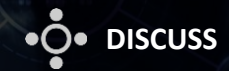
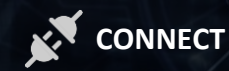




Fall Series 2021
Coating and Printing
4 Nov 2021



Magic Box “Coating and Printing”

What if you could enchant any product with the features you want?

Dr. Lars Sommerhäuser
Empa

Motivation «Independence»

- **Decoupling properties** of the inner material and the outer surface
Coating and printing are technologies to equip products at their surfaces with properties or functionalities that are different to the inner material of the product
- Properties and functionalities are manifold
 - Optical: equip a reflective watch glass with an anti-reflective coating
 - Mechanical: equip a “soft” drill with a “hard” coating to reduce wear
 - Chemical: equip a plastic implant with a titanium layer to enable cell growth
 - Functional: build a solar cell from a stack of thin layers on a flexible substrate



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Nam Pyo Suh and Axiomatic Design Theory

Nam Pyo Suh

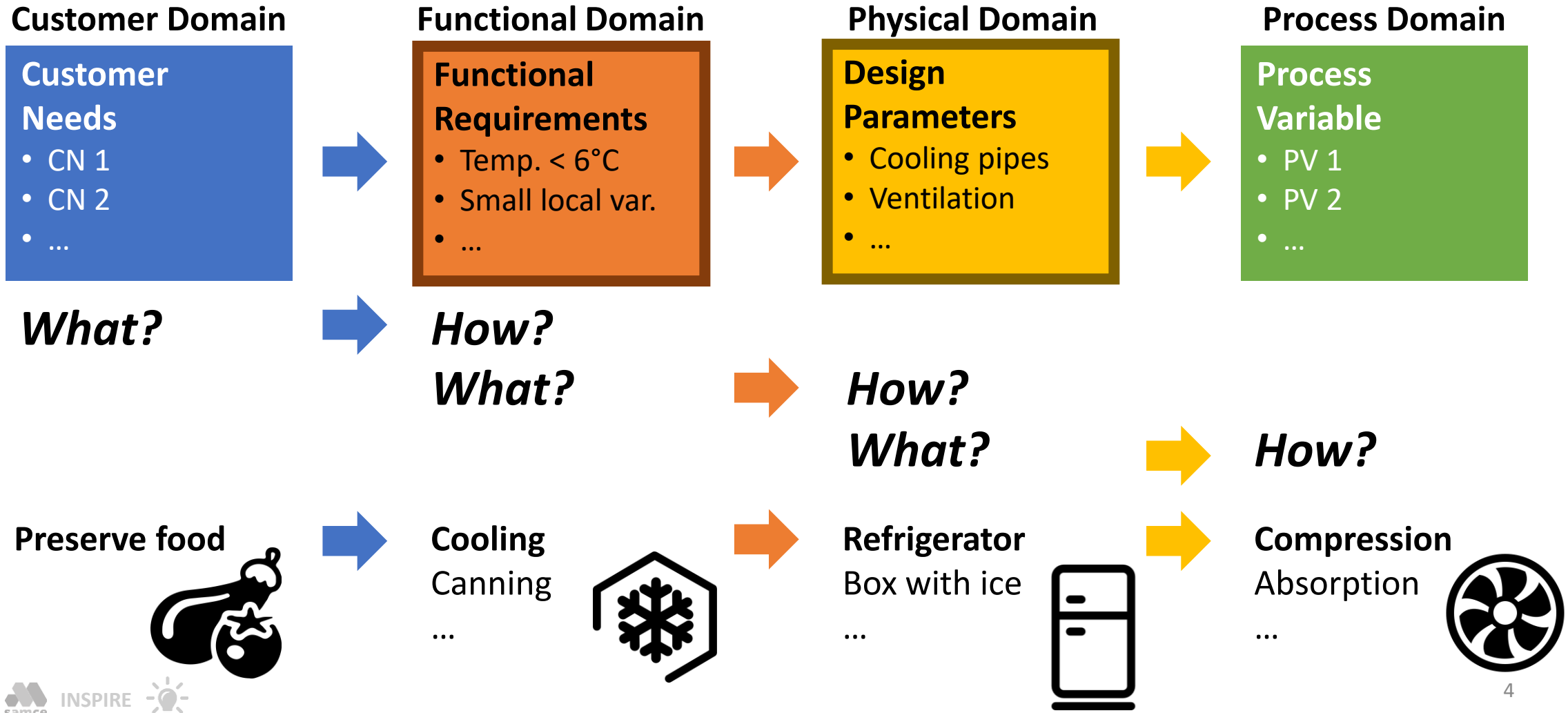
- Professor for Mechanical Engineering at MIT
- President of KAIST in Korea
- Written more than 100 patents, 300 papers and 8 books
- Inventor of the Axiomatic Design Theory



