Inštitut za celulozo in papir
Pulp and paper Institute

DEVELOPMENT OF ACTIVE AND INTELLIGENT PACKAGING

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INTRODUCTION

- Pulp and Paper Institute Ljubljana participated in a public tender and successfully acquired the funding from the European Social Fund and the Ministry of Education, Science, Culture and Sport necessary for launching a new project
- Strengthening R&D departments in the company
- The field of the research is development of active and intelligent packaging

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European Social Fund

INTRODUCTION

Ad1

Functionalization of the substrate surface and **development** of specialty structure and surface characteristics

Ad2

Active packaging methodology for monitoring the quality of packaging

Ad3

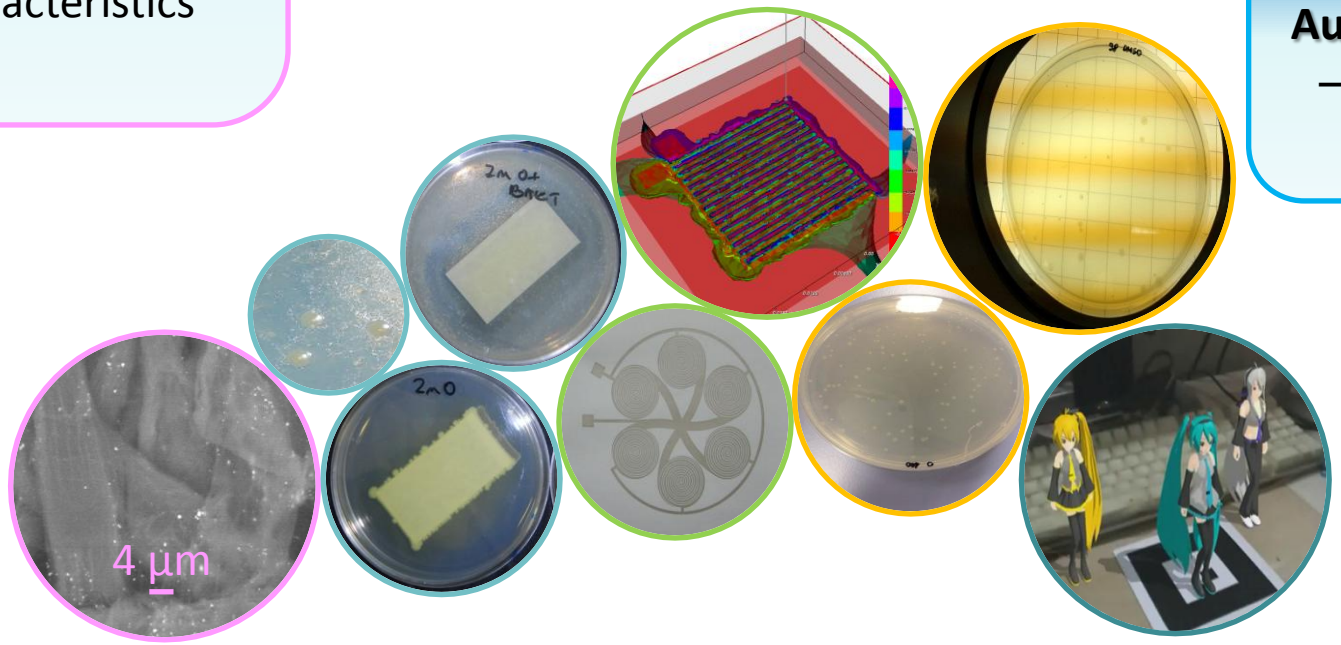
Printed electronics development of sensors

Ad4

Ecology – politics of packaging waste

AR

Augmented reality – integration on packaging



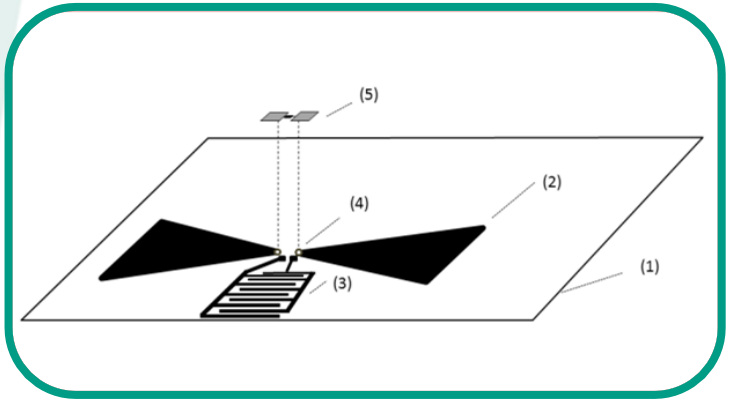
PROJECT GOALS

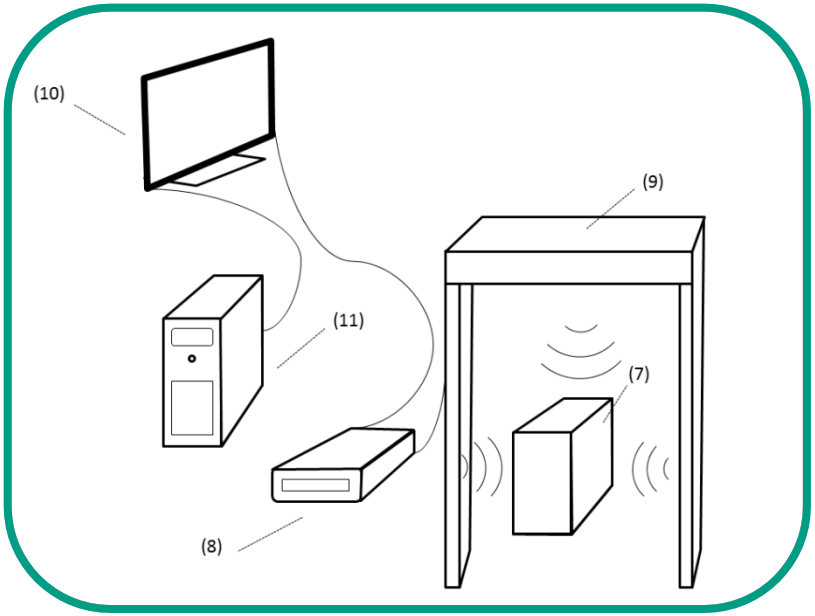
- Cooperation between industry and scientific–research sphere
- Three patents
- Development of special paper and cardboard known as active packaging and intelligent packaging
- LCA in paper industry
- Testing the toxicity of coatings and conductive inks
- Different surface treatments of cellulose fibers
- Use and development of (bio)polymer composites to improve barrier properties of paper/cardboard
- Development of paper with lower grammage and better mechanical properties.

