MATERIA NOVA Materials R&D Center

ionics surface technologies

I4BAGS Workshop

Ion implantation potentials for smart materials. Applications in energy storage industries

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Outline

1. Presentation of **Materia Nova & Ionics SA**

2. Thin Films Solid State Battery

3. Ion beam implantation technology

4. Applications in SS Battery

Presentation of

Materia Nova R&D center

&

Ionics SA

1. Presentation of Materia Nova

24 years

9 Millions €

75 Experts

Advanced Equipment

Strong network

200 Projects

MATERIA NOVA Materials R&D Center

THE TECHNOLOGICAL ACCELERATOR OF RESPONSIBLE INNOVATION IN MATERIALS AND PROCESSES

1. Presentation of Materia Nova

Open to the world, we innovate and federate for a sustainable future, promoting social cohesion and territorial integration

Fundamental research → Scientific Valorisation → Feasability → Process Design → Validation → Up-scaling → Production → Equipement & product sales

UMONS Université de Mons

MATERIA NOVA Materials R&D Center

B-SENS GATE2 ESIX ionics surface technologies

1. Presentation of Materia Nova

OUR TECHNOLOGIES

PROCESS

- Surface deposition and treatments (wet or dry)
- Surface conversion
- Compounding
- Chemical synthesis
- Advanced 3D printing (Additive manufacturing)
- Biobased processes
- Electropolymerization

MATERIAL

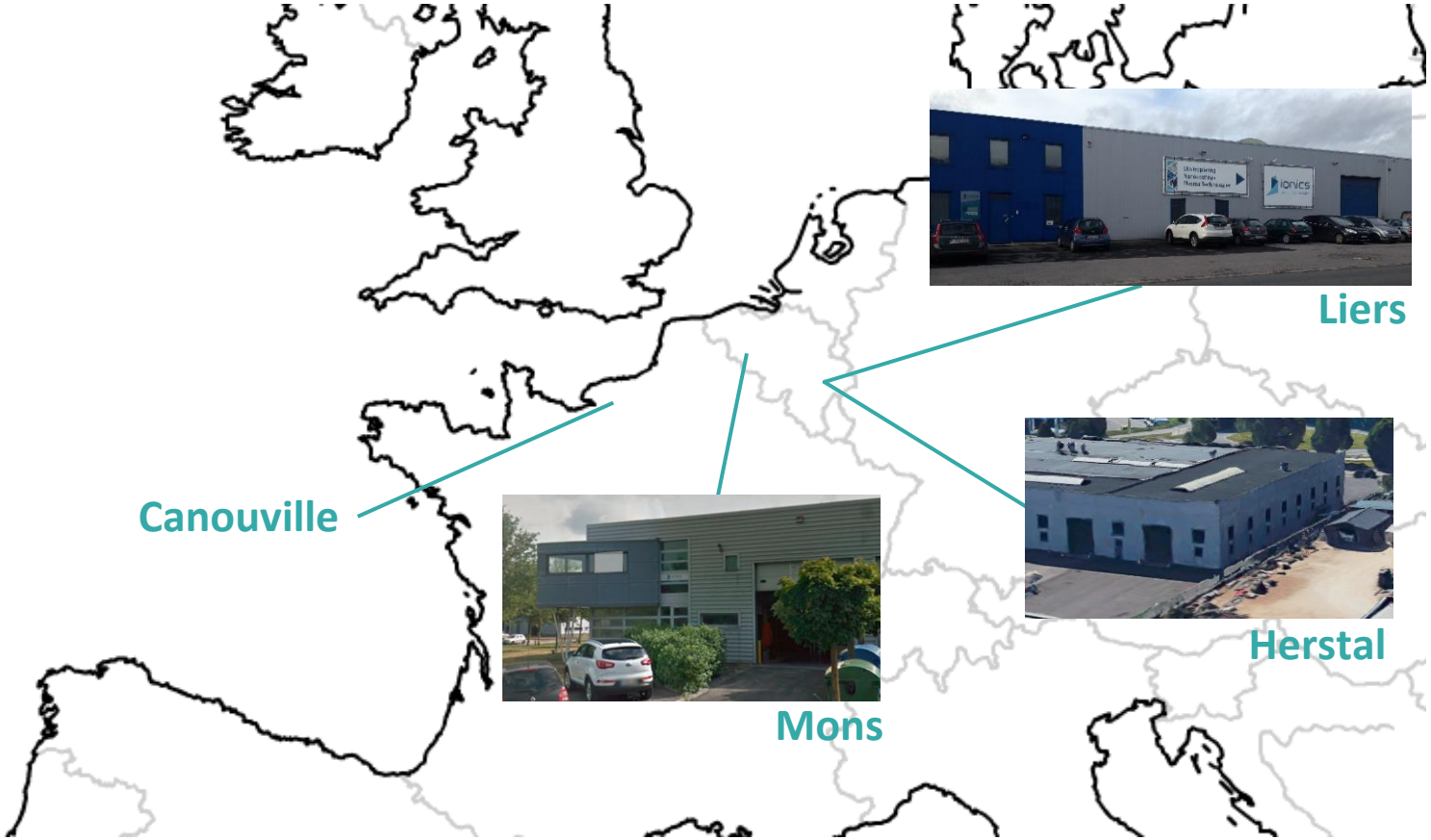
- Hybrid coatings (sol-gels)
- Paintings, varnishes, inks
- Metallic, alloys and ceramic coatings
- Biomolecules
- Organic semiconductors
- (bio) polymers and (nano) composites

