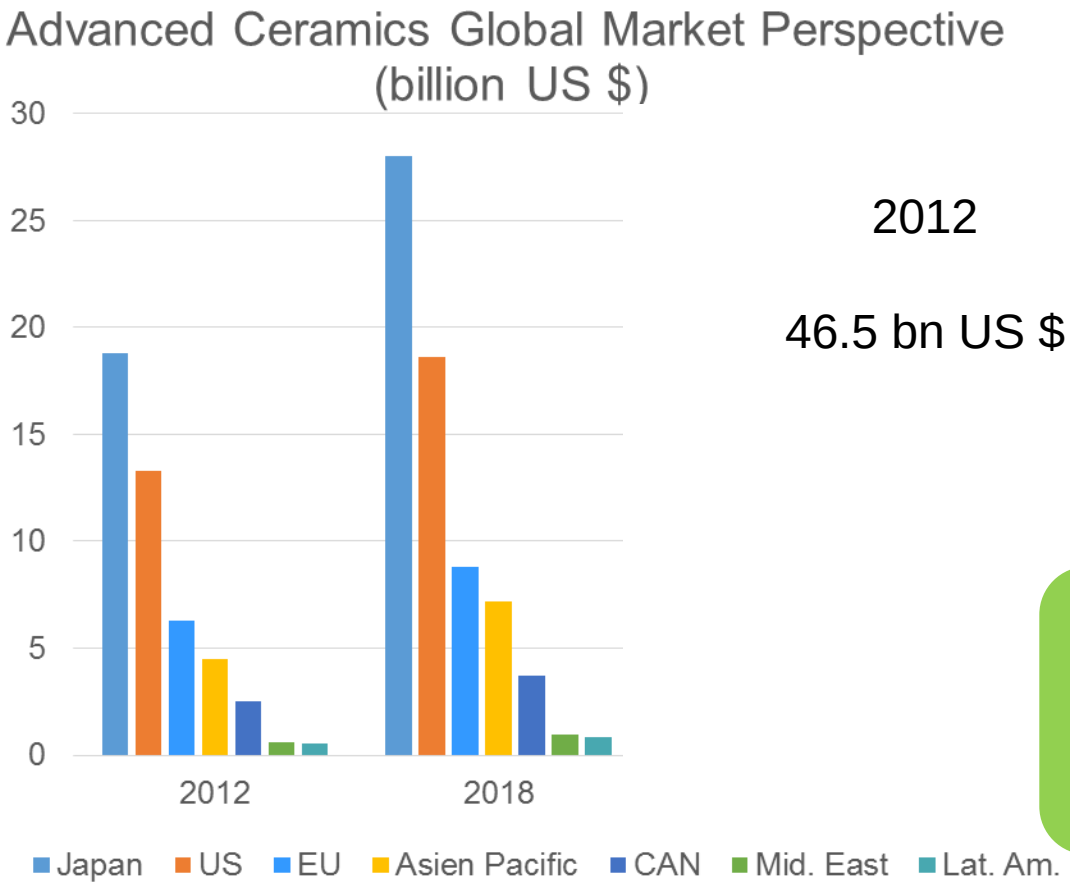
Roadmap for Ceramics, Research in Japan and Germany

Haibo Zhang
Guangdong HUST Industrial Technology Research Institute

Contents

1. Ceramics as an enabling technology
2. The approach for making a roadmap in general
3. The German Roadmaps
4. The innovation indicator
5. Industry – university collaboration in Japan
6. Industry – university collaboration in Germany

Relevance of Advanced Ceramics



Source: Global Industry Analysts, Inc. 2012

Total growth

2012

46.5 bn US $

+ 6.18 % / year

2018

68.1 bn US $

Growth by region

Asia Pacific(亚太)	8.0 %
Japan(日本)	6.3 %
EU(欧洲)	5.6 %
US(美国)	5.5 %

Ceramics as enabling technology

From high performance material to diesel injection system

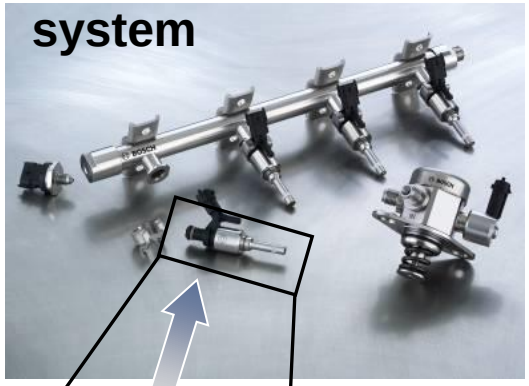
2006: 16 million piezo-injectors, > 100 % growth rate