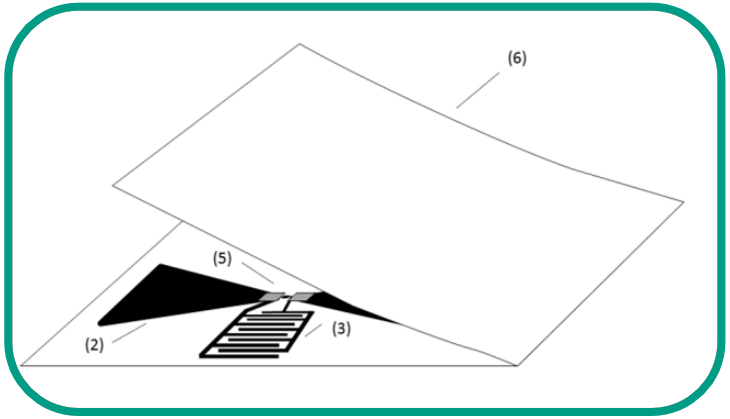
PATENTS

- **First national patent (January, 2013) – accepted**

Cardboard package with build in smart tag for radiofrequency identification with possibility to record of various parameters



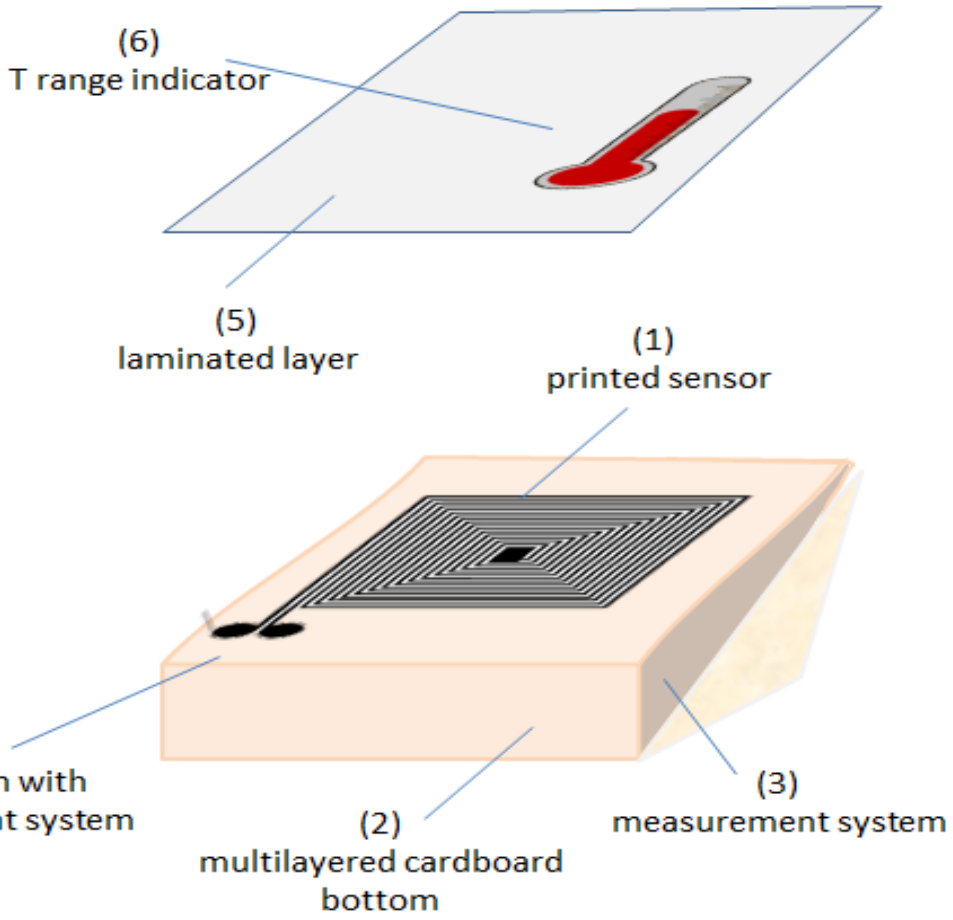


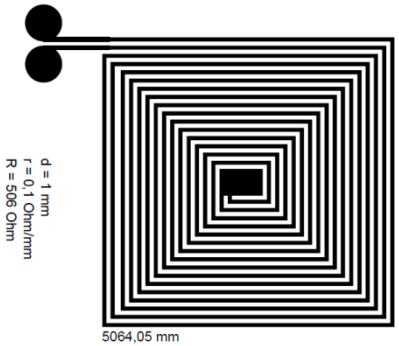


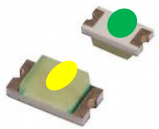
PATENTS

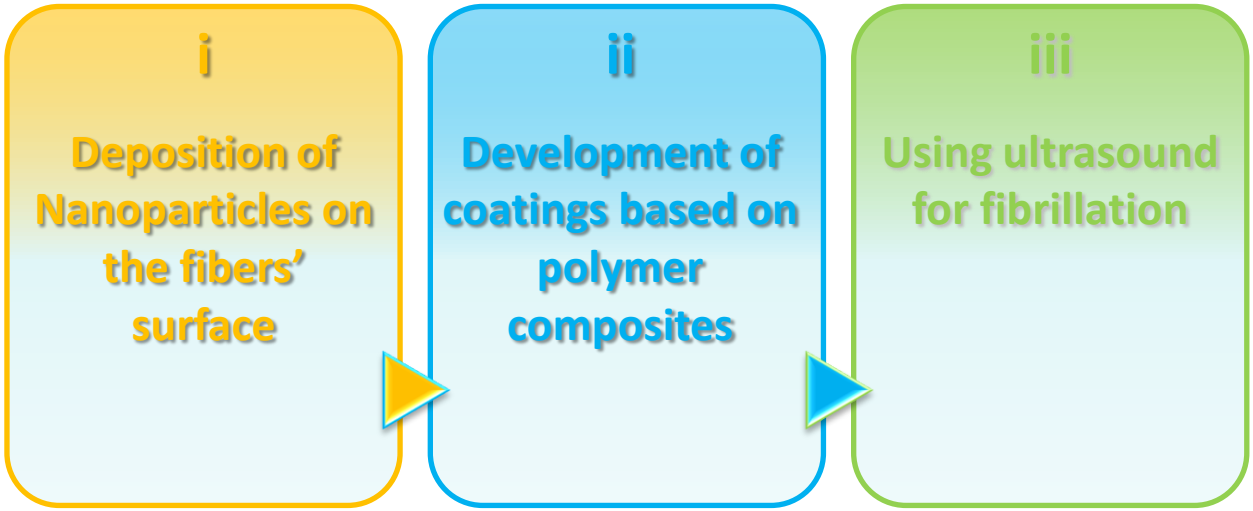
- **Second patent (September 2013)**