DEVICES

- (Bio) sensors
- Optoelectronic
- Piezo et thermoelectric
- Self-managing surfaces

1. Presentation of Ionics SA

- 4 sites
- 22 employees



1945 — **La Protection Métallique** (Electroplating)

2001 — **Thermo-Technologies** (Electroplating)

2005 — **TECLYSE S.A** (Electroplating)

2006 — **Matrio Group S.A** (Electroplating)

2014 — **IONICS** (Electroplating, Plasma)

2024 — Celebrating 10 years of IONICS

Offered Technologies

Conventional Business

Electroplating

- Improving metals wear and corrosion resistance
- Reel-to-reel plating
- Barrel plating via partners
- Majority of business in Automotive sector & household appliances

Strategic Technology

PVD / PECVD

- Functional coatings of metals / ceramics / polymers
- Countless coating types, e.g. metallic alloys, Diamond-like C, Nitrides, Carbides, etc.
- Coating of the powders, beads and 3D objects

Ion Implantation

- Our key technology with 38 patents
- Improving corrosion resistance, hardness, COF & fine-tuning optical properties
- Modification of metals, polymers, elastomers, etc.
- Processing of flat surfaces, reels, powders and 3D objects

1. Presentation of Ionics SA - Facilities

Batch/Lab-scale plasma system

- Equipped with ion implantation and/or PVD/PECVD
- Flat samples up to 40x40cm and powder up to 100cm³

ionLAB 400™

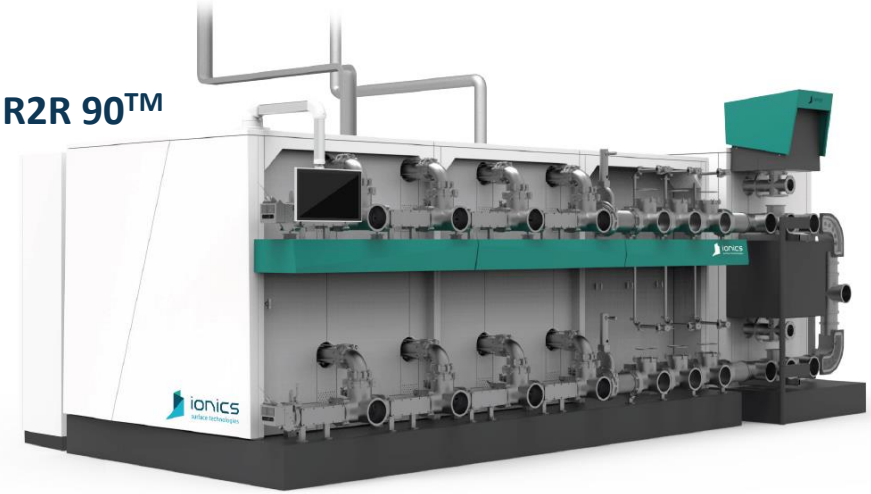
ionPOWDER 100™

Semi-industrial ion implanters:

