

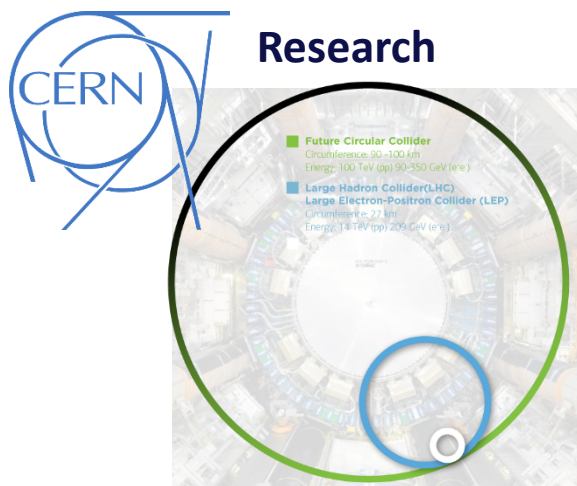
Bridging research & industry:

Creating value from FCC's technologies for the general public

A series of overlapping, wavy lines in shades of blue and grey, creating a sense of motion and flow across the middle of the slide.

by LINN KRETZSCHMAR
FCC Week 2021, June 30th 2021

In the industrial cycle, supporting the industry implies supporting research



Scientific Advancements

Various Industrial Application Fields

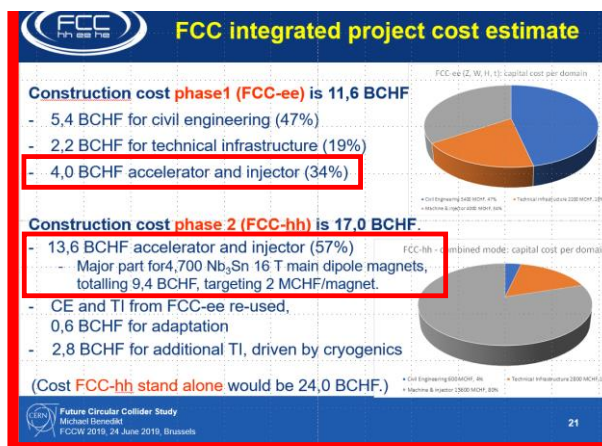


Reduced Manufacturing Costs

Higher Production Rates

The more needs a technology satisfies:

- Demand
- Economies of Scale & Scope

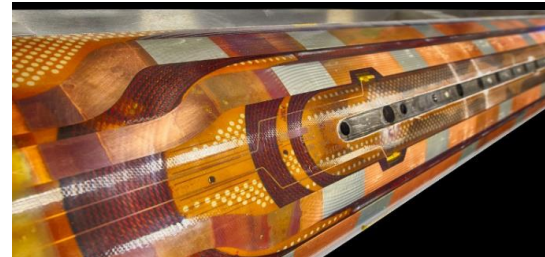


From 2017- 2021, we analyzed the potential of selected FCC Technologies

Analyzed FCC Technologies



Rutherford Cable



Vacuum epoxy impregnation



Thermal treatment oven

From 2017- 2021, we analyzed the potential of selected FCC Technologies

Analyzed FCC Technologies



Rutherford Cable

FOCUS



High power impulse magnetron sputtering (HiPIMS)

- Coating of copper cavities with thin layer of Niobium
- Costs: Niobium: 42,000 USD/t vs Copper: 5,700 USD/t

