TUBE-Davm a unique equipment to design and engineer new and efficient material
1980: Micro-electronic
2015: Nano-electronic: Internet Of Things
Much more new functionalities using less materials

Interdisciplinary Physics

Low dimension Electronic
Opto-electronic and photonic
Piezo-electric and acoustic
Magnetism and Spintronic
Much more complex system: multi-material approach.

**ELEMENTS OF A SMARTPHONE**

**SCREEN**
- Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.
- The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al₂O₃) and silica (SiO₂). This glass also contains potassium ions, which help to strengthen it.
- A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone’s screen. Some compounds are also used to reduce UV light penetration into the phone.

**ELECTRONICS**
- Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.
- Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.
- Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.
- Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

**BATTERY**
- The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery’s casing is made of aluminium.

**CASING**
- Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.
Much more Material Efficiency:
Low dimension - Nanomaterials

From 3D Bulk properties:
Large volume

To 2D Interface properties

+ Still 70 Kg of material is needed for one 200 g cell phone
+ IOT: 7% of energy Consumption in 2015
  : 100% of energy Consumption in 2050 ??
2050: ?

Nobody knows
2050 : ?

- Reducing sizes: At the atomic scale
- Interdisciplinary: Complex system: multi-material Approach
- Understand the physics: Exemple: Ultra fast dynamic
Cost of data storage per Gigabyte

Consequence: A revolution

3 000 Exabytes Data storage capability in the word:
60 millions time the data ever written
144 billions – emails per day
Data - Storage

Multi-material

- Insulators
- Metals
- Semi-conductors
- Magnetic - Material

Nanometer scale (3D)
Solar, Thermal, Photovoltaic

Multi-material
- Insulators
- Oxides
- Semi-conductors
- Polymers

Nanometres scale (3D)
Nanoscience and medical applications

Lab on Chip (3D view)

Multi-material
- Insulators
- Oxides
- Semi-conductors
- Polymers

Nanometres scale (3D)
Why a 70 meter TUBE at Lorraine University?

70 m under $10^{-10}$ mbar

40m + 30m (Zone VIT)

23 equipments

40 mètres

30 mètres

10 equipments

A wagon to transfer samples
Growth, characterization of thin film materials under Ultra-High Vacuum: A local expertise

- **Material Growth**: atom per atom
- **Characterization**: chemical and structural
  Where are the atoms?
- **Micro & Nano Patterning**
- **Physical properties**

→ **Devices**

→ **Ultra-High Vacuum Chambers**
1980

40 years experience in Material growth under ultra-high Vacuum
Interdisciplinary, complexes systems,…

Multi-material, multi-analyses, multi-structuration approaches
Great Project IJL

- Create a unique in the world: Growth, characterization of material at the atomic scale
- Share the tools and the know-how
- Multilateral and interdisciplinary Approaches
Types of Equipment on the TUBE

**Growth**
- 6 MBE
  - Rare-Earth
  - Transition Metals
  - Semi-conductors
  - Oxides
  - Organic
  - Matériaux sous atmosphère
- 3 PVD
- 1 PLD (Oxides)
- 1 ALD (Atomic Layer Deposition)

**Characterizations**
- Structural
  - STM, AFM
  - + RHEED
- Chemical /spectroscopies
  - XPS Auger
  - Photoemission
- Physical
  - Magnétism : Kerr in situ
  - Optic: ellipsometry
  - Microscopy

**Patterning**
A Project to connect people

160 persons: 60 Academic researcher / 80 PhD student, post-doc / 20 Technician

- Team Nano magnetism and spintronics (101)
- Team surfaces & spectroscopies (102)
- Team Nano-matiériaux (104)
- Team Esprits (201)
- Team Thin film Growth (202)
- Team Metallurgy & Surfaces (203)
- Team Micro & Nano systems (405)

- Team UMI2958: Optique

400 publications in 5 years
20 ANR projects - 2 European project

Different materials
Different growth
Different proprieties
Different Application

Share Tools, Knowhow and ideas
In the Building

Connecting Research - Academia - Industrial Partners
A general trend in strong research center around the Globe

Almaden research center
Silicon Valley
Magnetic Memory integration on semi-conductor
Le Tube : a unique tool open to ...