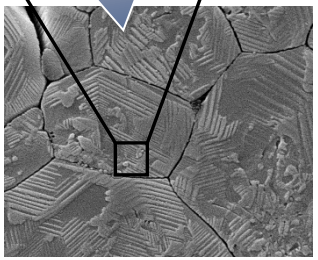
raw material

4 €

10^3 €

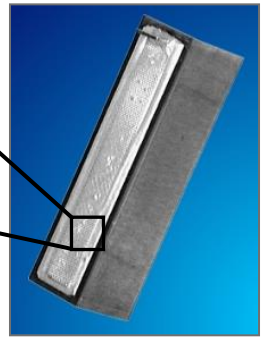
system





micro structure

component



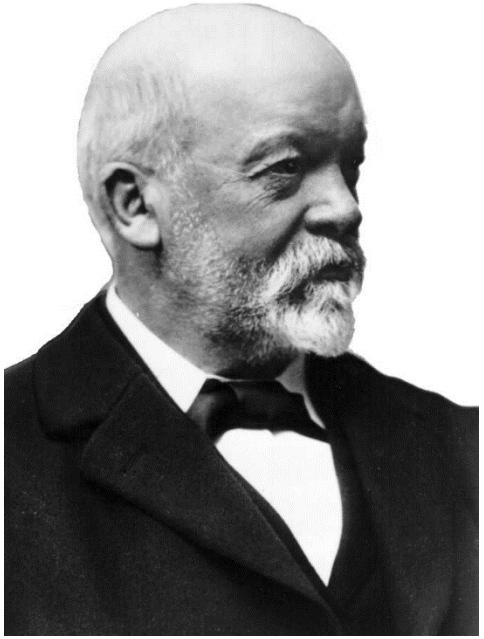
10^1 €

device

10^2 €

Source: Robert Bosch GmbH

Foresee the Future （long term prediction）

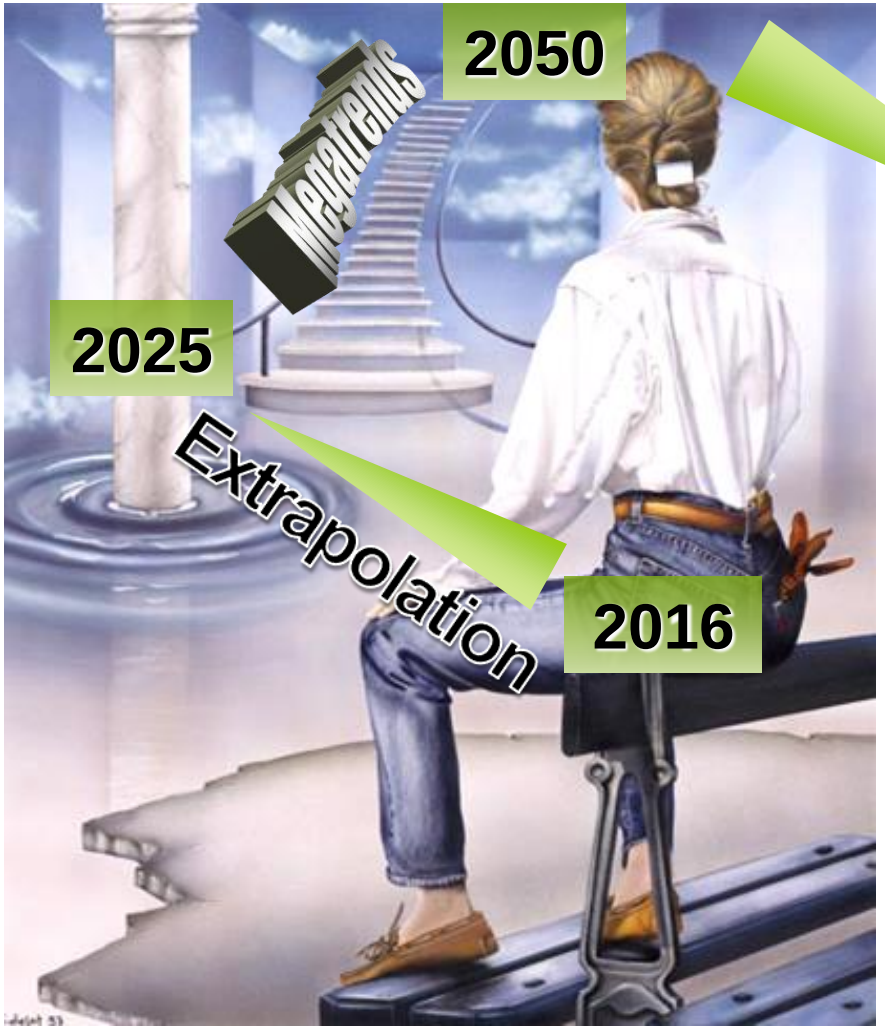


Gottlieb Daimler (1834-1900)

The worldwide demand for motor vehicles will not exceed 1 million – simply due to the lack of available drivers.

Roadmaps should help to establish a joint understanding about possible future trends and initiate thinking about changes.

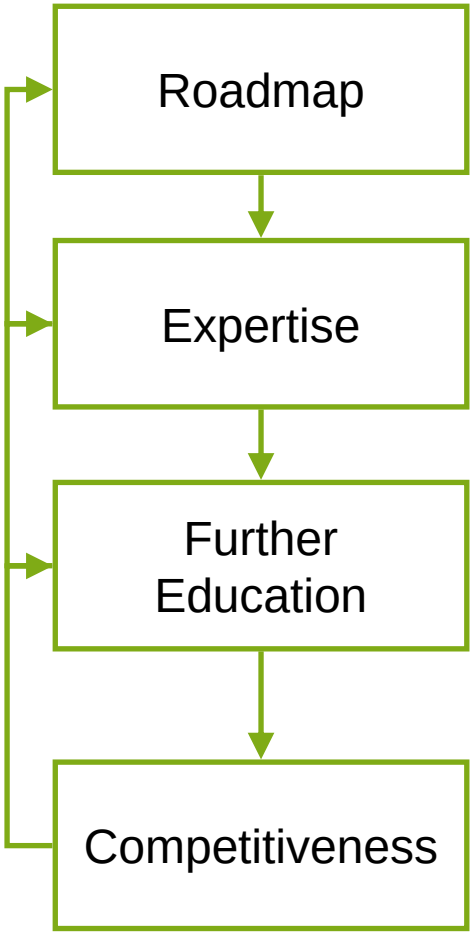
2 Steps



high performance ceramics

Source: Siemens GmbH

Relevance of Roadmaps



Continuous updates of roadmap to anticipate future trends and initiate thinking about changes.

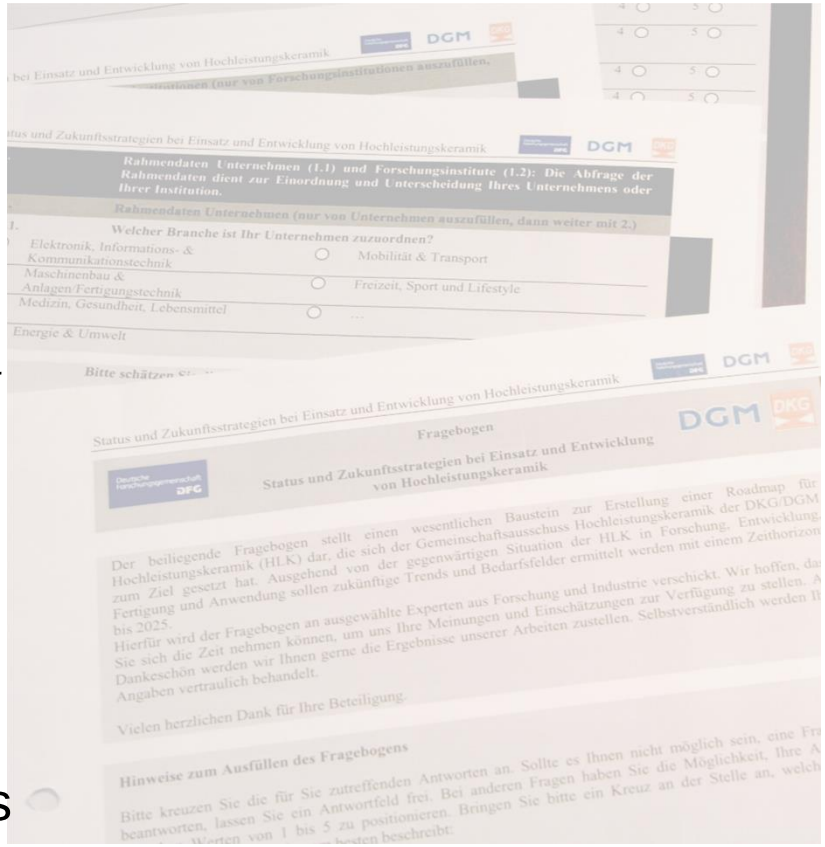
Information about future trends help Materials Science to develop and prioritize essential expertises.

Further development and transfer of expertise into education to guarantee future strategy on materials and technology of processes and products.

Adjustement of education can strengthen the competitiveness on the global market.

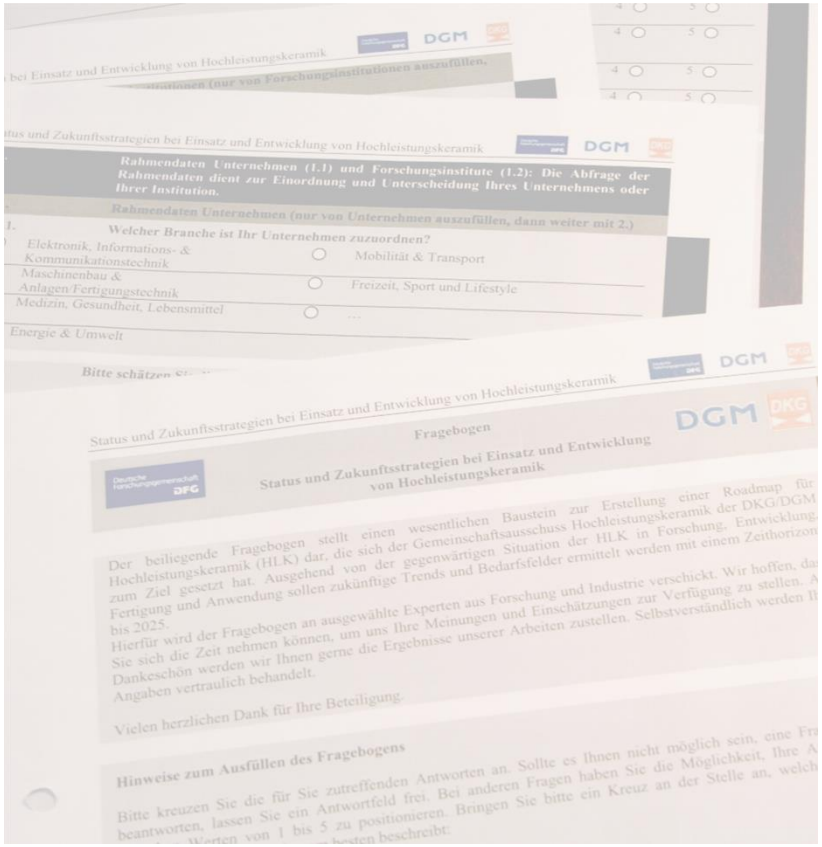
Approach to the Roadmap 2025 in Germany. Project from 2005-07