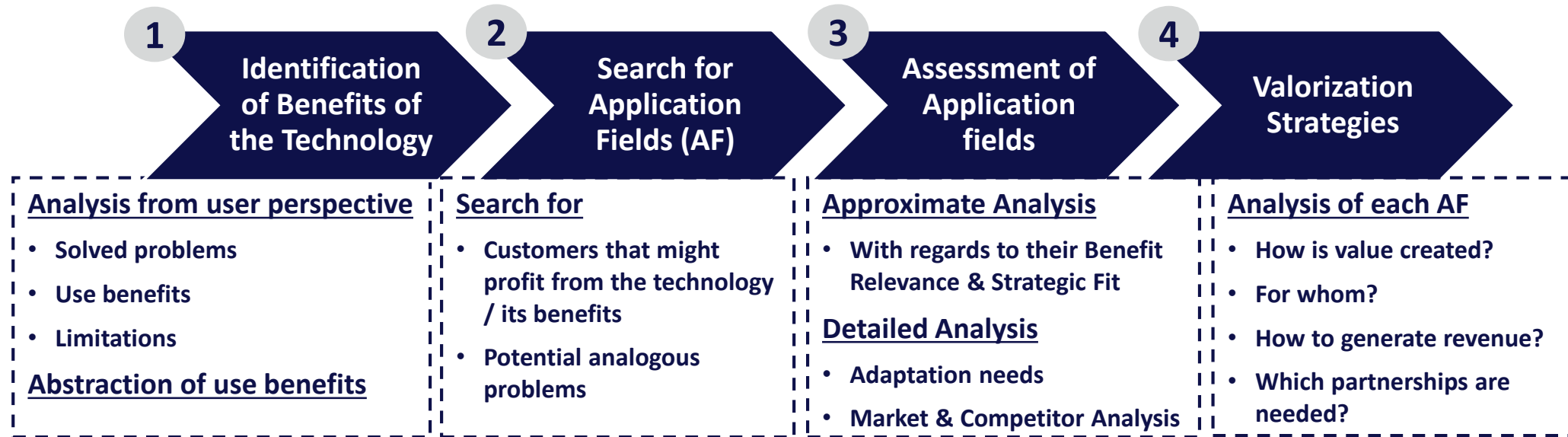


Thermal treatment oven

How to trigger finding innovative application fields

Technology Competence Leveraging*

Systematic, proactive & crowdsourcing-based method to identify and evaluate innovative application fields (AF) for (existing) technologies



* Pioneered by Keinz, P & Prügl, R. (2010)

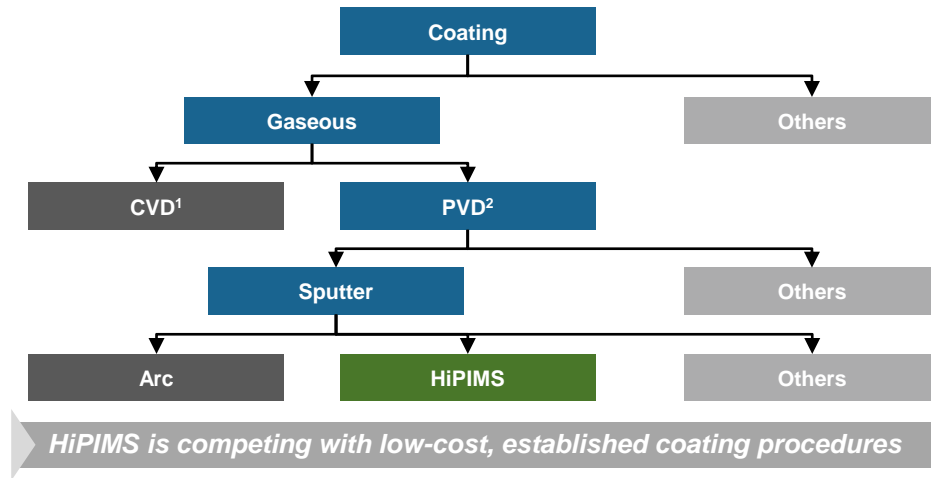
Secondary & primary research helped to make informed assessments

- Scanning of scientific articles, patents, expert online communities, databases
- 18 in-depth expert interviews were conducted to evaluate the potential of the technology in various application fields



Benefits of HiPIMS

Classification of Coating Procedures



Comparison of Coating Procedures

| | Arc | CVD ¹ | HiPIMS |
|-------------------------|---------------|------------------|--------------|
| Surface | Droplets | Rough | Smooth |
| Coating Temperature C° | 500 | 1000 | 500 |
| Max Layer Thickness | 4 um | 10-15 um | 12 um |
| Residual coating stress | High compress | Tensile | Low compress |
| Ductility of layer | High | Low | Very high |
| Ease of Production | Yes | No | Yes |
| Flexibility | Low | None | High |

Advantages



Possibility to coat complex 3D-structures



Thinner, more precise coatings



Longer lasting coatings

¹Chemical vapor deposition, ²Physical vapor deposition

HiPIMS application fields



Automotive Industry

- ▶ Engine components
- ▶ Gears
- ▶ Plain bearings
- ▶ Ball bearings



Aerospace Industry

- ▶ Drones
- ▶ Satellites
- ▶ Spacecrafts



Medical Industry

- ▶ Implants
- ▶ Prostheses & Stents
- ▶ Catheters



Electronic Devices

- ▶ Touchscreens
- ▶ Electronics (e.g. chips)



Clothing Industry

- ▶ Shoes
- ▶ Gloves
- ▶ Active wear



Glass Industry

- ▶ Windowpanes
- ▶ Solar panels
- ▶ Optical glass



Other Industries

- ▶ Rails
- ▶ Drill heads (oil & tunnel drilling)
- ▶ Food manufacturing machines



