Vigtige aspekter ved effektiv implementering af forskningsresultater i produkter

Topics of importance for efficient implementation of research results in products

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”Optimering af materialer, processer og ressourcer”

JÖNKÖPING UNIVERSITY

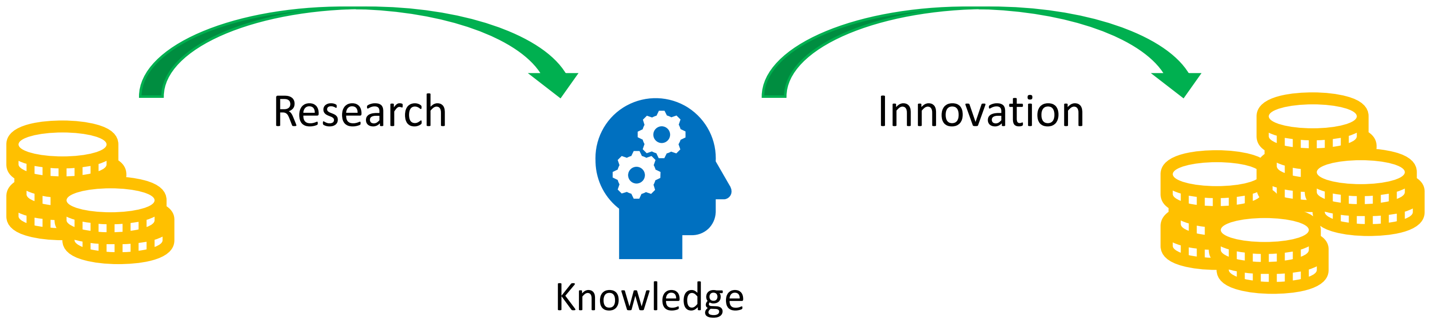
Outline

- Introduction
- TRL – Technology Readiness Level
- Aspects to be considered when making innovation out of promising research results
- Exemplified by cases from surface treatment of metals
    - Case 1: Ceramic coating for electric contacts
    - Case 2: Pd and Pd alloy plating
- Summary