Printed temperature sensor in electronic measurement system for the purpose of the smart packaging application









Ad1 - Functionalization of the substrate surface and development of specialty structure and surface characteristics

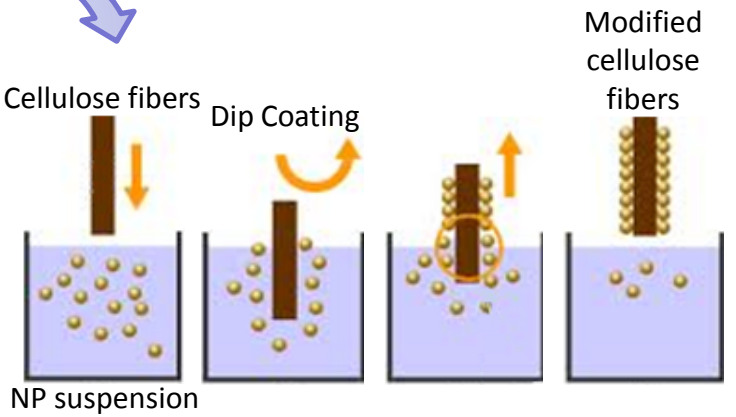
(i) Deposition of Nanoparticles on the fibers' surface …

Nanoparticles

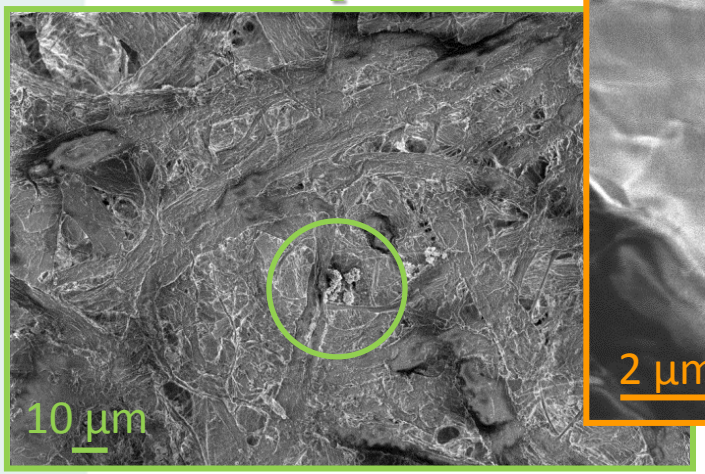
SiO_2 MMT ZnO CNC
Al_2O_3 Clay MFC/NFC
Ag TiO_2 Cu