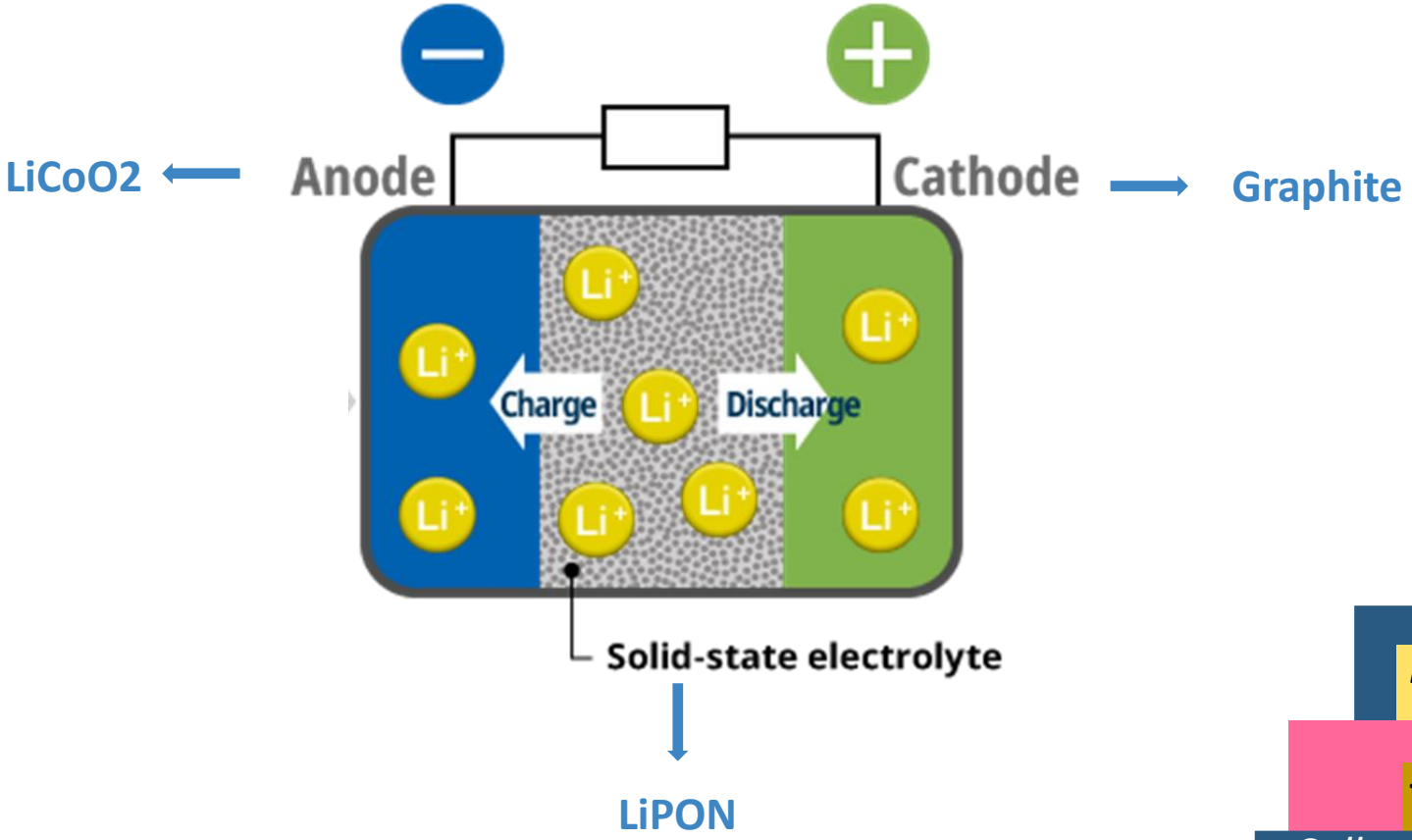
- Load-and-Lock system for flat samples up to 1,6 x 1,6m
- Continuous Roll-to-Roll for strips