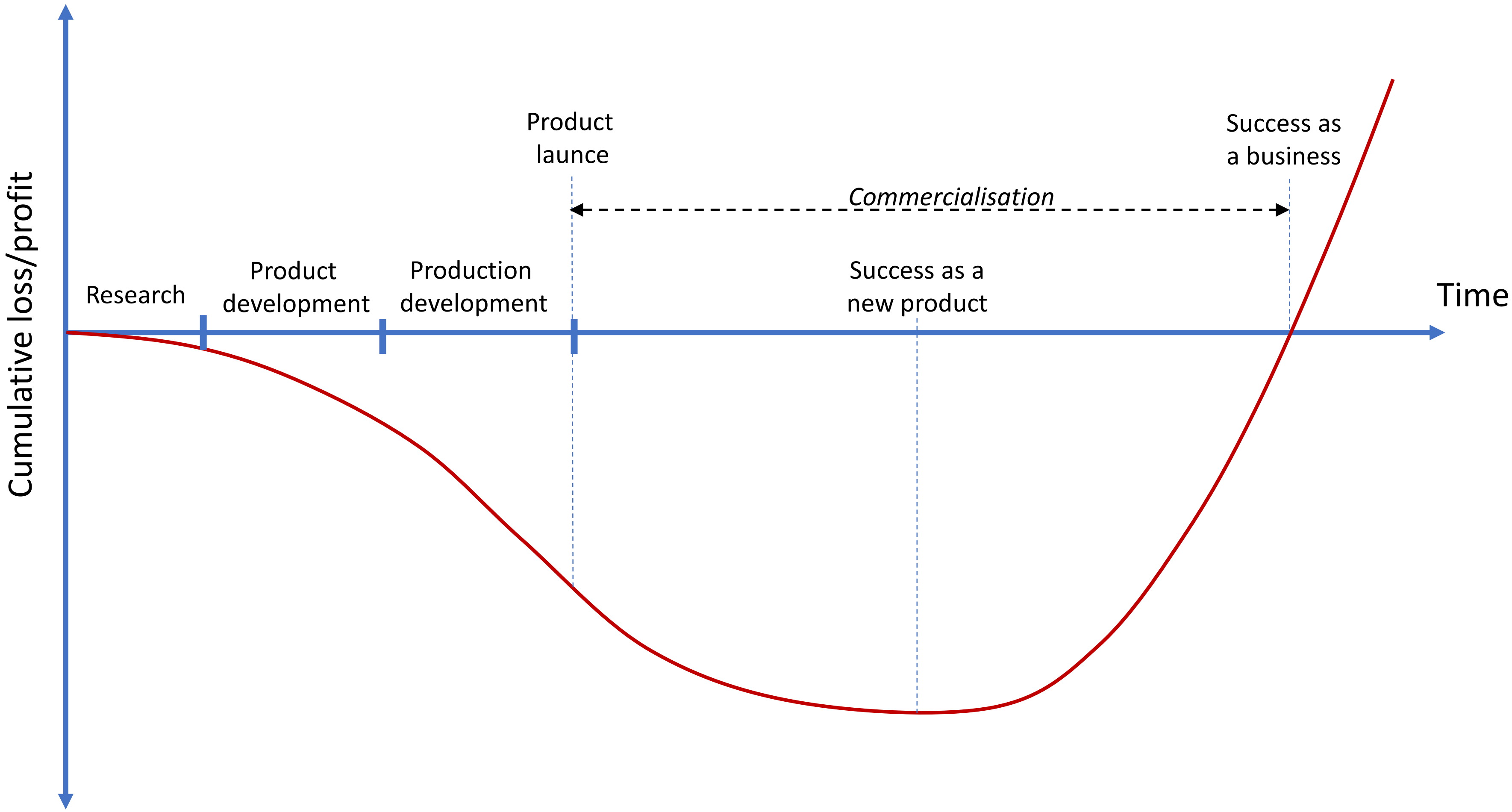
Innovation

Translating knowledge into a useful product that **creates value.**

- There most be a specific need
- You must have an idea to meet the need
- Somebody must be willing to pay for it