1. Review international literature (USA, UK, Japan, Global approach)
2. Questionnaire from experts
3. Interviews of experts
   - Academia
   - Industry
4. Workshop with experts
5. Draft roadmap, prepare talks, publications, advise funding agencies



Management: Roadmap project from 2006-08

1. Two scientists were hired, one each in management (Kassel) and in ceramics (Darmstadt)
2. Funding was provided by DFG
3. 125 Questionnaires were evaluated
4. 25 experts were interviewed in Germany, Switzerland, Austria, UK, USA
5. Participants in the effort came from Industry, national labs, universities
6. Advice was provided to EU, DFG, ministry



Goals

Collaborations

Project Funding

- Find areas for new scientific developments

Project Funding

- Determine needs of industry
- Advise funding agencies

Source: BASF; DFG; TU Darmstadt

Parallel Approach as utilized for German Roadmap 2025

（德国2025年发展路线的制定方法）

Application fields
（应用领域）

- Energy & Environment
- Electronics & Communication
- Production Technology
- Medicine & Health
- Mobility & Transport
- Sports & Lifestyle

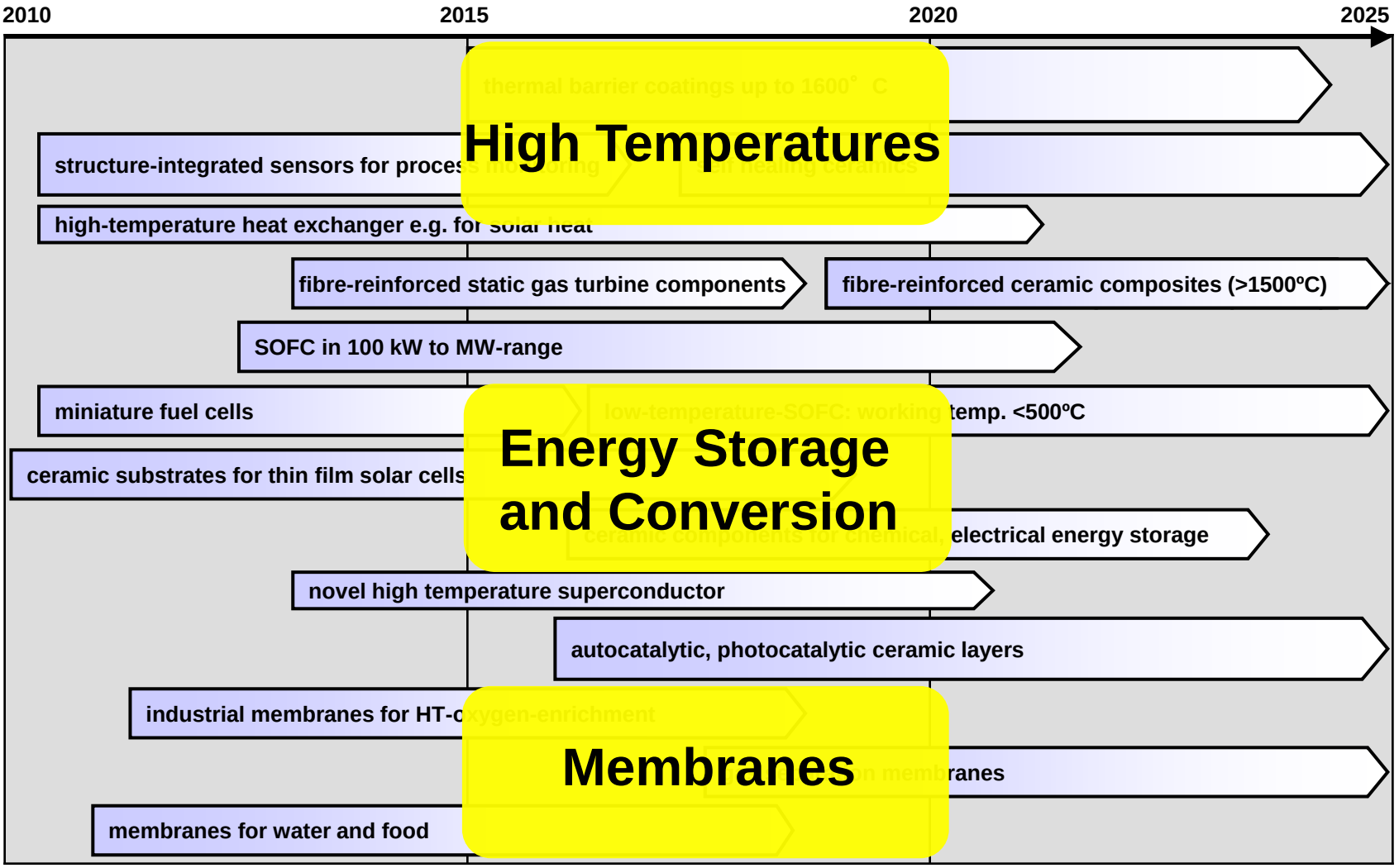
I. Extrapolation
II. Megatrend

Knowledge fields
（知识领域）

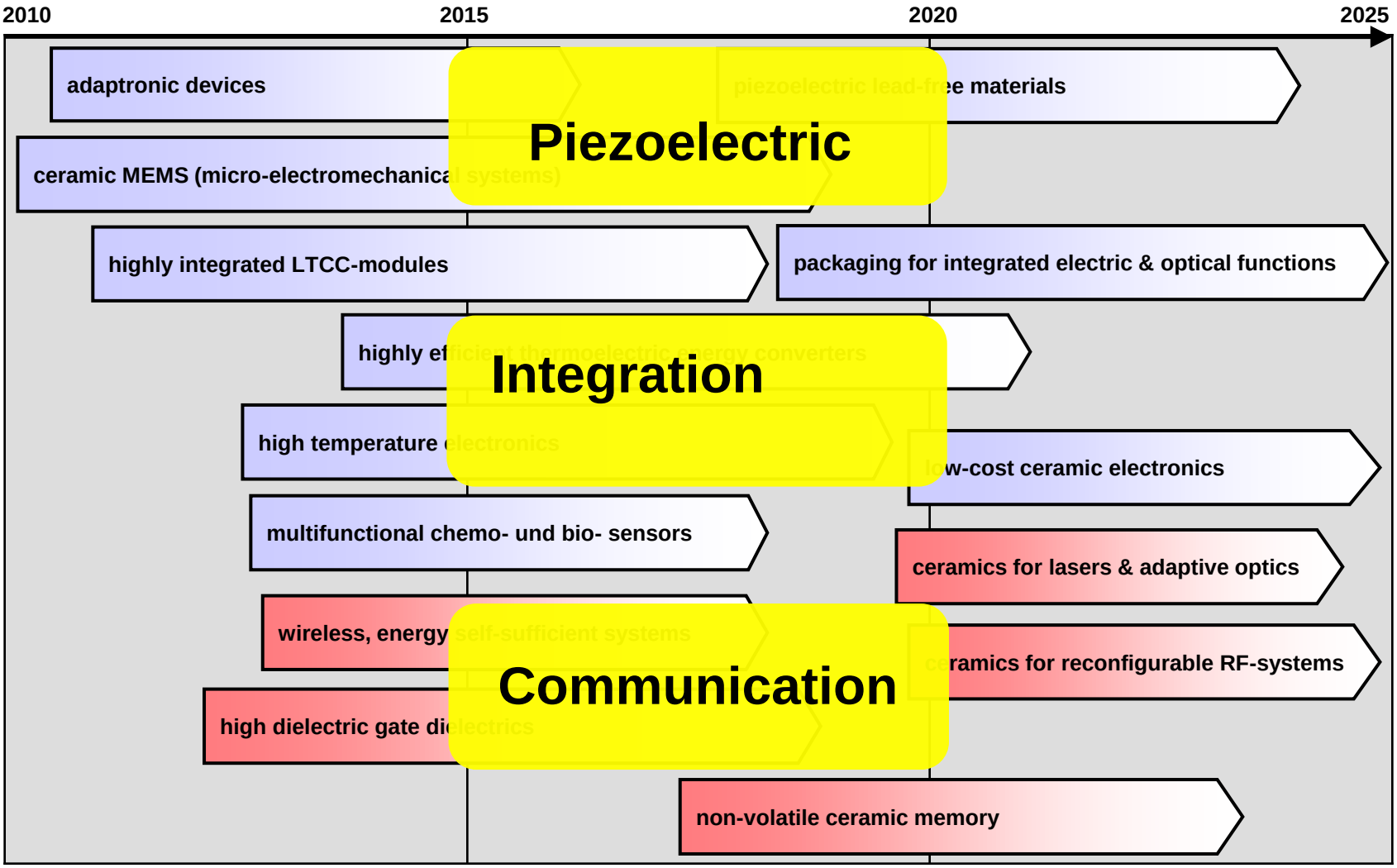
- Structural & Functional
- Process Technology