Axiomatic Design

- Method to systematically analyze and transform customer needs into functional requirements, design parameters, and process variables

Axiomatic Design «What-How Domain Zigzagging»



Axiom 1 – Independence Axiom

- **Independence Axiom**

Keep Functional Requirements (FR) independent and avoid Design Parameters (DP) that impact more than one Functional Requirement

- **Visualization Tool “Design Matrix”**

Matrix of Functional Requirements (FR) and Design Parameters (DP)

System A	DP 1	DP 2
FR 1	X	O
FR 2	O	X

Uncoupled

System B	DP 1	DP 2
FR 1	X	O
FR 2	X	X


Partially
Decoupled

System C	DP 1	DP 2
FR 1	X	X
FR 2	X	X

Fully coupled

Example A – Warship Design



CSS Virginia	DP 1: Ship's Rudder	USS Monitor	DP 1: Ship's Rudder	DP 2: Rotating Tower / Turret
FR 1: Direction of motion	X 	FR 1: Direction of motion	X	O
FR 2: Direction of fire	X	FR 2: Direction of fire	O	X



Uncoupled

Example B – Water-Tap Design

Equipment to control of the water flow in our bathroom or kitchen



Two valve armature	DP 1: Turn cold valve on / off	DP 2: Turn warm valve on / off	Single lever tap	DP 1: Turn left / turn right	DP 2: Lift / push down
FR 1: Change temperature	X	X	FR 1: Change temperature	X	O
FR 2: Change flow rate	X	X	FR 2: Change flow rate	O	X

Coupled



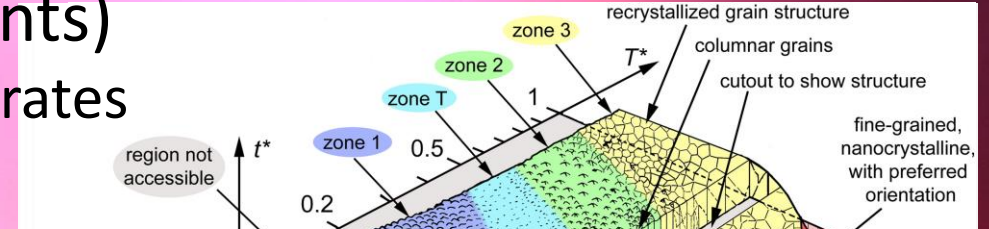
Uncoupled

Example C – PVD Coating Processes

PVD processes often need high substrate temperatures to equip atoms or ions with sufficient energy to form dense layers with good adhesion

Various Design Parameters, e.g. pulse power, pressure or ionization rate, impact various Functional Requirements

- Functional Requirements (spinal implants)
 - FR 1: No damage of temp. sensitive substrates
 - FR 2: Dense layers with good adhesion



DC Sputtering	DP 1: Substrate temperature	DP 2 various other process parameters	HiPIMS	DP 1: Substrate temperature	DP 2: Pulse power and duration
FR 1 Damage of substrate	X	(X)	FR 1 Damage of substrate	X	O
FR 2 Dense layer/adhes.	X	(X)	FR 2 Dense layer/adhes.	X	X

Coupled



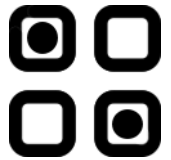
Partially decoupled

Take Home Messages



- **Understand your challenge**

Define Functional Requirements (FR) and structure them.



- **Go for independence**

Find Design Parameters (DP) in your processes that ideally influence only one of the Functional Requirements.



- **Reduce complexity and simplify**

Focus on the most important Design Parameters.



- **Invent new processes**

If your process design does not follow the independence axiom, invent new processes with Design Parameters that uncouple or decouple different Functional Requirements.

Thank you very much for you attention!

Dr. Lars Sommerhäuser

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Surface Science and Coating Technologies



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A black icon of two electrical plugs facing each other, symbolizing connection.

CONNECT

Pitches on research challenges that stimulate exchange and collaboration

The logo for CONNECT, featuring a black icon of two electrical plugs facing each other, with the word 'CONNECT' in a large, red, sans-serif font to its right.

CONNECT

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