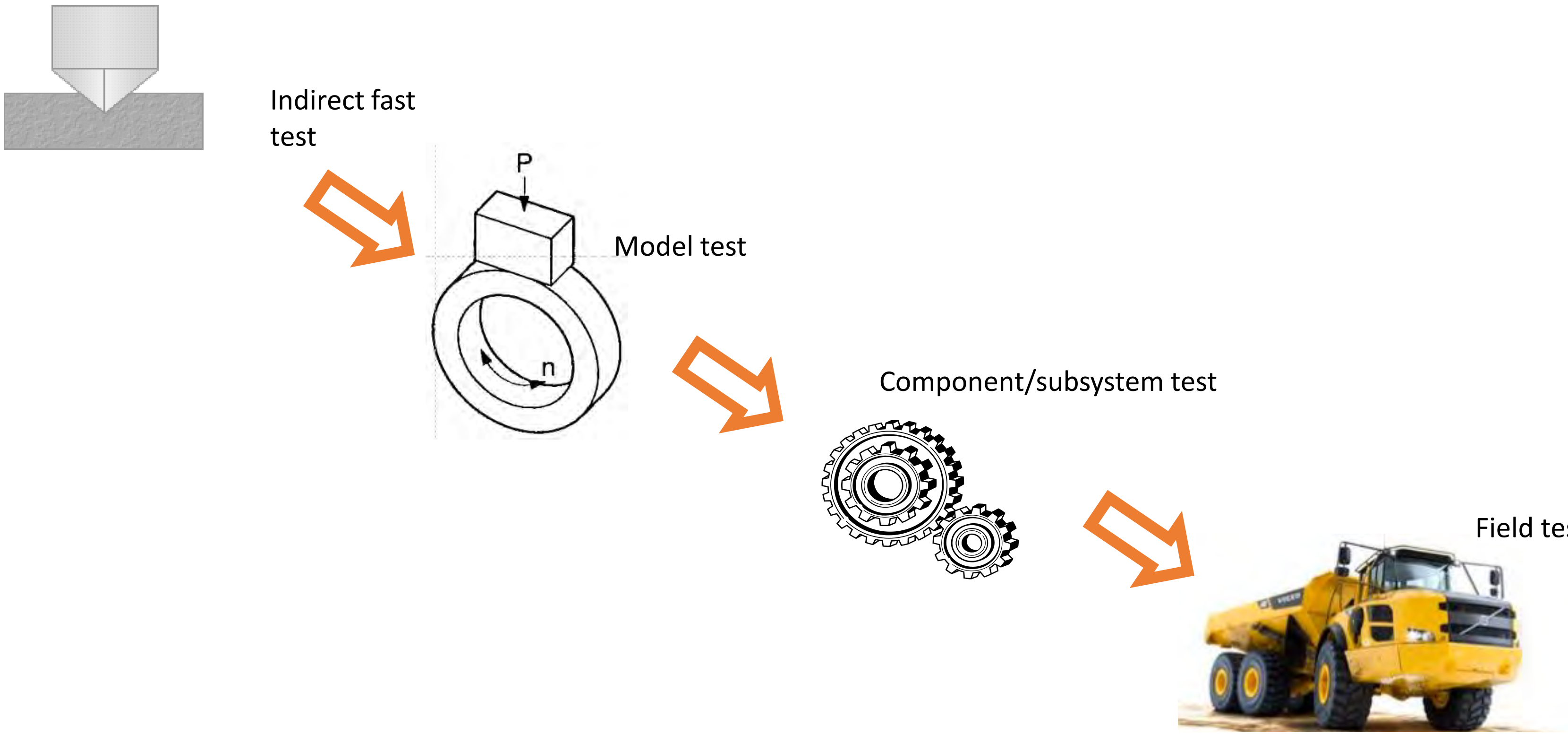


The ”death vally” of product commercialisation



Development steps in materials engineering

The normal route of investigating and selecting a material solution exemplified by tribological testing



We are evaluating the maturity of the technology in several steps

TRL – Technology Readiness Level

Origination

- Defence and space technology in the 1970s
- US DoD decided to use TRL in new major programs
- 2010 Start of being adopted by other industries, authorities, funding agencies …

Challenge
Introducing premature technologies in new product development projects will ultimately generate cost overruns and schedule delays

https://www.youtube.com/watch?v=e-Qf-X54wAA

Accident in 1989 with protorype of Swedish jet fighter at the first presentation to the public