I. Extrapolation
II. Megatrend

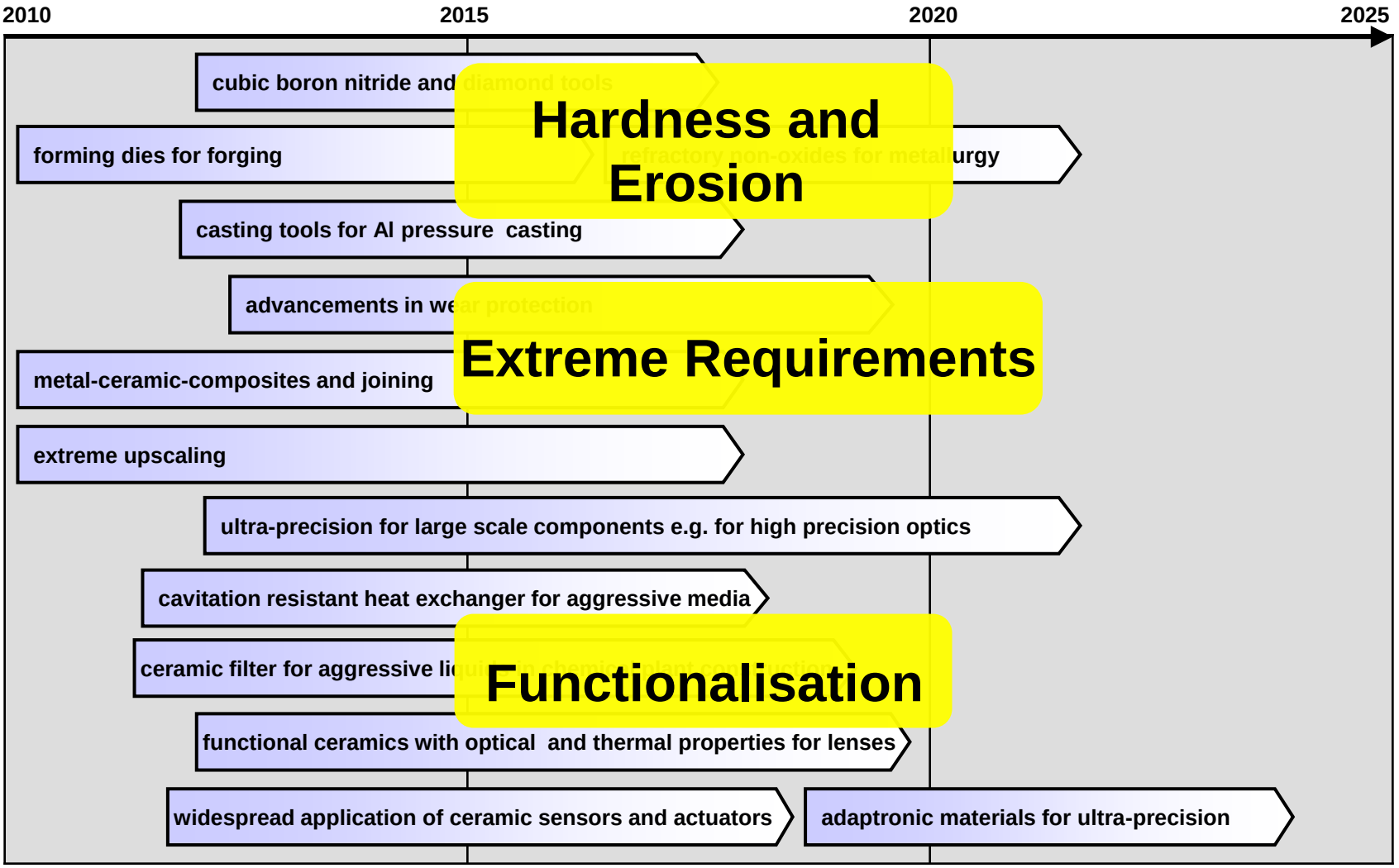
Roadmap:
Energy & Environment



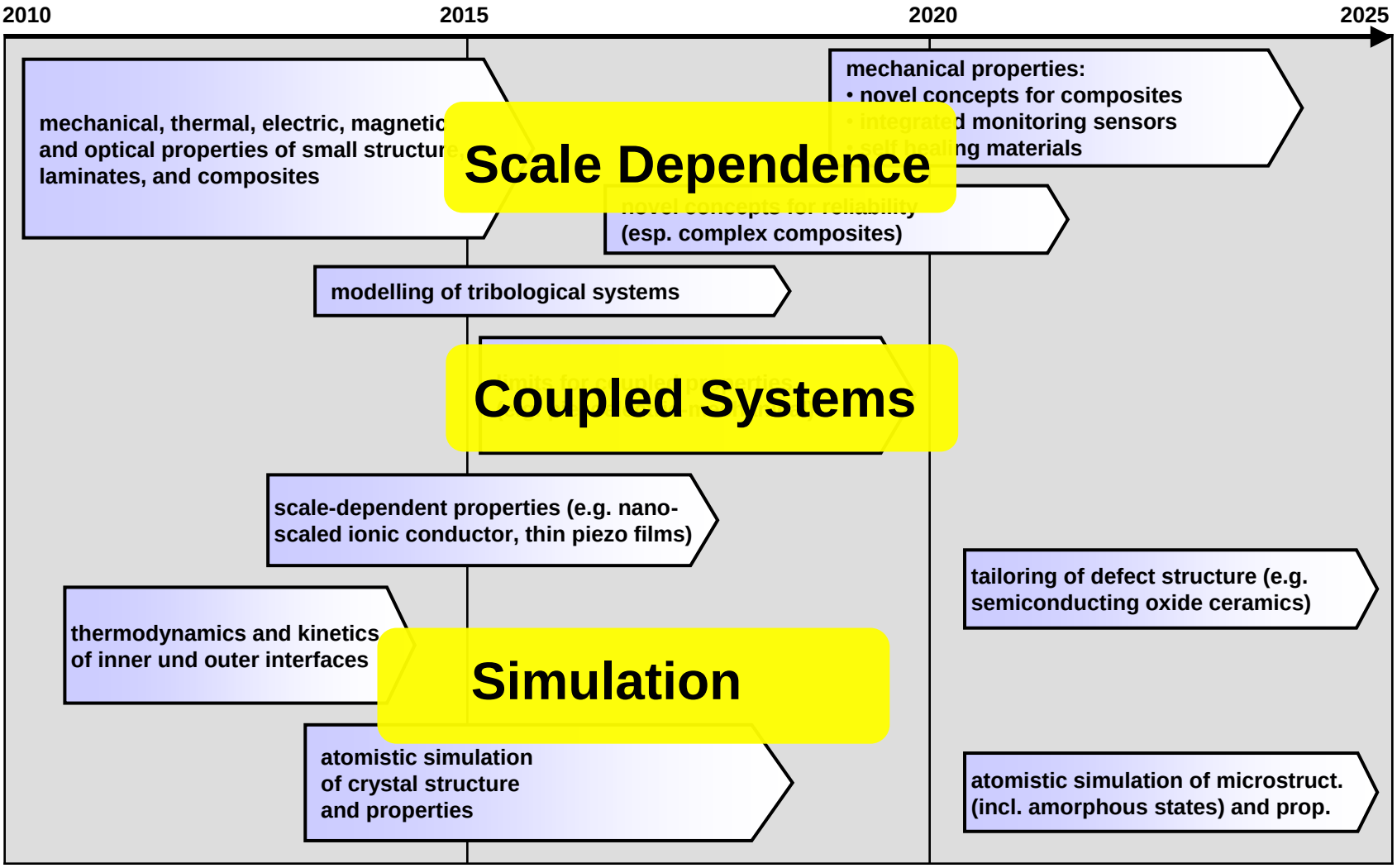
Roadmap:
Electronics & Communication（电子与通讯）



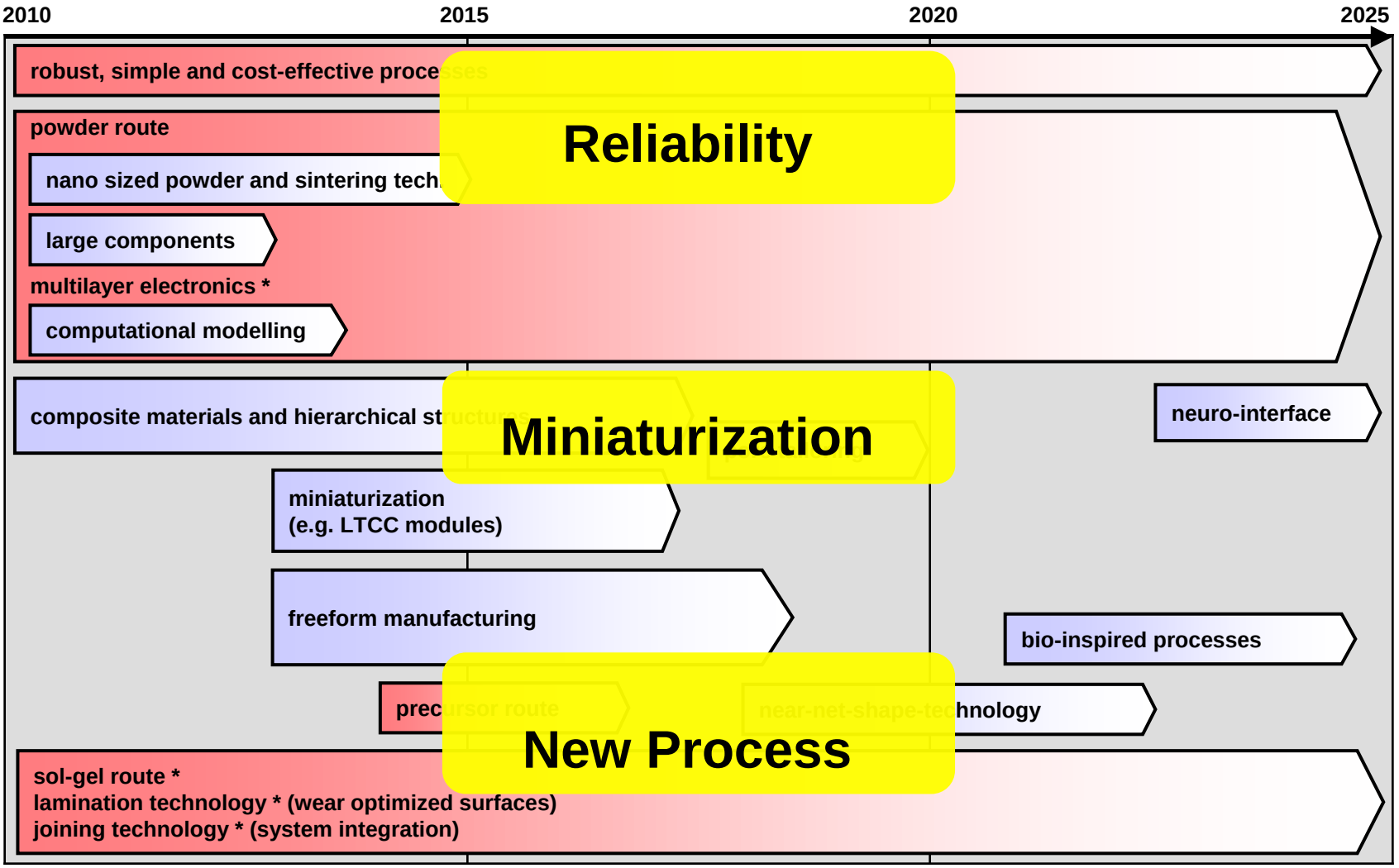
Roadmap:
Production Technology



Roadmap:
Structural & Functional



Roadmap:
Process Technology



Conclusion I

Virtual Design Promising area for the design of new materials is atomistic simulation. It can give information about defect concentration, polarization and other parameter.

Materials for Energy Materials for energy storage: diverse concepts, supercapacitor, accumulator.