Methods for coating

Sol-gel ALD LbL PVD
LFS CVD Plasma EPD
Dip Coating

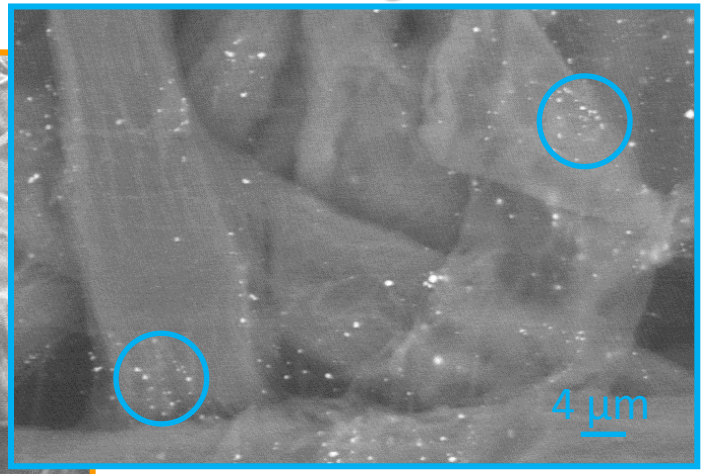


TiO_2



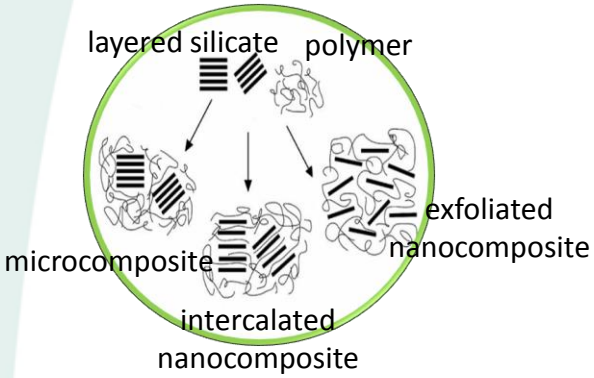
ZnO

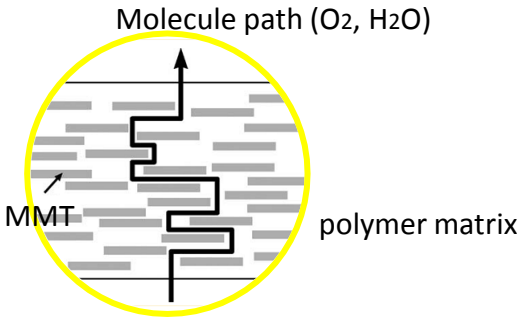
Ag



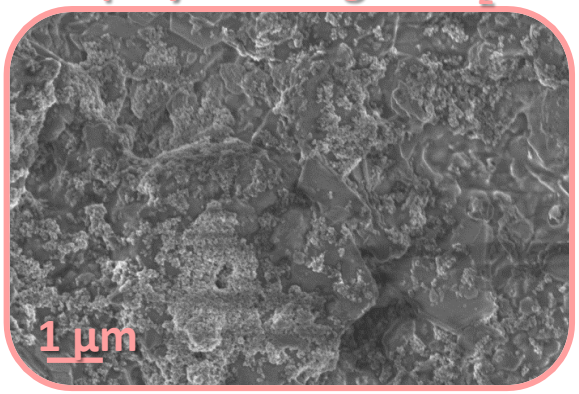
(ii) Development of coatings based on polymer composites

- Paper Industry antimicrobial coatings oxygen barrier water vapor barrier UV barrier
- Montmorillonite (MMT) – (bio)polymer

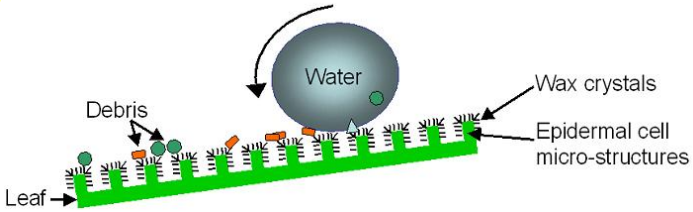




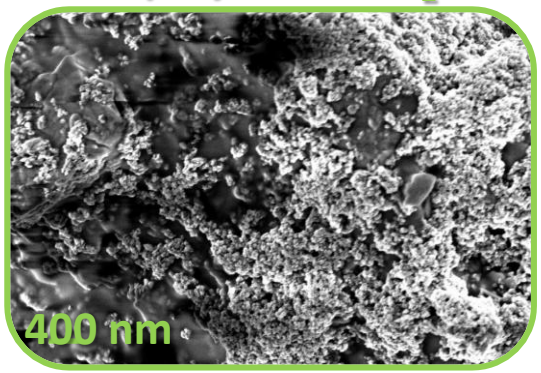
polymer + Ag + TiO_2



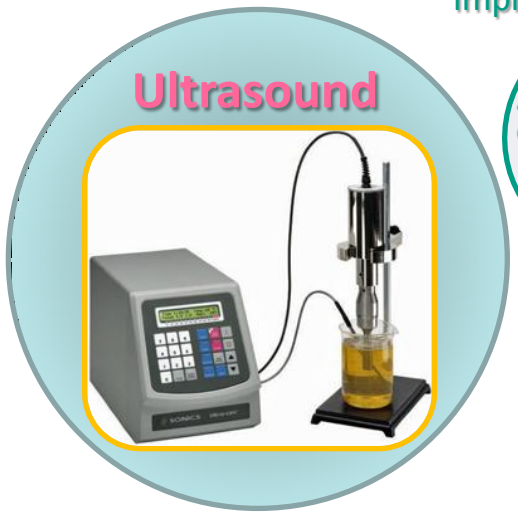
- Superhydrophobic surface, self cleaning – imitation of lotus leaf



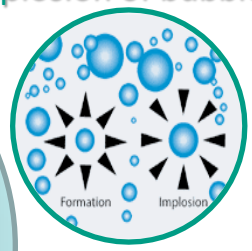
polymer + TiO_2



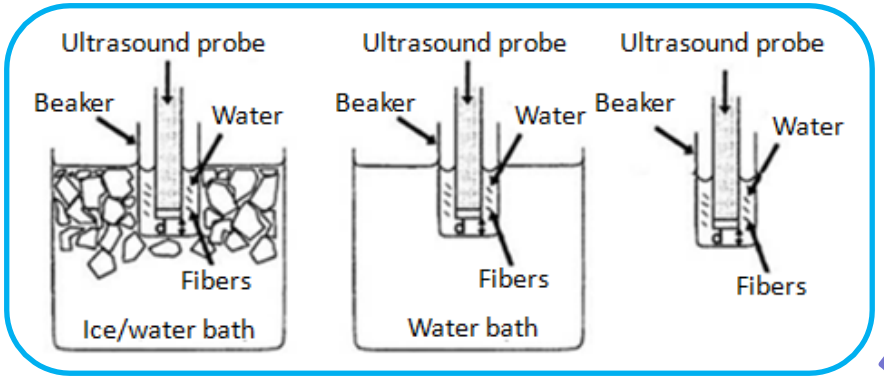
(iii) Using ultrasound for fibrillation …