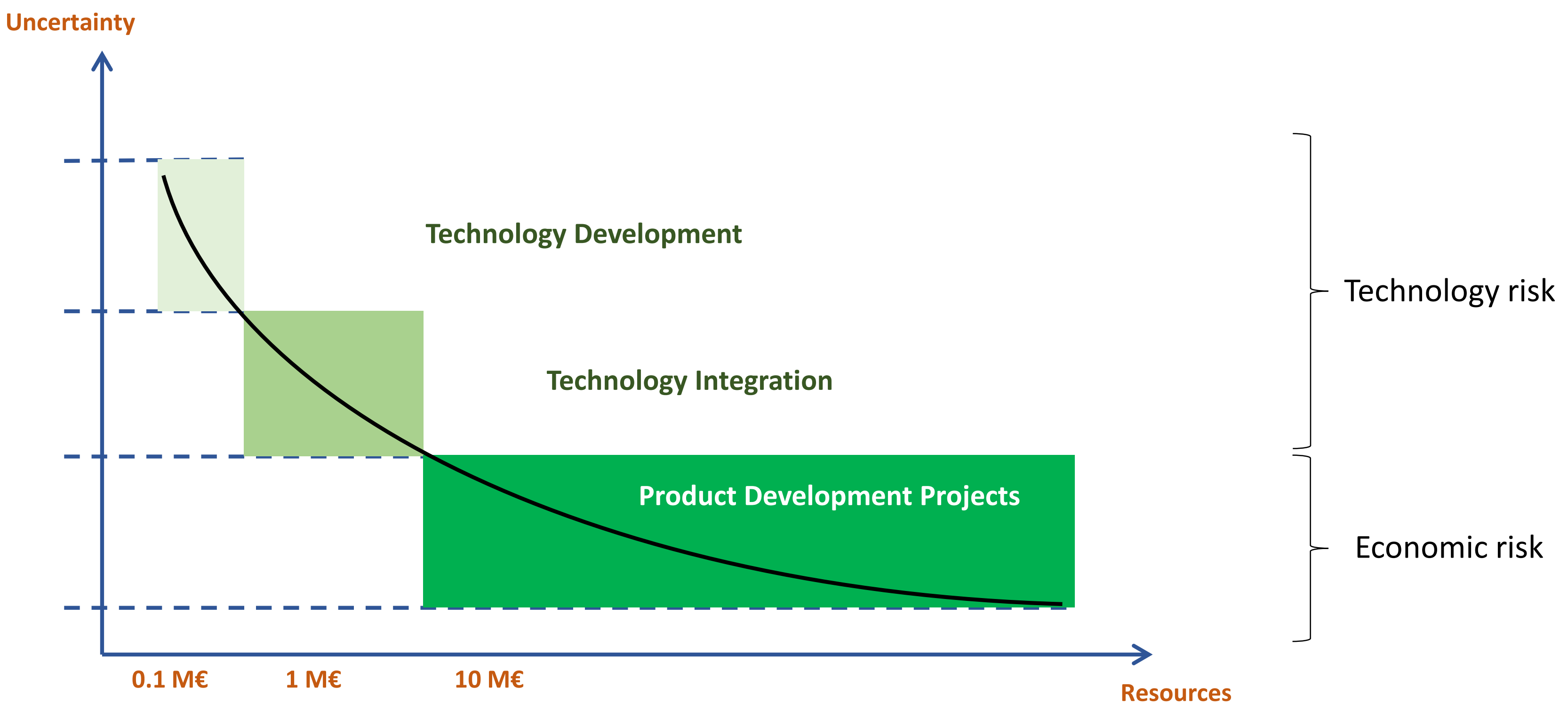
https://www.youtube.com/watch?v=BqGf8pqCZi0

Elon Musk presents Teslas Cybertruck with "amored" glass November 2019

Solution

- Consequently, assess carefully the technology's maturity and the potential consequences on product projects during the development.
- In order to assess the technology's maturity, Technology Readiness Levels is used.

TRL – Managing uncertainty



TRL – Definition

Basic research

TRL1	Basic principles observed and reported

Applied research

TRL2	Technology concept and/or application formulated
TRL3	Analytic and experimental critical function and/or characteristics proof of concept
TRL4	Component and/or breadboard validation in laboratory environment
TRL5	Component and/or breadboard validation in relevant environment

System development

TRL6	System/subsystem model or prototype demonstration in a relevant environment
TRL7	System prototype demonstration in an operational environment
TRL8	Actual prototype completed and qualified through test and demonstration

Product development

TRL9	Actual system proven through successful mission operations

The original definition by US DoD
(DoD, Defense Acquisition Guidebook, 2010)

Integrated in EU definition of maturity of technology

Criteria for selection of surface treatment

Technical properties	Corrosion, wear, electric, magnetic, etc => TRL
Environment	External environment, working environment, recycling
Legislation	Environment, medical, food, IPR, other restrictions
Economy	Direct costs, investment, added value in the whole value chain
Design	Does the design fit the process (substrate, size, shape)
Lifetime	Does the lifetime fit the rest of the product (too short or too long?). Meet the quality demands – the right quality, not the best quality.
Availability	Production volume, delivery time, reliable delivery, costumer service

