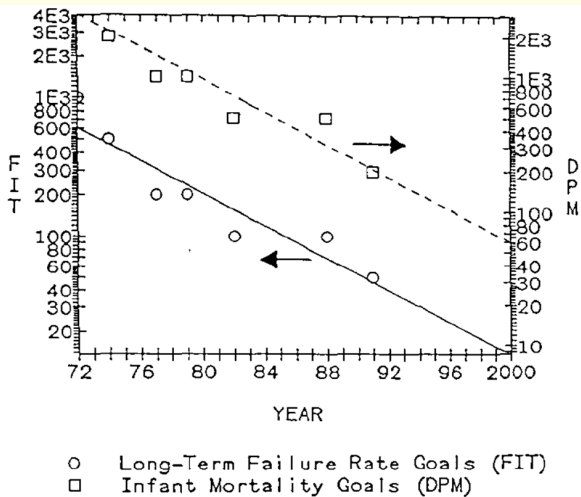
❑ Solution:

- Comprehensive Quality & Reliability Engineering



❑ Systematic Quality Management & Engineering Results in Microelectronics:

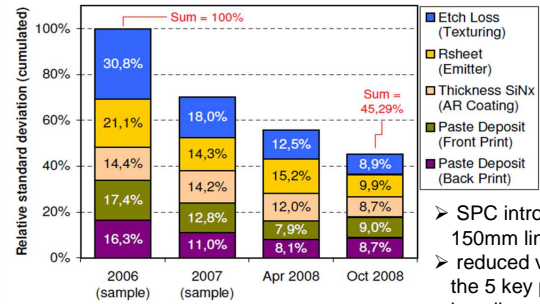
- remarkable x100 quality improvement demonstrated at INTEL



Crook, D.L., "Evolution of VLSI reliability engineering," in *Reliability Physics Symposium*, 1990, 28th Annual Proceedings, International, vol., no., pp.2-11, 27-29 March 1990 doi: 10.1109/RELPHY.1990.66052

Quality Engineering Results in Photovoltaics

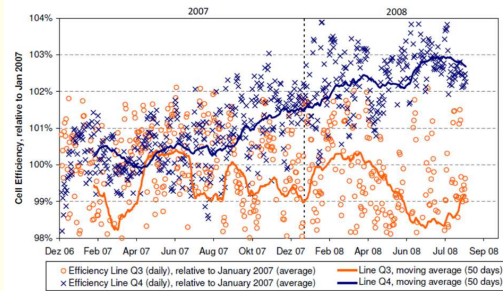
❑ Result 1a: Reduction of Variability by SPC



- SPC introduced in 150mm line
- reduced variability in the 5 key parameters in cell processing

(from PhD Thesis Thomas Dinkel, Jacobs University, Bremen 2008)

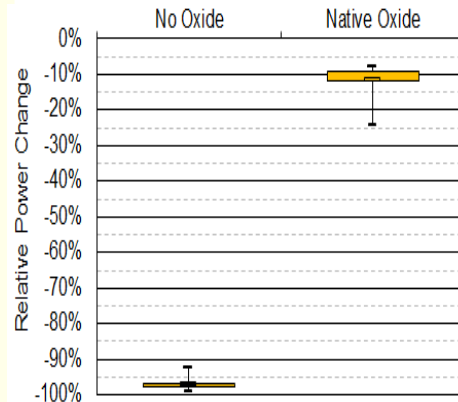
❑ Result 1b: Efficiency improvement by SPC



- significantly better efficiency improvement by SPC

(from PhD Thesis Thomas Dinkel, Jacobs University, Bremen 2008)

❑ Result 2: Potential Root Cause for PID



- power loss by PID dramatically reduced by oxide between Si and Si₃N₄
- Mechanism similar to the positive effect of PAD OXIDE in the LOCOS process in microelectronics

(from PhD Thesis Andrey Raykov, Jacobs University, Bremen 2015)

Conclusions

1. QM systems are not “nice to have” but NECESSARY to ensure stable and predictable production
2. SPC control reduces process variability → PV strings with lower mismatch losses
3. QM = the only way to ensure durable and reliable PV modules → bankable PV

“Quality is not a question of technology but of mindset” (Toyota)