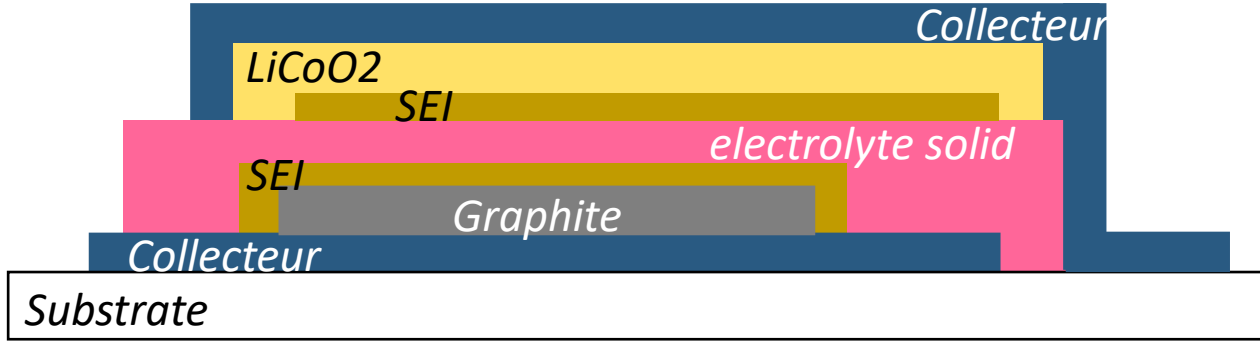
ionPRO 1800™

ionR2R 90™



2. Thin Film Solid State Battery





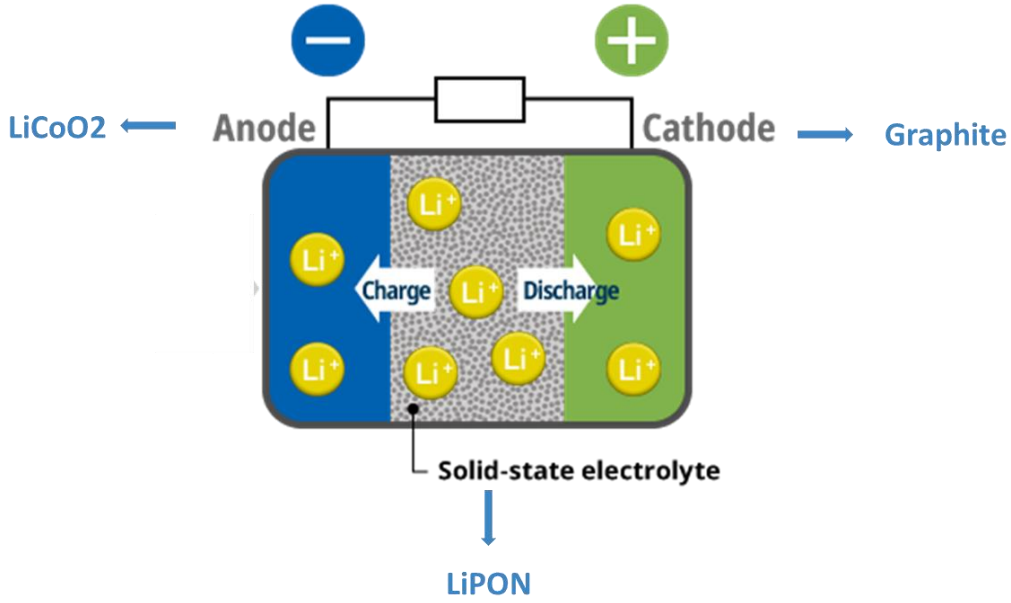
2. Thin Film Solid State Battery

Ion beam Implantation

→ LiCoO2 Anode

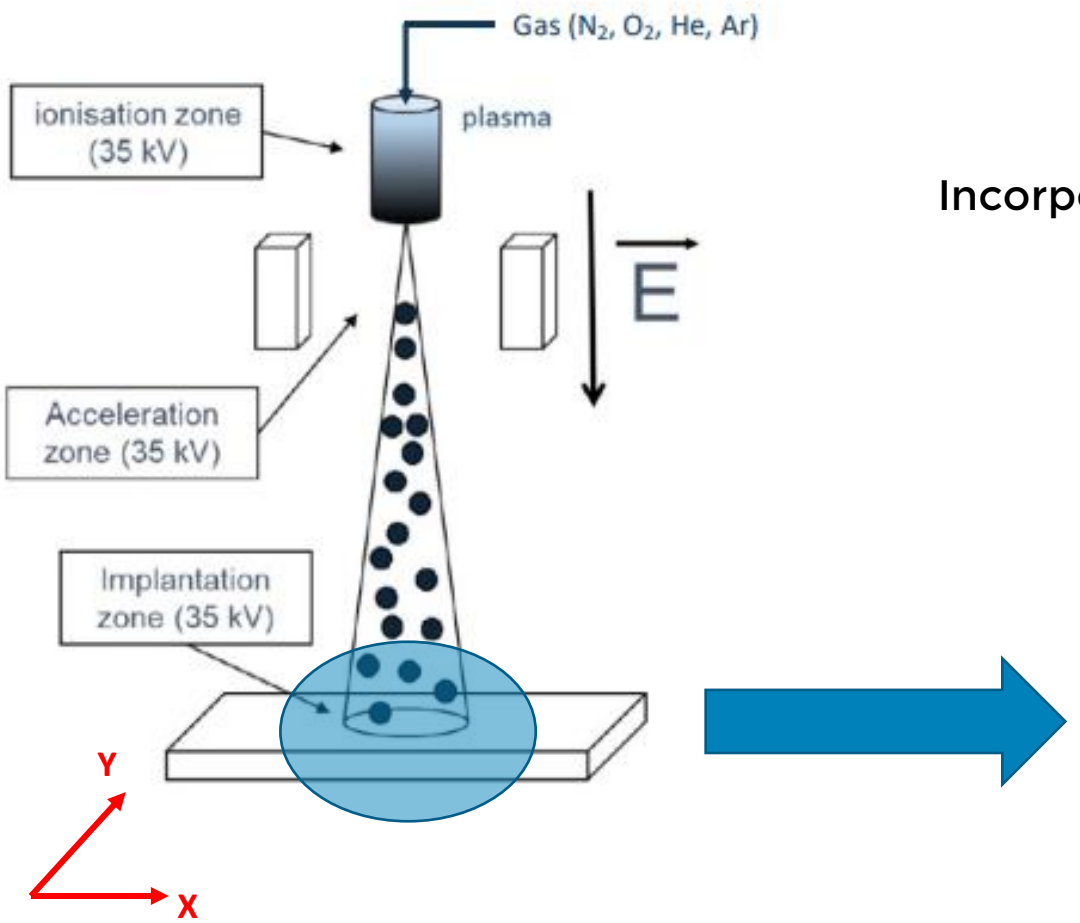
→ Graphite Cathode

→ Solid State Electrolyte



3. Ion beam Implantation technology - Principle

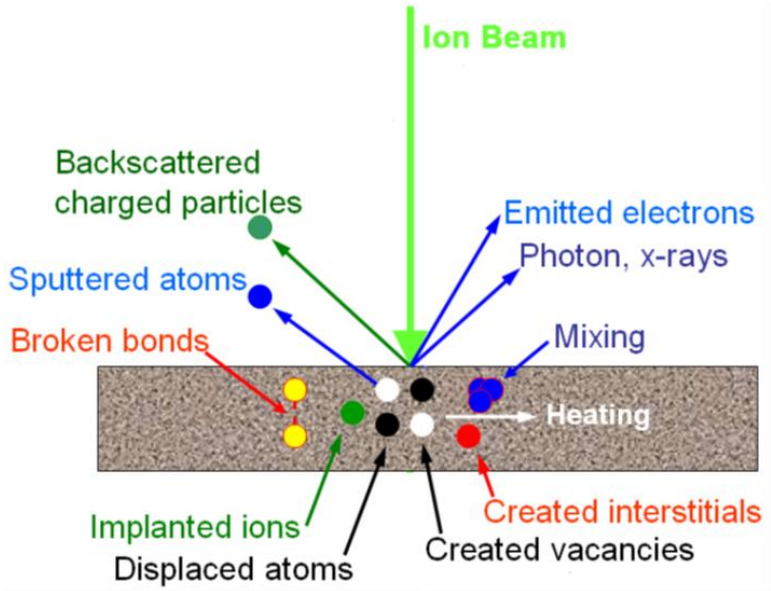
Principle

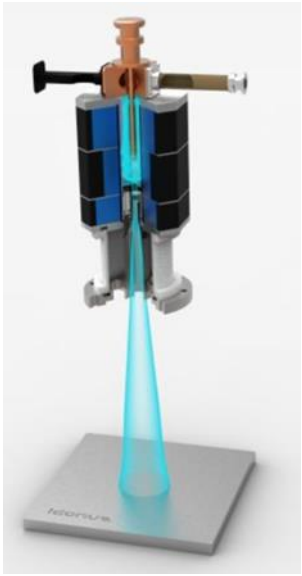


Definition