Case 1: Ceramic coating for electric contacts

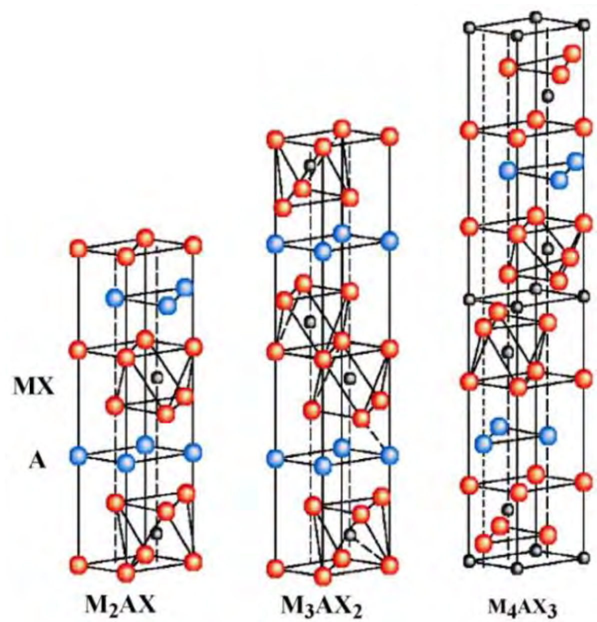
MAX phases

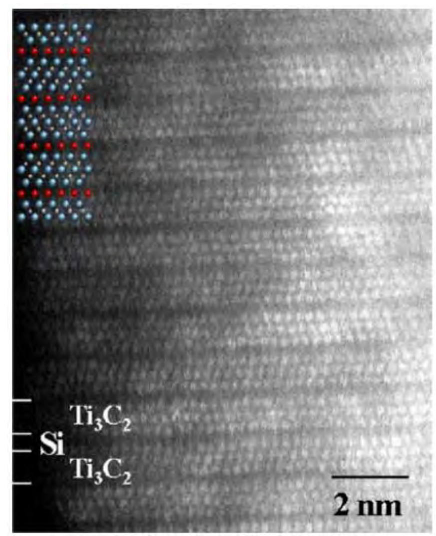
- $M_{n+1}AX_n$ (where n=1, 2 or 3)
- M is an early transition metal (e.g. Ti and Cr)
- A is an A-group element (mostly IIIA and IVA, e.g. Al and Si)
- X is C or N

Combines properties of

- metals (machinable, electrical and thermal conductivity)
- ceramics (oxidation and thermal shock resistant)

M.W. Barsoum, Prog. Solid St. Chem. 28 (2000) 201-281





Ti_3SiC_2

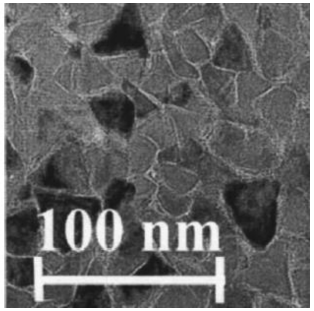
H. Högberg et al., Surf. Coat. Technol. 193 (2005) 6-10

Case 1: Ceramic coating for electric contacts

True MAX deposited by PVD at 800-900 °C

Low temperature PVD deposition

- < 300 °C
- Nano-composite structure: *nc*-TiC/*a*-SiC
- Relatively ductile
- Electric conductive
- Low contact resistance
- Corrosion resistant
- Thermal stability
- Environmentally friendly