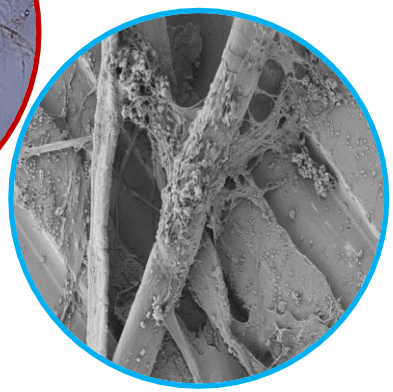


Formation and implosion of bubbles

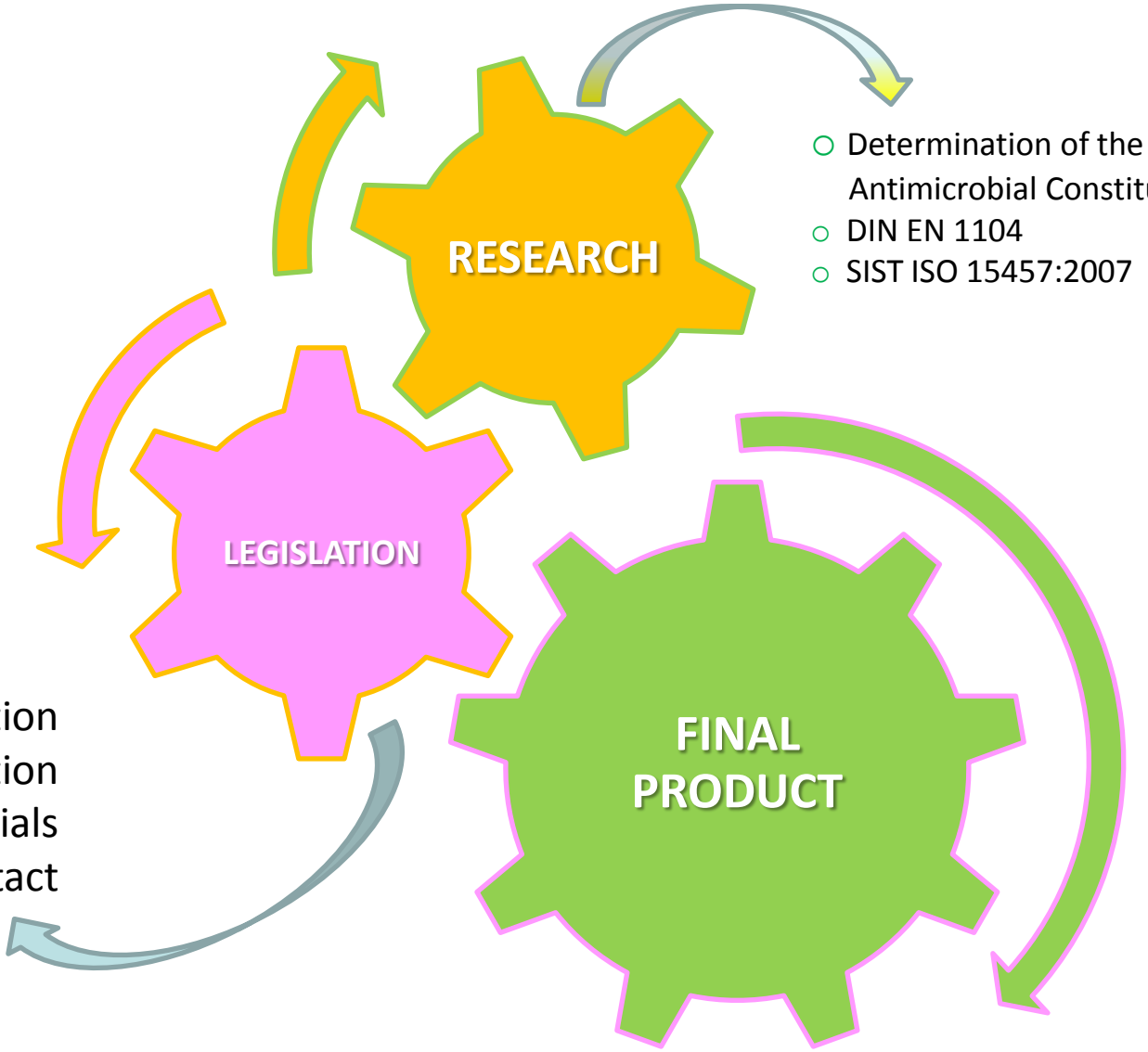


- power
- time
- concentration
- amplitude
- temperature
- distance





- Comparison of the properties
- Optical micrographs vs SEM micrographs

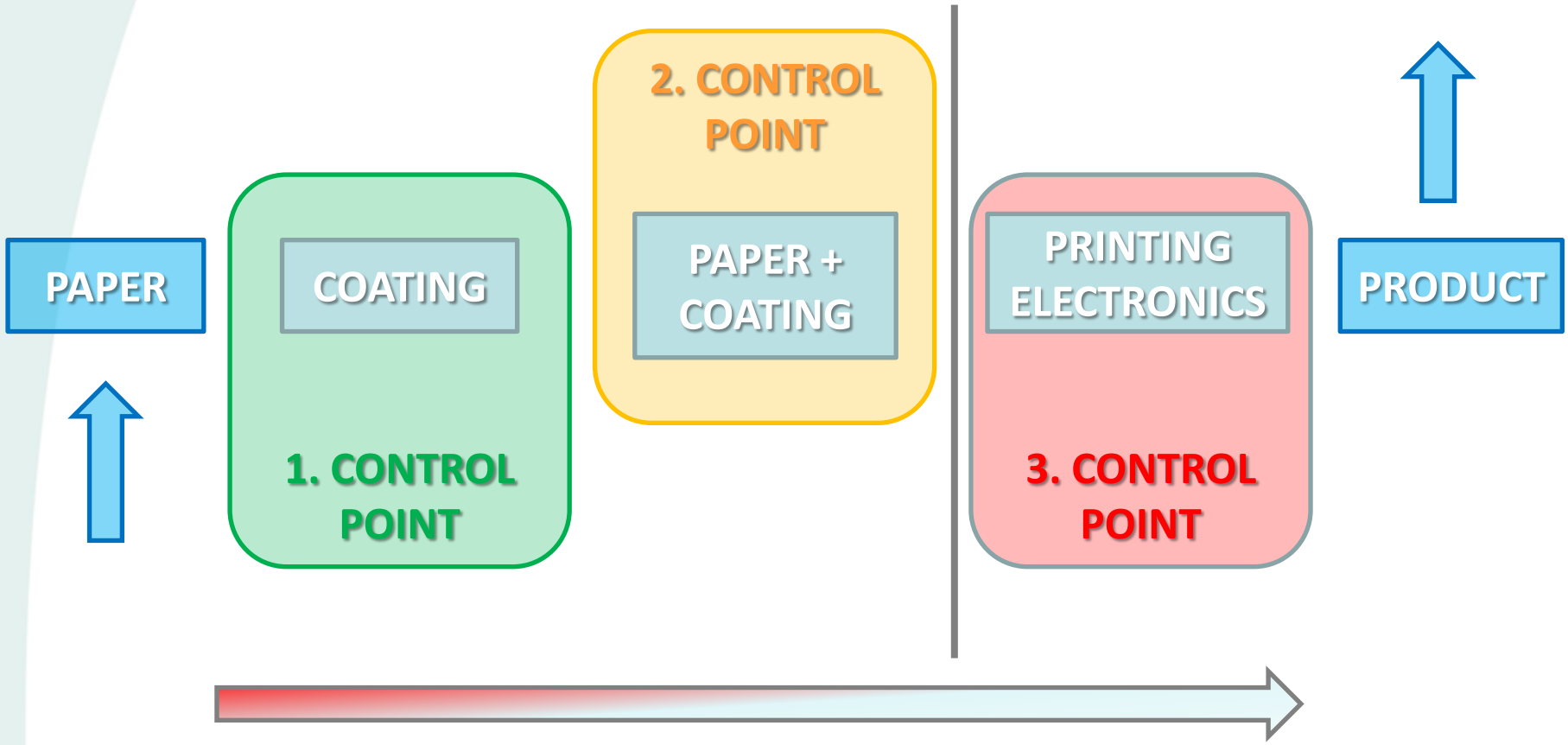


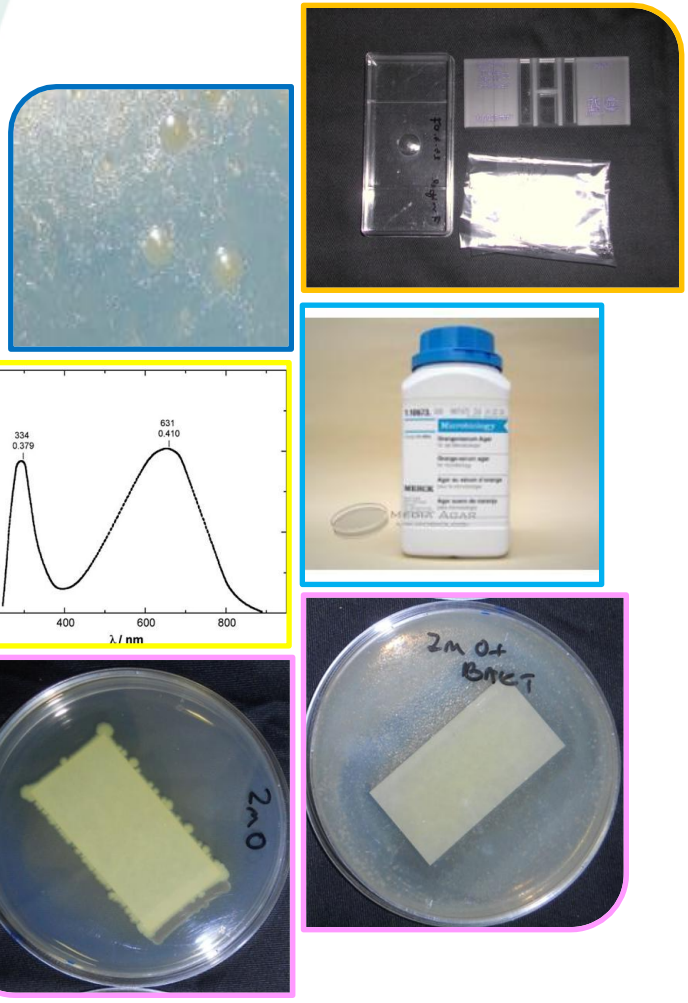
- Determination of the Antimicrobial Constituents
- DIN EN 1104
- SIST ISO 15457:2007

EU Legislation
National Legislation
Polymer materials
Food Contact

Ad2 – Active packaging – methodology for monitoring the quality of packaging

Ad2


PAPER
COATING
1. CONTROL POINT
2. CONTROL POINT
PAPER + COATING
PRINTING ELECTRONICS
3. CONTROL POINT
PRODUCT



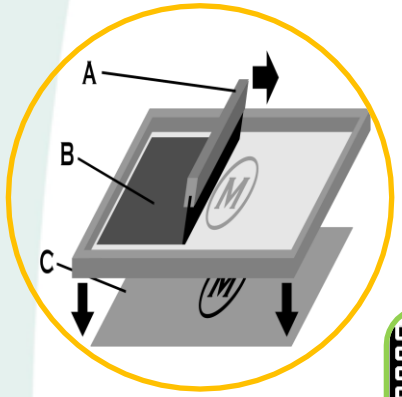
ANALYSIS OF THE PAPER

CHOOSING THE RIGHT PARAMETRS