Sports Equipment

- ▶ Helmets
- ▶ Sport balls
- ▶ Climbing equipment
- ▶ Skiing equipment

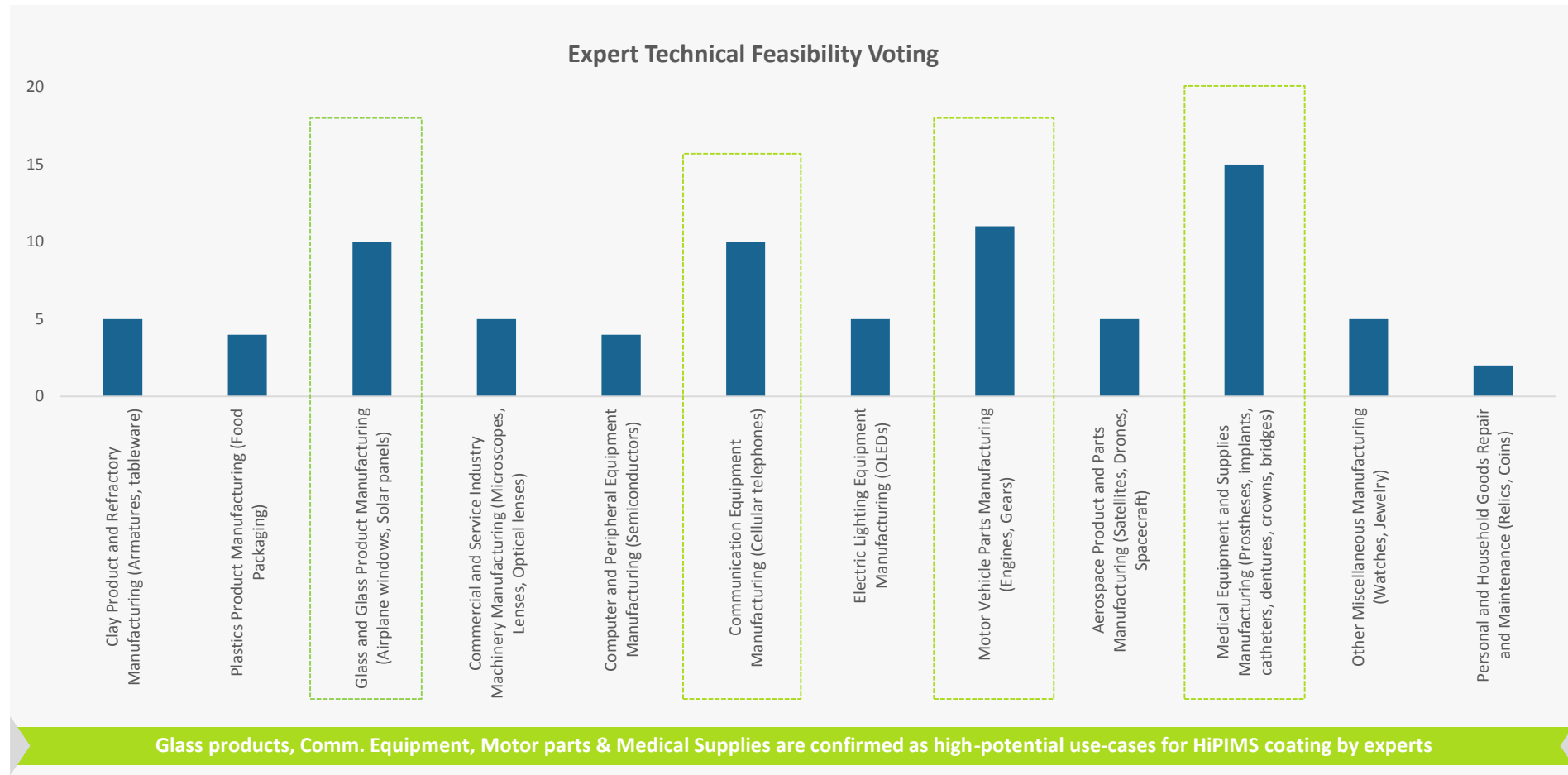


Engineering

- ▶ Gripper
- ▶ Stamping tools
- ▶ Cable car drive pulleys

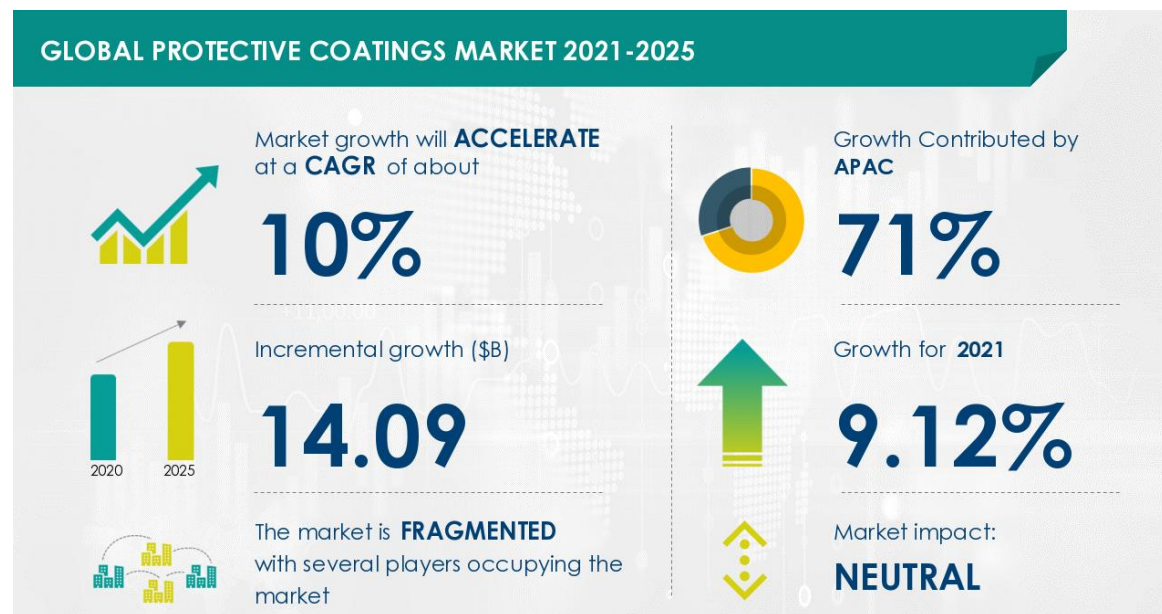
HiPIMS application field feasibility assessment

Current and potential application fields



Application field I: Communication Equipment

- Coating of frames of **smart devices** is emerging application field of HiPIMS
- offers outstanding advantages compared to conventional PVD coating methods (**against corrosion, sticking and wear**)
- Major mobile electronic production firms (e.g. Apple, Samsung) increased their R&D efforts
- Potential to expand to further use-cases (e.g. luxury products)



Apple's iPhone 12 Pro Gold is less prone to fingerprints & more durable due to HiPIMS coating



Source: Technavio (2021)

Application field II: Glass Manufacturing

- Currently: HiPIMS Coating of architectural glass due to thermal insulation properties
- Especially **solar panels** and **windows** are promising application fields
 - Limits stress from environmental influences
- Fastest-growing glass products:
 - solar control glass (low-emissivity glass, reflective glass and "smart" glass)
 - heads-up display windscreens; self-cleaning glass & ultraclear glass
- HiPIMS coating allows glass to be curved for consumer electronics (smartphones, tablets, ...)



Curved ITO coating on glass following a tempering and bending process at 650 °C (Fraunhofer IST)

Benefits of curved displays



More visible in ambient light



Produces less reflection and glare