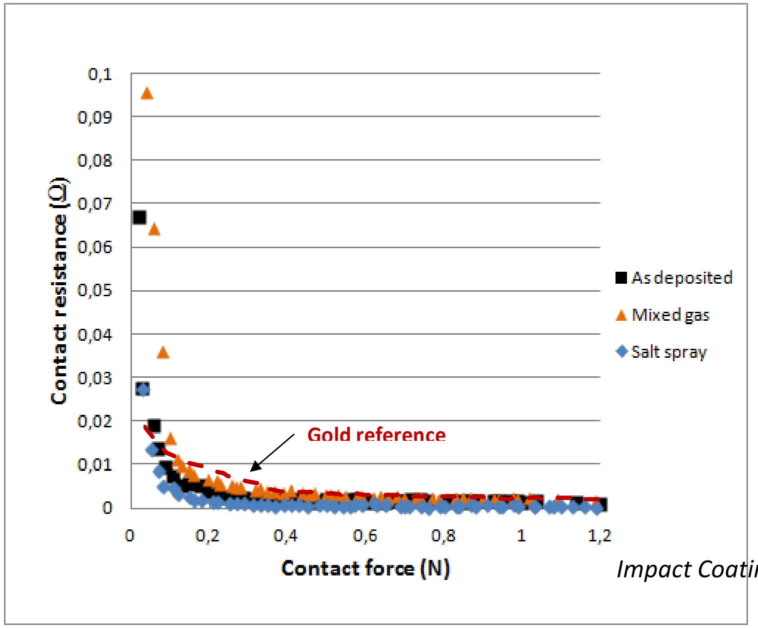


nc-TiC/*a*-SiC

P. Eklund et al., J. Vac. Sci. Technol. B23, 6 (2005) 2486-2495

Further development by doping/alloying with silver

- Even lower contact resistance
- Solderable
- Replacement for gold
- Can be applied on plastic



Impact Coatings AB

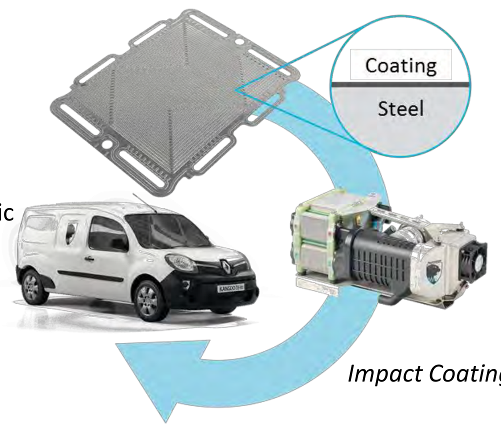
Case 1: Ceramic coating for electric contacts

Application on bipolar flow plates in PEM fuel cells

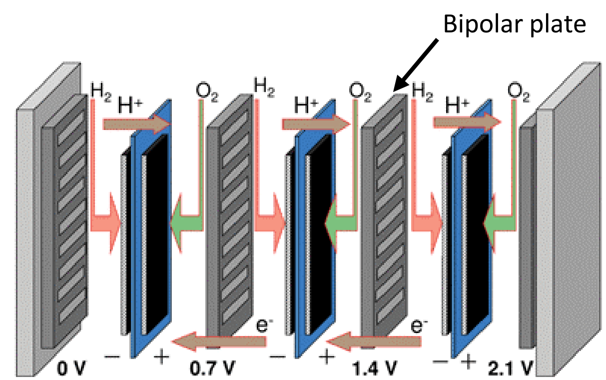
- one side connect to the anode of one cell, the other side to the cathode of the next cell (series)
- compact device
- increase the output voltage
- maintain low electric contact resistance over the lifetime
- represent a significant part of the weight and cost of a fuel cell

DoE and IEA agrees on the need of: Lower cost, lighter, corrosion-resistant bipolar plates

Fuel Cell Electric Vehicle (FCEV)



Impact Coatings AB



About **350 bipolar plates per fuel cell stack** for a FCEV rated at 100 kW power (*Impact Coatings AB*)