Vacuum process where ions are accelerated by an electrical field towards a solid sample

Incorporation of **high energety ions** into materials to modify the chemical and mechanical properties at the surface



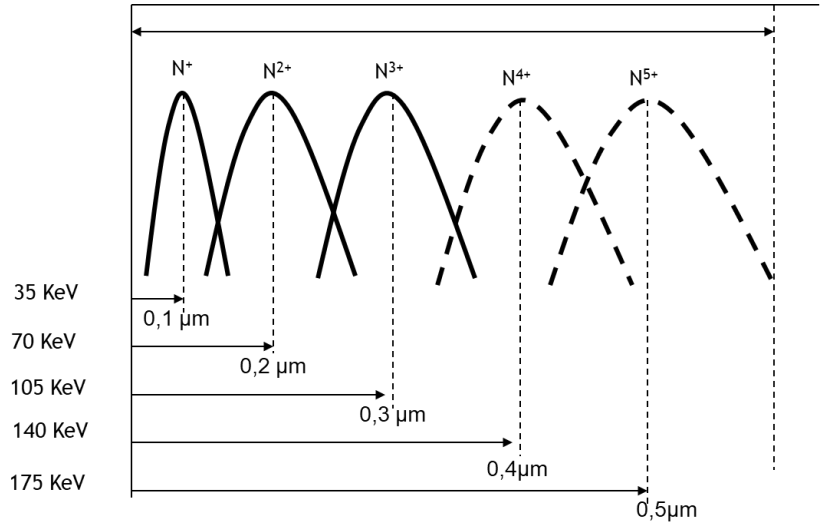


3. Ion beam Implantation technology - Principle

3. Ion beam Implantation technology – Ion depth profile

Multicharged ion beam

States	+1	+2	+3	+4	+5
He	89%	11%			
N	57%	32%	8%	2%	1%
O	57%	32%	8%	2%	1%
Ar	65%	25%	7%	3%	