Ceramic concepts for high reliability

Component monitoring and self healing

Conclusion II

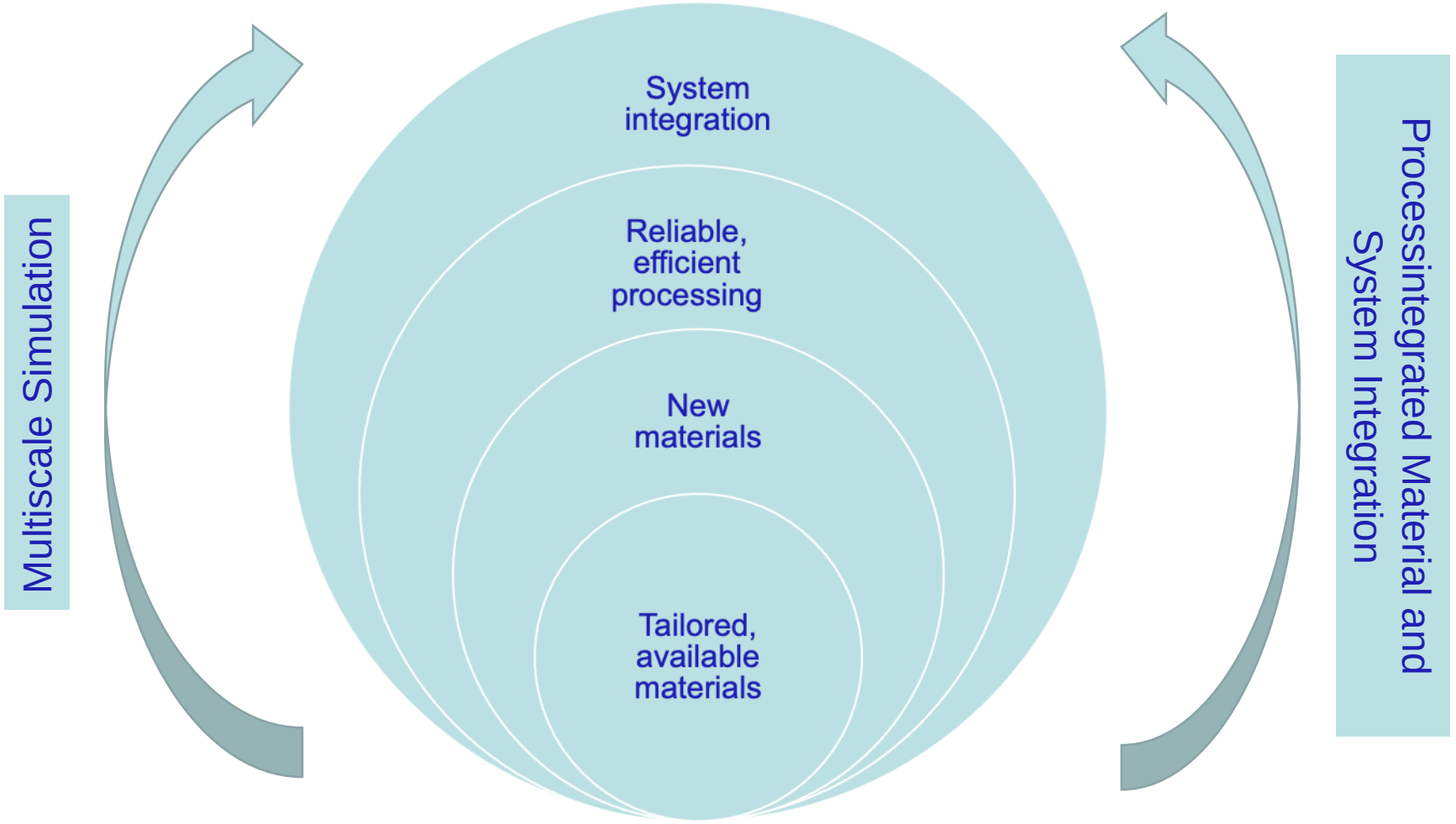
Piezoelectric

lead-free piezoceramics, high temperature piezoelectrics, high strain, transparent piezoelectrics, textured piezoelectrics.

Semiconducting Ceramics

Printed semiconductors for operation under harsh conditions, as bar codes, as printed electronic, as cost-efficient alternative, for high temperatures.

German Roadmap from 2014/15



German Roadmap from 2014/15

Focus Fields

- Smart ceramics
- Smart manufacture
- Smart materials to systems
- Smart quality

Application / Markets

- Energy
- Environment
- Mobility
- Health

German Roadmap from 2014/15

Results:

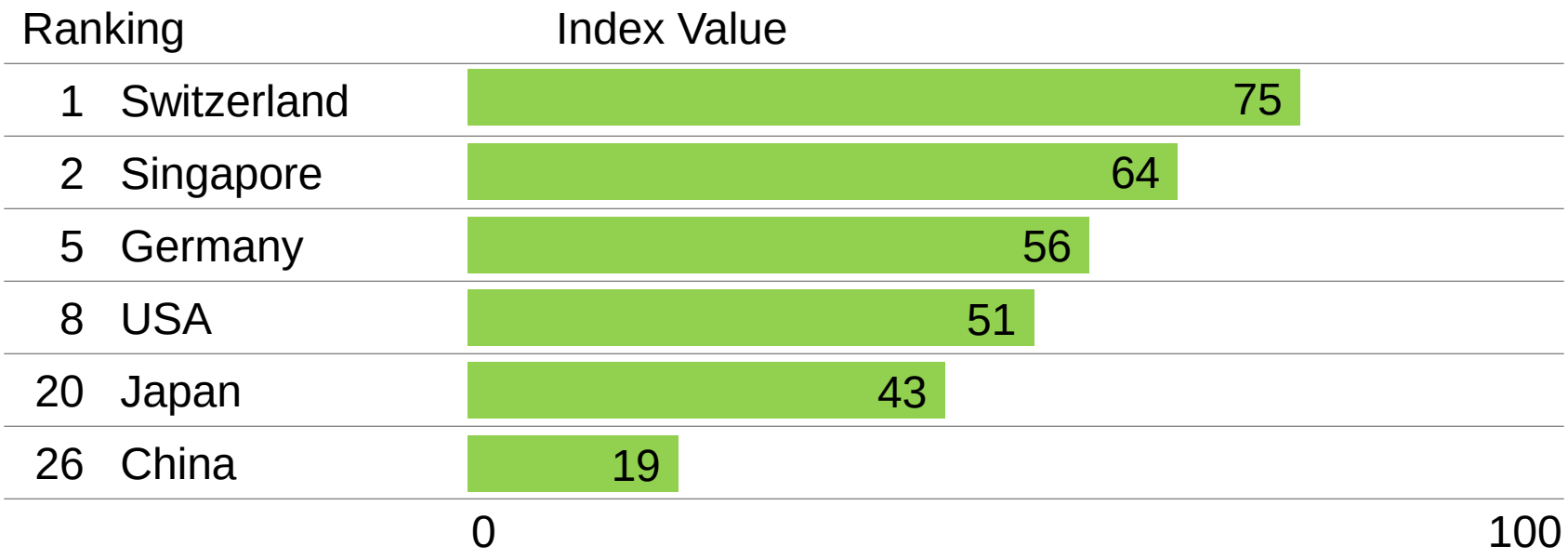
- Fiber-reinforced ceramics for gas turbines
- Battery materials
- Sustainable magnets for wind turbines
- Ceramic membranes for gas separation
- Ceramics for combustion engines
- Ceramics for thermal car management
- Bioactive ceramics for prosthetics