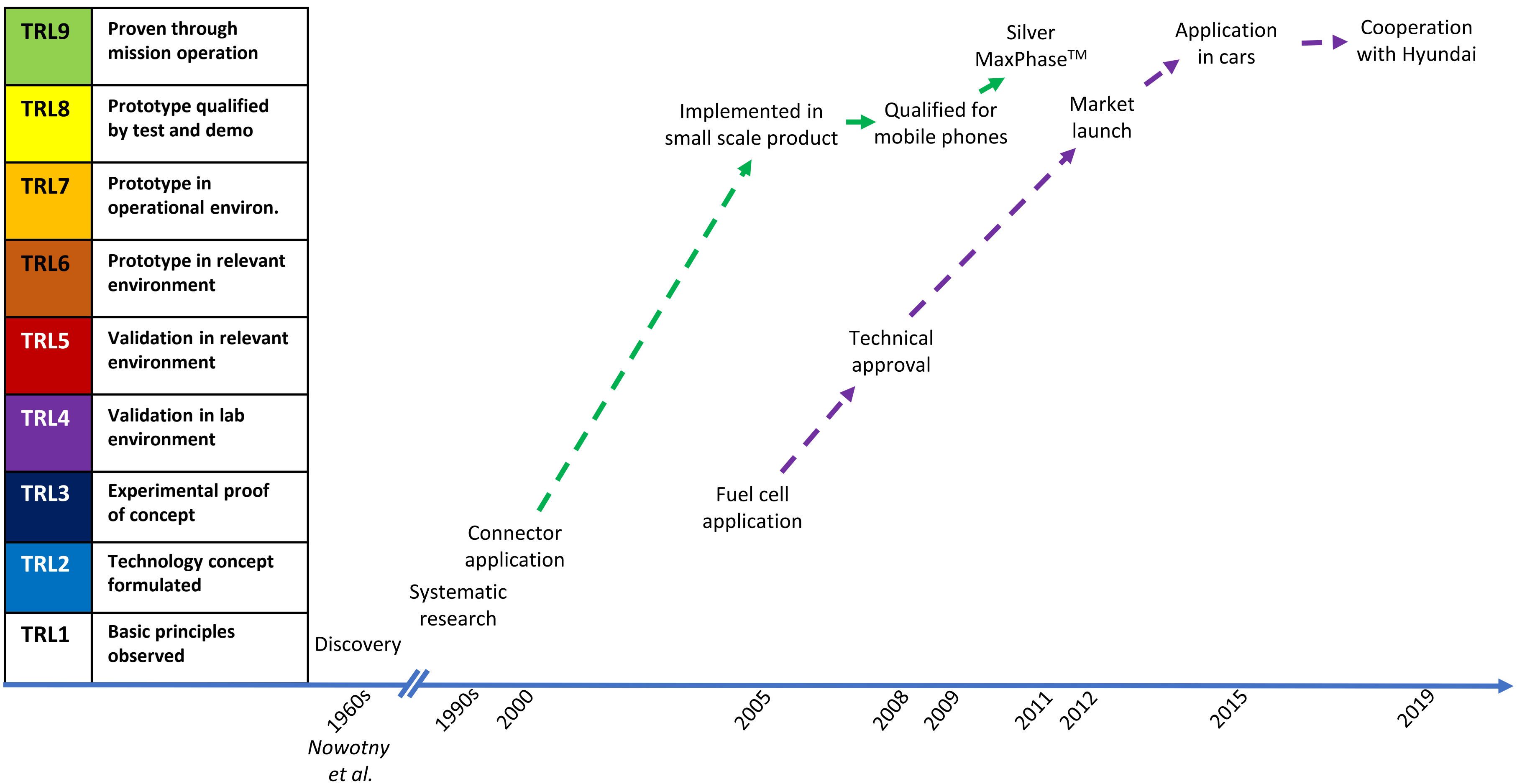
Very different application and environment

- *Restart on TRL3*

TRL3	Analytic and experimental critical function and/or characteristics proof of concept

Case 1: Ceramic coating for electric contacts

Innovation time line



Case 1: Ceramic coating for electric contacts

What did we learn from this case?

Rule of thumb:

When changing application of the technology, you most often have to start over to verify at TRL4 or TRL5 even if the technology is verified at TRL9 for the original application.

TRL4	Component and/or breadboard validation in laboratory environment
TRL5	Component and/or breadboard validation in relevant environment

Sometimes, by comparing specification, an by making an ”Engineering judgment” you can argue that you only need to start over from TRL6-7.

TRL6	System/subsystem model or prototype demonstration in a relevant environment
TRL7	System prototype demonstration in an operational environment

If the change in application is very big, you might need to start over to verify at TRL3 (e.g. going from electric connector to bipolar plate inside a fuel cell).

TRL3	Analytic and experimental critical function and/or characteristics proof of concept

Case 2: Pd and Pd alloy plating

Hard gold (Au-Ni, Au-Co) is used on high quality electronic connectors.

To save costs Lucent Technologies implemented Pd plating (based on several patents) in 1980s and 1990s.

Technically

Pd is more ductile than hard gold. Better contact bending tolerance.

Wear resistance is less good than hard gold.

In general Pd and hard gold coatings are comparable and interchangeable.