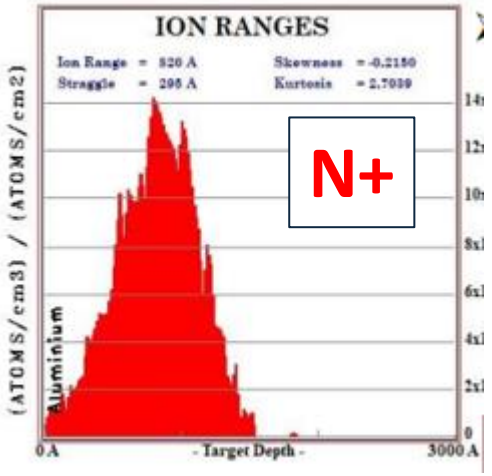


Example : N implanted Aluminium

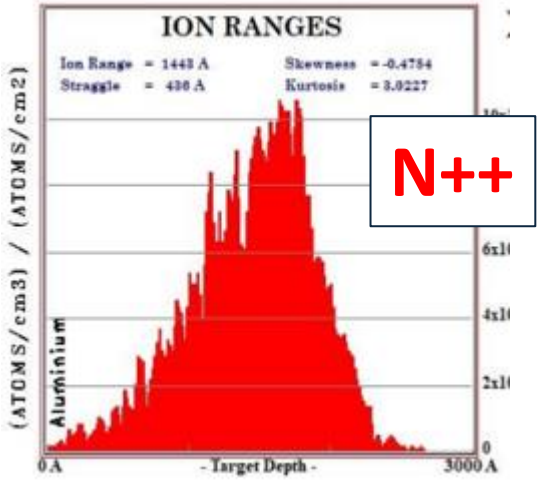
SRIM-2013 software simulation

Stopping & **R**ange of **I**on in **M**atter

Energy = 35keV



Avg depth = 82nm
Max depth = 150nm



Avg depth = 114nm
Max depth = 250nm

3. Ion beam Implantation technology - Properties

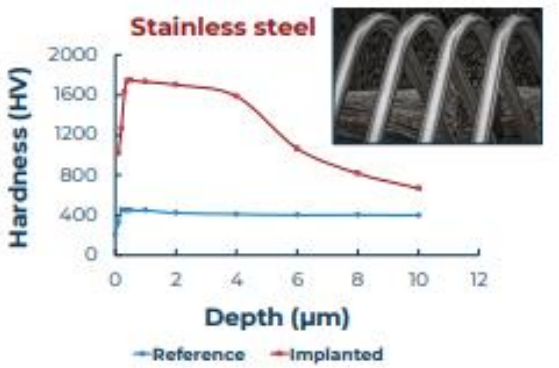
Process

- Simple process ⇨ Industrialization
- Any solid materials: metals - polymers - glasses…
- Any shapes: flat - powders - small 3D objects, wire…
- No adherence issues
- Environmental-friendly process

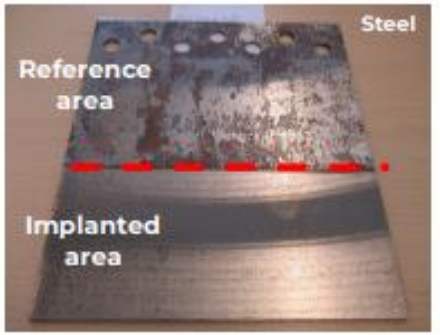
Benefits

- Surface hardening
- Tribological properties : friction coefficient reduction, wear resistance…
- Improved corrosion resistance and high temperature oxidation resistance
- Wettability modification (hydrophobic - hydrophilic)
- Adhesion improvement at the interface between 2 materials
- Advanced products with optical, electronic, catalytic properties…

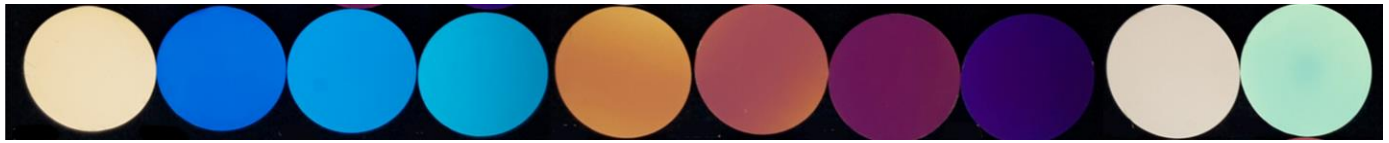
Hardness



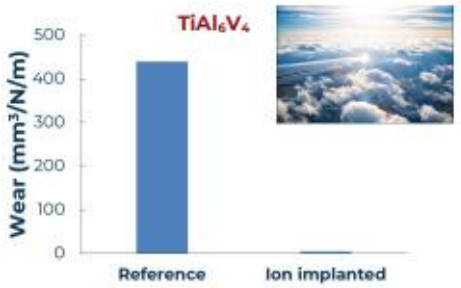
Corrosion resistance



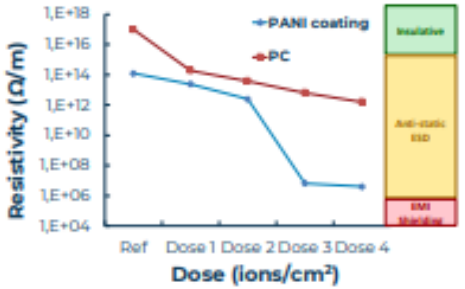
Metal coloration



Wear



Polymer conductivity



Applications in Solid State Battery

Graphite case

4. Applications in Solid State Battery – Graphite case

Effect of Ion beam Implantation on the electrical properties of graphite thin films

Thin graphite film produced by PVD plasma technology

- Thickness = 500nm
- Substrate : 4inch quartz wafer

Ion Beam Implantation parameters:

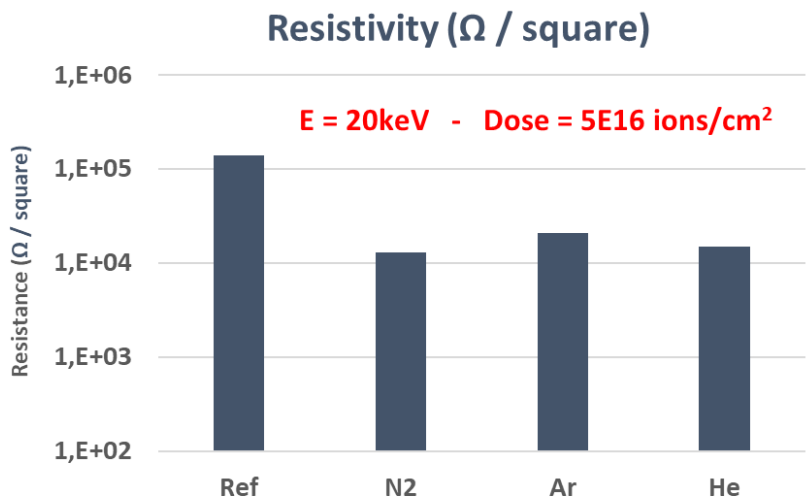
- Gas : He (small size), Ar (big size), N_2 (reactive gas)
- Ion energy : 10 to 35 keV
- Ion dose : 5^E15 to 3^E17 ions/cm^2
- Sample surface temperature : 100 to 300°C