Courtesy: B. Voigtsberger, W. Rossner, K. Joachim

Innovation Indicator（

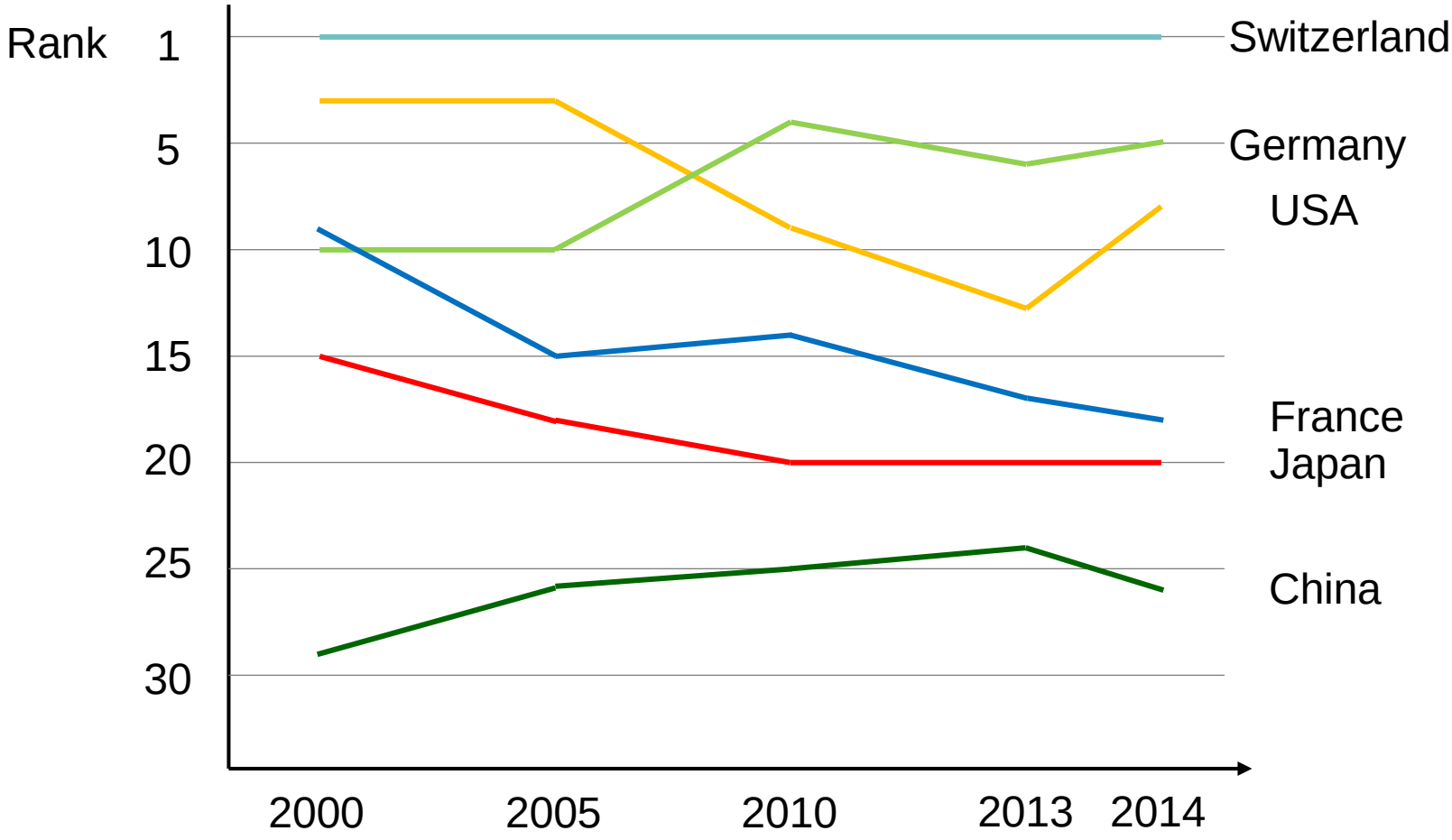
Analysis by German National Academy of Science and Technology and Association of German Industries:

(based on a set of 38 single indicators)



www.innovationsindikator.de

Innovation Indicator



www.innovationsindikator.de

Innovation Indicator

Hidden Champions:

Small to medium enterprise (SME) with a commanding role on world market

- Can be new or old applications, too small to be of interest to large companies

Comparison Germany / Japan:

Almost 50 % of the worldwide 2700 hidden champions comes from Germany

- The German hidden champions are mostly quite old
- Japanese SME deliver mostly to national champions
- Japan has 10 % of exporting SMEs as compared to Germany
- Until recently the Japanese view was that international competitiveness rests solely on the national champions ?

Moment of reflection I.

Approach:

With your current methodology, would you have predicted the ceramics world in 2016 if you had been asked to make a roadmap in 1984?

The roadmap in 1984 for 2016

- Ceramic engine
- Huge market for ceramic fibers
- Near-net shape manufacturing
- No traditional ceramics, but functionally graded materials
- Materials for energy not a topic
- Sustainable materials was a topic

Moment of reflection II.

What happened from 1984 for 2016

Extrapolation did not work over this distance

Megatrends in society were relevant, for example:

- need for energy
- need for environmental protection in general

- Megatrend in science was: mobile communication

- Ceramic markets in smartphones, tablets etc. developed not because of a need in society, but because of an availability of science and technology

My word of caution

Big Data（大数据）

- Strong trend to big data, allowing to get large data sets for farmers
- Large communication opportunities for smart homes
- Large data sets for sensors in your body
- Tracking of every single car and human being
- No need to think about what you need to buy, your refrigerator will buy
- Your refrigerator can read the advertisements and order
- This allows governments to manipulate and steer people
- There is much reduced political awareness as compared to 1980s

Approach in Japan:
The example of Murata

Business Fields of Murata

Innovative electronics solutions

- from core electronics for mobile phones, audiovisual, home appliances and computers,
- to new applications in automotive, healthcare, energy and environment.

Increasing safety, quality of life and efficiency

MOBILE PHONES

- Smartphones
- Mobile router
- 智能手机元件

PCs & PERIPHERALS

- Laptops
- Tablets
- Printers
- 计算机

AV & HOME APPLIANCES

- Flat-screen TVs
- Refrigerators
- Digital Still Cameras
- Air-con电视机

AUTOMOTIVE

- Safety systems
- Electric cars
- Infotainment
- 汽车

HEALTHCARE & MEDICAL

- Medical devices
- Lifelog
- 医疗电子

ENERGY & ENVIRONMENT

- HEMS
- BEMS
- Smart meters
- 能源与环境领域

Expansion in New Applications

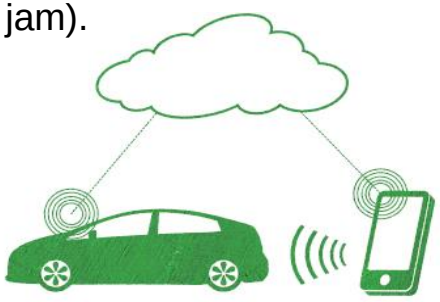
AUTOMOTIVE

- **Safety & Accident Prevention**

  Sensor technology and Communication technology supporting driving, turning and stopping.

- **Infotainment**

  Communication modules to connect car and information equipment to increase comfort and safety thanks to new services (e.g. traffic jam).

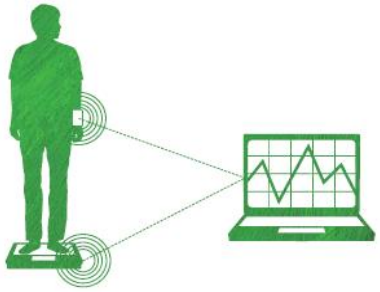


HEALTHCARE & MEDICAL

- **Solutions for Medical and Healthcare Applications**

  Low energy communication modules to connect healthcare devices and PC / smart phone to support exercise.

  Sensor technology supporting digitalization and portability of medical applications.



ENERGY & ENVIRONMENT

- **Home / Building Energy Management Systems (HEMS/BEMS)**

  Wireless communication modules for air and lightning control systems, combined with sensor technology to save energy.