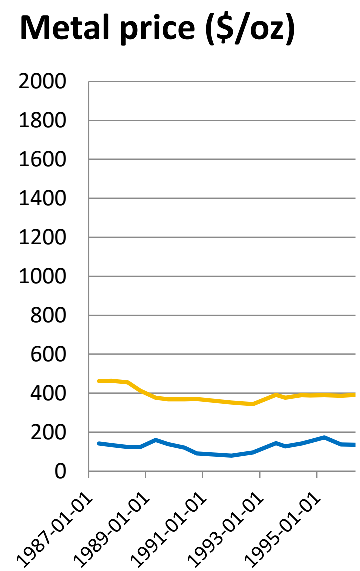
Costumer acceptance

If costumers are not convinced, a gold flash on top helps. This result even in less wear and better solderability.

Financial case

During 1995 Lucent Technologies saved more than 100 M$ in gold costs!

Lucent Technologies got an innovation award.

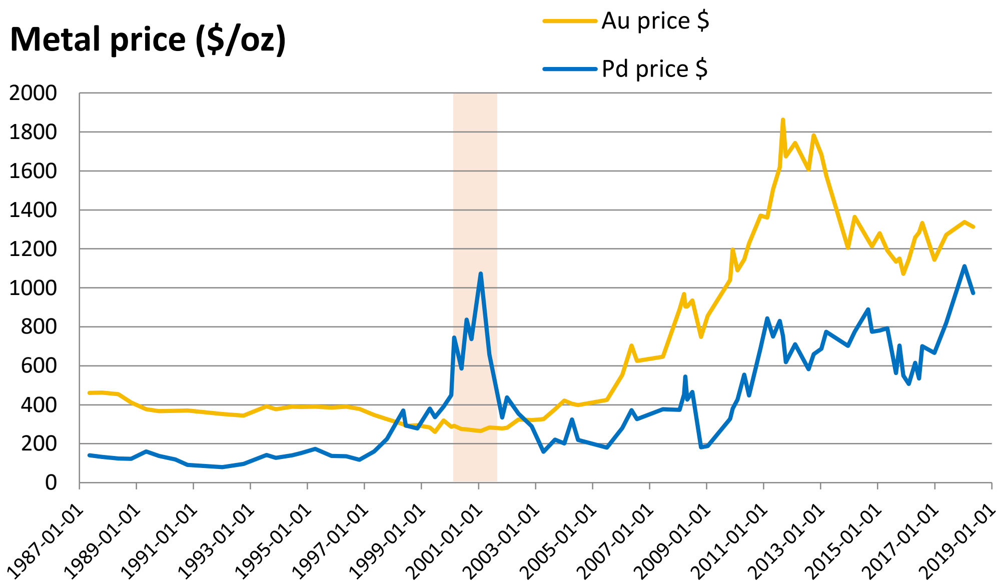


Case 2: Pd and Pd alloy plating

How did it develop?

- Prices changed
- Alloying became important:
  - Pd-Ni (80/20 to 50/50)
  - Later Pd-Co (80/20)
- A family of processes are available allowing fine-tuning to meet application specific demands:
  - Lower cost
  - Better wear resistance
  - Ductility
  - Wirebondable
  - Solderable
  - Corrosion resistant
  - High temperature resistant
  - Protective for Cu-substrate and low porosity
  - Thinner coating

Metal price ($/oz)



Case 2: Pd and Pd alloy plating

What did we learn from this case?

Technical properties	Corrosion, wear, electric, magnetic, etc => TRL
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Availability	Production volume, delivery time, reliable delivery, costumer service
Costumer expectation	

These factors are not constants!

A long lasting innovation should have many qualities and the ability to evolve

Summary

Your research result only becomes an innovation if it <u>satisfies a specific need</u> and <u>creates value</u> for customers.

Be aware of what TRL your technology is at in each specific case.

Other important issues to consider (these factors are not constants!)

- Environment
- Legislation
- Economy
- Design
- Lifetime .
- Availability
- Costumer expectation

A long lasting innovation should have many qualities and the ability to evolve

Commercial Readiness Index (CRI) runs in parallel with the TRL scale and beyond.

Australian Renewable Energy Agency (ARENA) 2014