Electrical characterization by 4-probes method

4. Applications in Solid State Battery – Graphite case

Effect of Ion beam Implantation on the electrical properties of graphite thin films

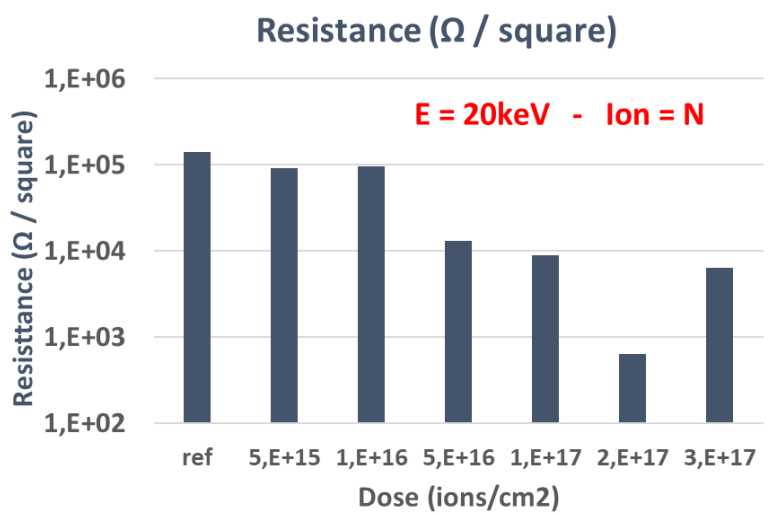
Ion influence



No impact of the ion

Mechanism not linked to the ion size or the ion reactivity

Dose influence

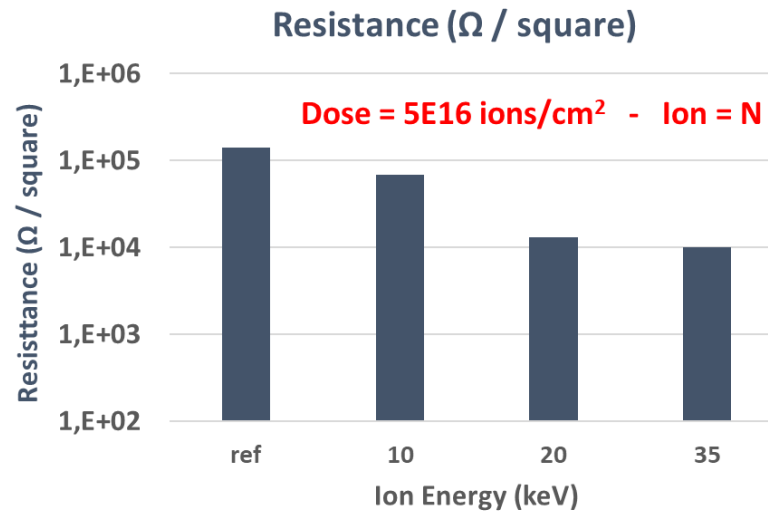


Max decrease of 2,5 degree of magnitude

Optimum dose

Gas Bubble formation at higher dose

Energy influence



Higher energy

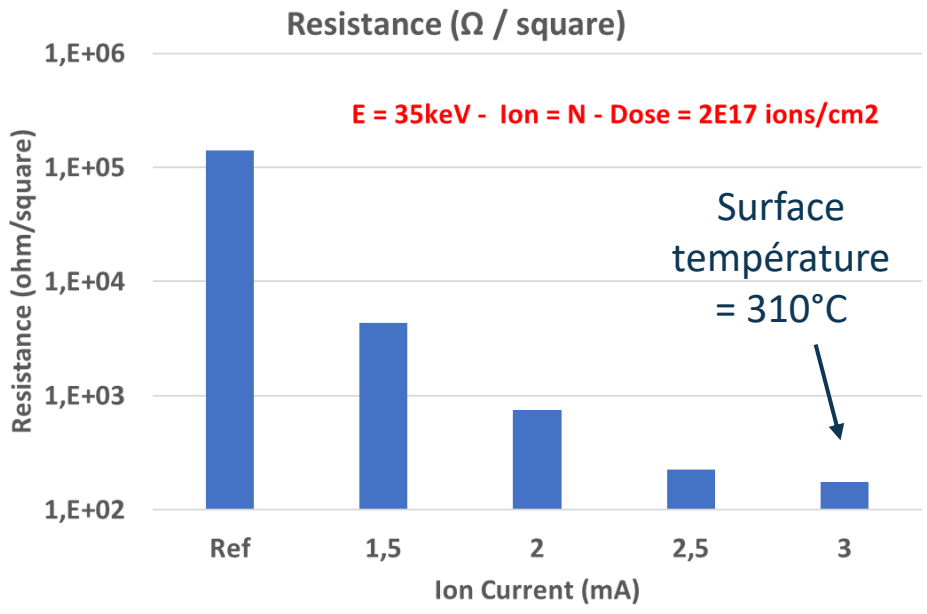
Higher ion depth penetration

Higher effect on the microstructture

4. Applications in Solid State Battery – Graphite case

Effect of Ion beam Implantation on the electrical properties of graphite thin films