Global Market Shares & Application Examples

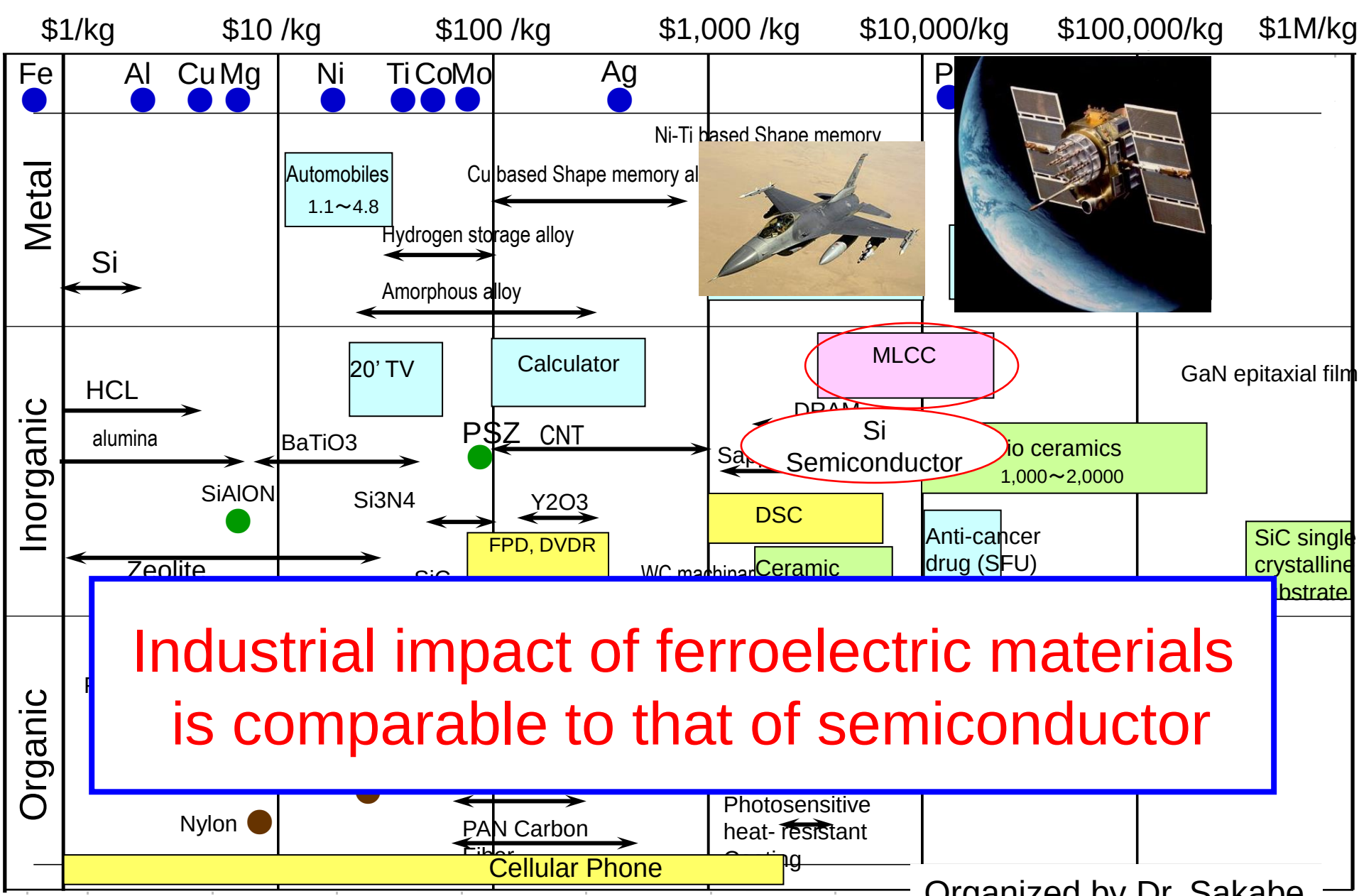
Typical No. of Components in a Smart Phone

700	25	10-15	1	50
CHIP MONOLITHIC CERAMIC CAPACITORS	EMI SUPPRESSION FILTERS (EMIFIL®)	SURFACE ACOUSTIC WAVE FILTERS	CONNEC-TIVITY MODULES	CHIP INDUCTORS
35%	35%	40%	60%	40%
600	60	4	1	30

SHOCK SENSORS	CERAMIC RESONATORS
95%	70%

Typical No. of Components in a Tablet

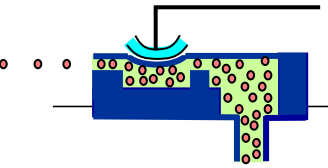
Price/weight Gross Unit Value



Industrial impact of ferroelectric materials is comparable to that of semiconductor

Organized by Dr. Sakabe

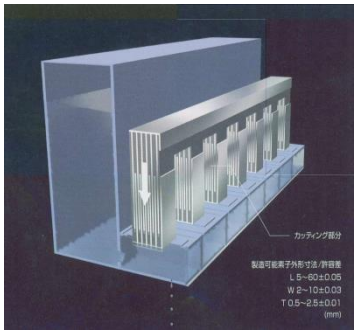
Piezoelectric ceramic technologies



Electrical → Mechanical wave

Ultrasonic Transducers

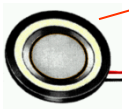
- Ultrasonic machining
- Ultrasonic detector (NDT, ME, etc.)
- AOTF
- Motors
- Flow meters

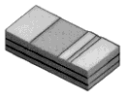


Electrical → Mechanical

Actuators, Buzzers

- Printer heads
- Fuel injectors
- Pumps
- Optical switches
- Aeronautics
- Buzzer
- HDD tracking

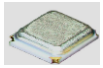




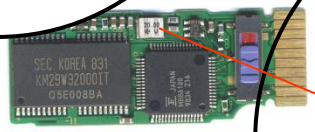
Sensors

- Gyroscopes
- Accelerometers
- Shock sensors
- Knocking sensors

Mechanical → Electrical

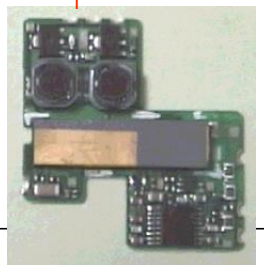


Electrical → Mechanical resonance



Resonance devices

- Filters, VCO, Traps
- Clock generators
- Discriminators
- Transformers



Approach in Germany:
Very strong collaborations between industry and university

Basic funding schemes for Universities

- DFG (corresponds to NSFC)
- Ministry of research and technology
- National laboratories (very big projects)
- Fraunhofer Institutes
- Direct money from industry

Ministry of research and technology

- Strategic orientation, e.g. new material processes, etc.
- Lead by industry
- Industry receives 50 % of costs
- University receives 100 % of costs

Fraunhofer Institutes

- About 40 institutes in Germany, some in other countries, each 100 – 400 employees
- About 25 % funded by government
- 75 % funded by industry project and other projects (DFG, European Union)
- Mainly for medium size industry without research capability
- Director jointly appointed with partner University

Direct money from industry

- Small service projects utilizing good equipment at university, size is € 500 – 40 000
- Small research projects over limited time, e.g. 6 months, done by undergraduate student as thesis or university funded employees, size as above
- Complete Ph.D. thesis: about € 250 000 in total

German specialty

- In mechanical and electrical engineering about 70 % of professors are hired from industry, after they worked there for 10 years
- Strong university funding for research groups, in engineering 4-15 internal positions
- Some university groups get more than 80% of research funding directly from industry

Thank you for your attention