- International Scientific community
- Student Training
- SCIENTIFIC EXCELLENCE

- Educational opportunities
  - SCIENTIFIC EXCELLENCE
  - EDUCATION

- JOBS - COMPETITIVITIE
  - Innovation Technological Transfert
  - Company's

- INDUSTRIAL PARTNERSHIP
  - Industrial partners
    - Start-up
International Partnership

Europe:

- Université de la Grande Région
- LEUVA
- GRMA
- Technische Universität Kaiserslautern
- UCL
- Centre de Recherche Public

International:

- ANR/NSF
- NSF
- ANR
- AIST
- UCSD
- NYU
- Université Paris Sud
- Université de Lorraine
- CNRS

International Laboratory
Collaborations Academy - Industrial partners

a) Design and build the equipment

b) Automatisation / Gestion

c) Design and improve new UHV chambers

d) Access the equipment to grow and characterise new materials
One success story ... Many others .... Much more to come

NIPSON

Transfer
Lab – COM (new Jobs)

Equipments

4 PhD Funded

International

Education

Exchange of 20 International Students

Fundamental Research

14 invited Professors

Outreach activities

Publications (Science, Nature Mat)

Trajectory for Material Value Chain
MATERIALS AND PROCESSING MATERIALS AND PROCESSING TECHNIQUES

Outreach activities

SMART SENSORS
Magnetic sensors ● Low dimensional Electronic Opto-electronic sensors ● SAW sensors

IWST 2016
International Workshop & School on Spin Transfer

300 Selected participants
CEOs, CTOs, professors, politics
1 Millennium Price, 1 Mitsubishi CEO
1 Minister of economy

150 Participants (Local Companies
Local researchers)

300 Internationals (16 Countries,
5 continents, 1 Nobel Price)

2000 Visitors
(High School students + ...)

OLYMPIADES DE PHYSIQUE FRANCE
Goal: make WMF a "must" meeting every year in June in order to develop win-win solutions that create value for all actors. Industrial companies need to speak a common language with other stakeholders so that financial and CSR objectives can coexist (see plastics recycling).

Over the first 2 editions we have had the pleasure of welcoming

Great partner CEOs: Arkema (France), Europcar (France/Germany), Faurecia (France), Guala Closures (Italy), Italcementi (Italy), Ivanhoe Mining (Canada/Singapore), Morgan Advanced Materials (UK), Mitsubishi Heavy Industries (Japan), PSA Peugeot Citroen (France), Rio Tinto Energy & Minerals (Australia), Saint Gobain (France), Smiths Group (UK), Solvay (Belgium), Versalis (Italy) and Voest Alpine (Austria).

Top executives: CEO of Airbus Helicopters & EVP Sourcing of Airbus Group (Germany/France), EVPs Europe of Hexcel (USA), Uber (USA) and PSA (France), the CEO of Ecobank Investment Branch (Ghana/Nigeria), the CTOs of Valspar (USA), Larsen Toubro (India) and GKN (UK), and some senior researchers of Nike (USA), Decathlon (France) or Yasaki (Japan).

World known academics from Stanford University, University of Yale, Max Planck Institut Halle Wittenberg, Tohoku University, UC San Diego and Irvine, Leiden University, Hanyang University, ESCP Europe, Mines ParisTech, ITV Denkendorf, Lulea Technical University, and Université de Lorraine.

Key representatives of CSR organizations: WRF and also DSD (Germany), Ecoemballages (France) or IUCN (Switzerland)

CEOs of start-ups: Adeneo, or I Pulse (France), Lithoz (Austria), Greener Way (Bhutan) or Clean Teq (Australia).
• **Offer an update on future materials trends shared by 3 of the world top experts** of the sector (Mc Kinsey, the French geological survey - BRGM, and the UK metal markets specialist based CRU).

• **Propose an all industry set of indicators that will efficiently monitor the decoupling of economic growth and use of materials while creating value for all economic actors** (WMF and Arthur D Little).

• **Demonstrate some key practical solutions**: design for light weighting AND recycling (rather than light weighting OR recycling), use Internet of Things and new mobility services to develop sustainable materials solutions, and support circular economy development thanks to standardized Life Cycle Analysis.

• **Organize a competition of world start ups that offer a technology breakthrough** in one of the following 6 domains: Internet of Things, 3D Manufacturing, Product Design, Materials Composition, Mobility Systems or Waste Management. The jury will select the top 10/12 candidates and WMF will give each of them a "package" including a booth at WMF for their start up and a full coverage of registration-transportation-accommodation costs for his or her CEO.
But more importantly, 150 people involved.
Thank you

Dank u wel
Born from 5 laboratories merging: 400 peoples

Nano-science  Surface science
Nuclear Fusion  Metallurgy

Jan 2015: New common building