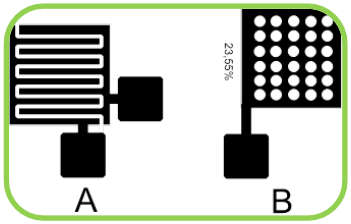
INTRODUCTION OF THE NEW METHOD

Main goals

- Design and fabricate capacitive humidity sensors of different geometry and configuration
- Test sensors on different cellulose based substrates
- Find the optimum design (electrically and economically) for future work
- The ultimate goal is to fabricate a RFID enabled system with screen printed sensors for use in smart packaging applications



Fabricated with screen printing



Materials

- Recycled paper – Vimax (Vipap)
- Cardboard – M-Liner (Količevo karton)
- Food packaging paper – FlexPack (Papirnica Vevče)
- Poly-carbonate foil

Ad3 – Printed electronics – Development of sensors

Assumption

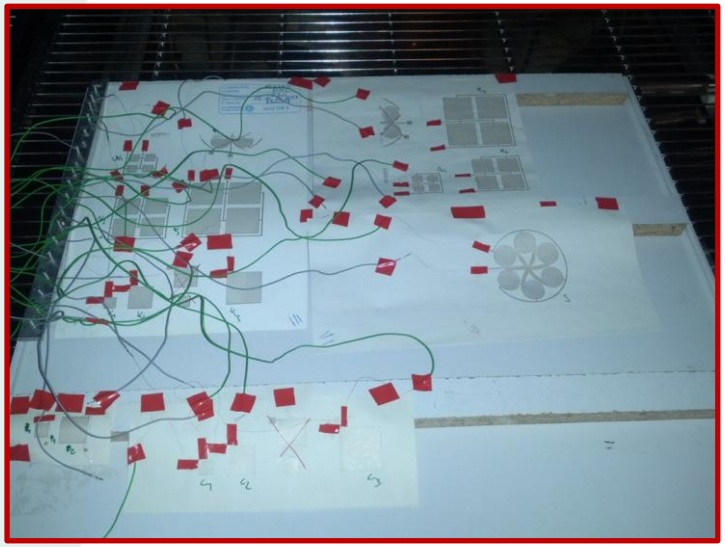
- Sensor response is a function of substrate