Improves battery life

USD 115.8 billion*

*Global flat glass market 2019

Application field III: Automotive Parts Manufacturing

- HiPIMS can be utilized for **functional** and **aesthetic** coating in automotive industry
- Functional: Engines, injectors, gears and other parts of motor vehicles
- Decorative coatings of external car parts
- Trends:
 - **E-mobility:** Decreased weight due to thinner, yet durable HiPIMS coating -> reduced fuel consumption -> increased driving range
 - Governmental pushes towards new coating technologies due to environmental threats of **volatile organic compounds (VOCs)** in current coatings
 - **Haptic interactions:** increased demand of functional coatings that facilitate haptic interactions, such as high scratch & mar resistance, easy to clean, anti-fingerprint, anti-glare



With HiPIMS, Bosch achieves higher component quality with increased process reliability in the production of common rail injectors

USD 69.28 billion*

*expected OEM coatings market size in 2022

Sources: Allied Market Research (2019): Automotive OEM coatings market; CemeCon (2004)

Take Aways

- (1) Consider not only the final product but **knowledge, processes & technologies** involved in **manufacturing** the product when assessing **market potential**
- (2) **Anticipate dead ends & unexpected turns** in finding suitable & valuable application fields → **Iterative process**
- (3) **Work together.** Exchange of knowledge & interdisciplinary collaboration between scientists & industry is crucial



Thank you!

Feel free to reach out

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