Process temperature influence



Sample heating controlled using ion current density

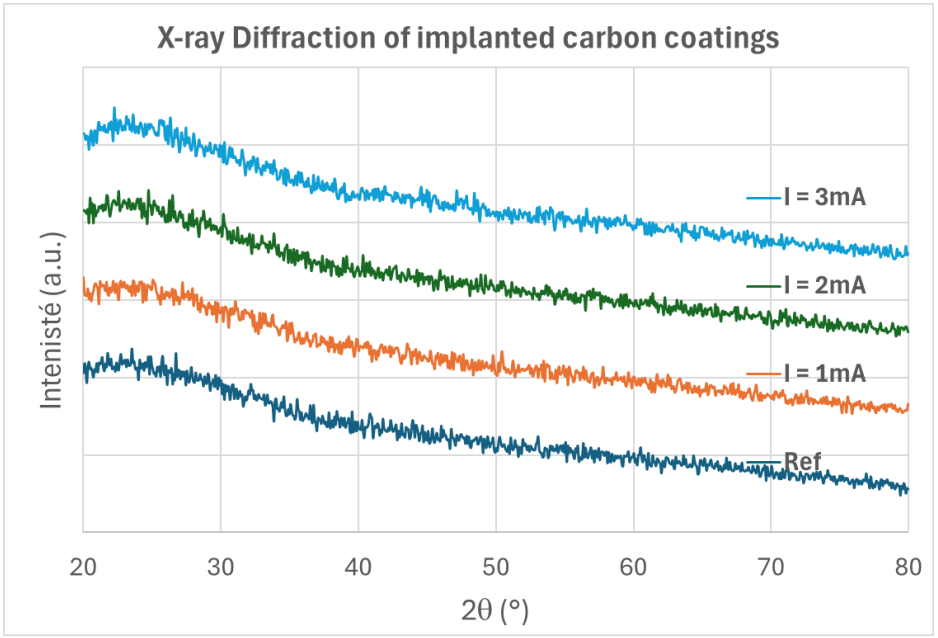
- Very high impact of the temperature during ion implantation
- Maximum decrease of 800X compared to reference

4. Applications in Solid State Battery – Graphite case

Microstructure characterization

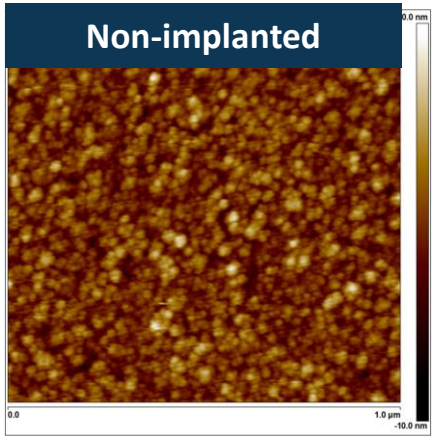
Cristallinity (X-Ray diffraction)

Resistance decrease not due to crystal structure modification after ion implantation



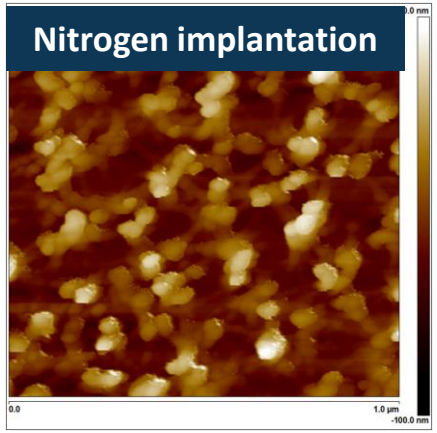
Microstructure (AFM)

Resistivity = 1,2E5 Ω/sq



Roughness Ra = 1,6nm

Resistivity = 1,7^{E}3 Ω/sq



Roughness Ra = 20,0nm

4. Applications in Solid State Battery – Graphite case

Conclusions:

- Ion implantation is a process that can successfully modify the electrical properties of carbon coatings
- The driving parameters are mainly the ion dose and the process temperature
- Microstructural characterization doesn't completely explain the involved mechanisms

Perspectives:

- Better understanding of the mechanisms by further characterizations
- Influence of thermal annealing before or after implantation
- Evaluation of the ion implantation interest on the modification of the battery anode ($LiCoO_2$) and solid-state electrolyte (LIPON)

Thank you for your attention

Exercice 2021 - project 9555
Convention région wallonne n° 21100149