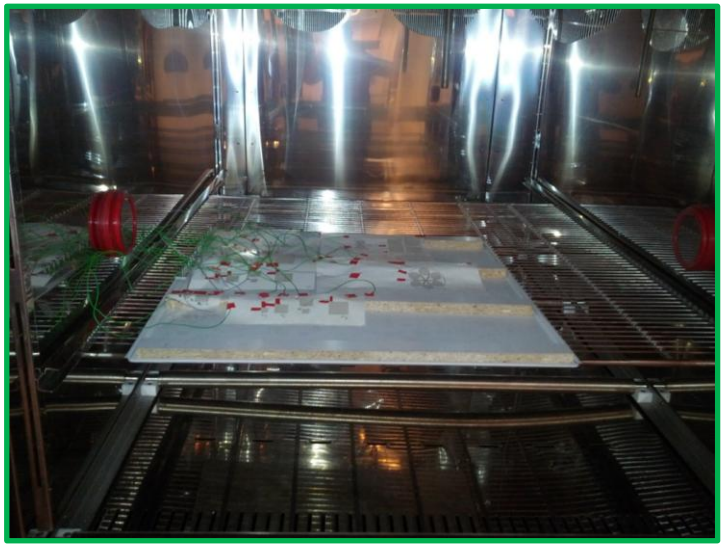
Constant temperature: **T = 23°C**
Relative humidity range: *35 % - 80 % Rh*

4 measurement series

- From **low** (35 % Rh) **to high** (80 % Rh) – **5 % Rh step**, step duration **1h**
- From **high to low** – 5 % Rh step, step duration 1h
- **Cycling** the Rh from *35 % - 80 % - 40 % Rh* – 10 % Rh step, 1h
- **Cycling** the Rh from *80 % - 35 % - 70 % Rh* – 10 % Rh step, 1h

Can track up to 16 sensors simultaneously with arbitrary period (30s)





Humidity chamber at the Faculty of electrical engineering, Ljubljana

Measuring quantities:

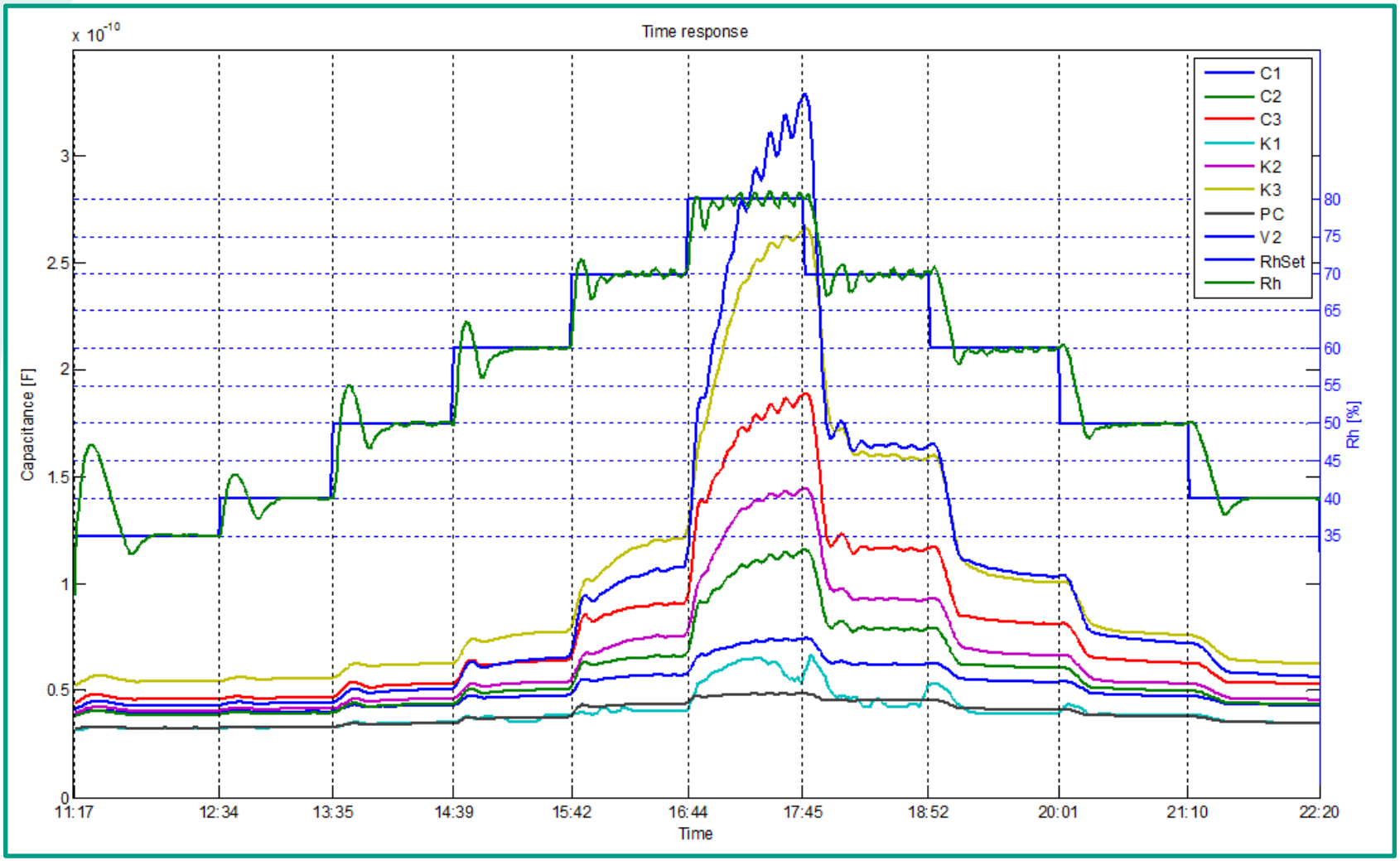
- *Capacitance [F]*
- *Transconductance [S]*

Time response plot

Ad3

Data from cycling measurement **(35 % - 80 % - 40 % Rh)**

- ❑ Lazy and lower response at low Rh (< 50 % Rh)
- ❑ Saturation and over response at Rh > 80 %



An example of results as time response plot

Screen Printed Capacitive Humidity Sensors

Ad3

In conclusion:

- Sensor response is **not a function of substrate**, it's a function of **conductive ink (polymer)**
- Logarithmic response
- Hysteresis
- Repeatability is poor
- Can be used for simple applications where it's only important to distinguish between dry and wet
- **Cheap (mass producible), easily fabricated and integrated into products (eg. Packaging)**

Future work:

- Research into conductive ink electrical properties (polymer) and use it to our advantage for sensor design
- Fabricate and test sensors and strip lines on inert material (eg. Ceramic)
- Design and fabricate a RFID enabled sensing system for smart packaging

Working areas…

- LCA
  - toxicology
  - carbon footprint
- water footprint

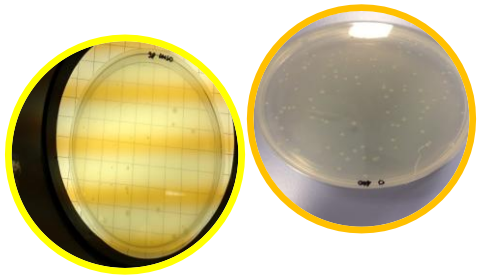
ISO Standards

- **ISO 14040: 2006**

Environmental management – Life cycle assessment – Principles and framework

- **ISO 14044: 2006**

Environmental management – Life cycle assessment – Requirements and guidelines



Toxicology

- **AMES assay** – S. thyphimurium (TA98, TA100)

Ad4 – Ecology – Politics of packaging waste

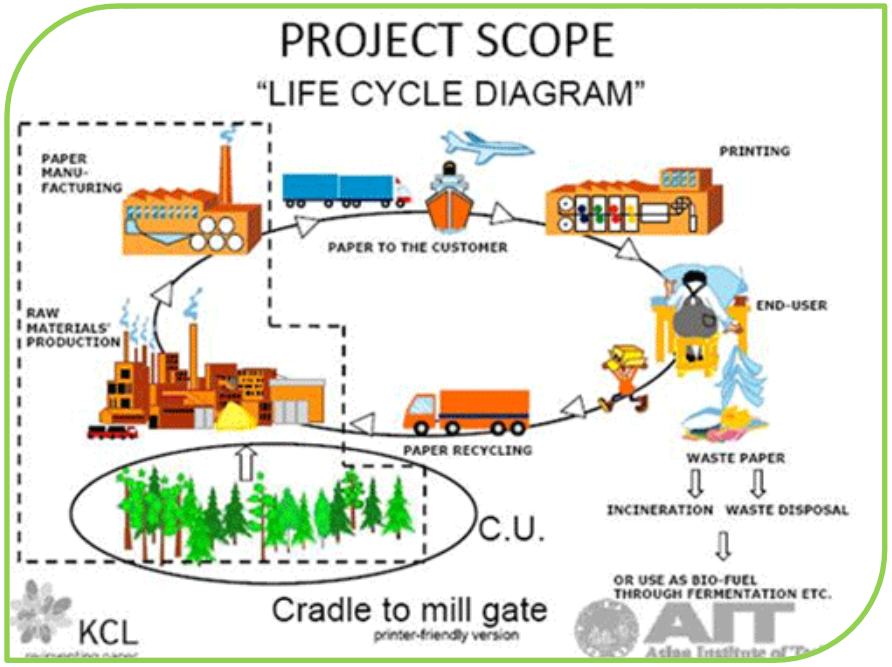
… ENVIRONMENTAL IMPACT …

- **global warming** (CO_2, CH_4 and N_2O)
- **acidification** (SO_2, HCl, NH_3, HF, H_2S and NO_x)
- **eutrophication** (NO_x – air, NH_3 – air, NO_3 – water, N – water, NH_4 – water, PO_4 – water, P – water and COD - water)
- **smog** (NMVOC, CO, CH_4, NO_x)
- **human toxicity** (AOX, TRS, SO_2, NO_x and particulates)

CARBON FOOTPRINT is part of LCA study …

the total sets of GREEHOUSE GAS emissions caused by an organization, event, product or person

- Includes extraction of raw materials from the earth
- Processing of raw materials
- Fuels
- Intermediate products
- Transportation steps
- Manufacture of paper
- Printing
- Distribution
- Final disposition



WATER FOOTPRINT

The water footprint of a product is defined as the total amount of fresh water needed to produce it

- **BLUE** – volume of fresh water that evaporated from the global water resources (surface and ground water) to produce the goods and services consumed by the individual or community
- **GREEN** – volume of water evaporated from the global green water resources (rainwater stored in the soil as soil moisture)
- **GREY** – volume of polluted water that associated with the production of all goods and services for the individual or community

The latter can be estimated as the volume of water that is required to dilute pollutants to such an extent that the quality of water remains at or above agreed water quality standards

What is augmented reality?

- Superposition of real (sensory) and digital inf.
- A real time view of the real world, ‘augmented’ with additional, computer generated information
- Various forms of additional content (text, image, 3D model, sound), its purpose can be very diverse, too
- The additional content is inserted in the real world automatically and in real time, while maintaining a specific semantic context with the real environment
- Two basic problems: where to insert the additional inf. and how (to successfully blend it with some real context)?

- An example of AR: enhanced book

AR and smart packaging

- Materials and coatings that facilitate the traceability of fiduciary markers;
- New forms of fiduciary markers that are also aesthetically acceptable;
- AR in conjunction with RFID and other attributes of smart packaging, as well as in the paper industry in general.

Thank you for your attention

For more information, visit us at our stand.

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