CAMBO Science Park Trnava: A 10-Year Journey of Innovation and Collaboration

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STU MTF
SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE
MATERIÁLOVOTECHNOLOGICKÁ FAKULTA SO SÍDLOM V TRNAVE

STU
UNIVERSITY SCIENTIFIC PARK
Centre of Materials Research – Slovakion

Outline

- Who we are
- Research facilities
- Brief history:
  - Establishment
  - 2016-2020
  - 2021-present
- Research activities and collaborations
- Innovation
- Future plans

CAMBO – the first University Scientific Park in Slovakia, established at MTF STU in 2015

Slovak University of Techology (STU)

Faculty of Materials Science and Technology (MTF)

est. 1986

STU
MTF

- Faculty of Civil Engineering
- Faculty of Mechanical Engineering
- Faculty of Electrical Engineering and Information Technology
- Faculty of Chemical and Food Technology
- Faculty of Architecture and Design
- **Faculty of Materials Science and Technologies in Trnava**
- Faculty of Informatics and Information Technologies
- Institute of Management

University Science Park

Primarily focused on Materials Engineering in the field of ion and plasma technologies and automation, ICT implementation in industrial processes.

- **Scientific Centre of Materials Research (Ion Beam Centre) - Research oriented**
- **Scientific Centre of Industrial Automation and Informatization – Education oriented**

In addition to the construction infrastructure and the acquisition of unique technologies for materials research and automation and computerization of production processes, the main planned activities were :

- Applied research
- Support for innovation and modern technology transfer into practice in the form of transfer of know-how and knowledge from the academic environment to practice, start-ups, spin-offs.

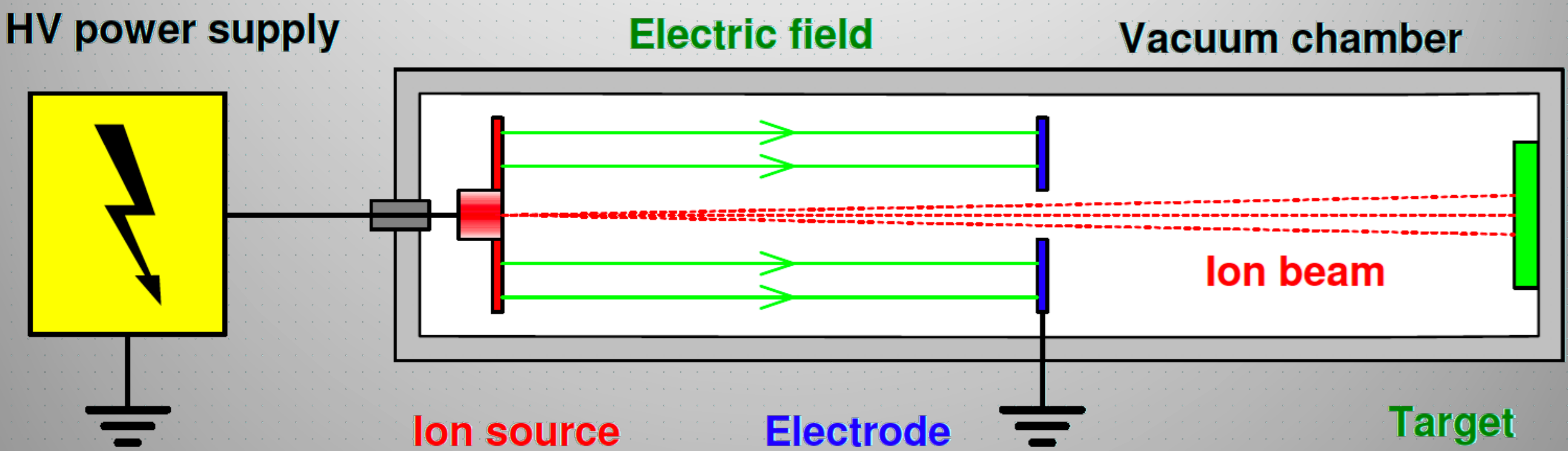
SlovakIon

Introduce novel, high-end ion technologies for materials engineering and nanotechnology in Slovakia and integrate them into the STU research infrastructure.

- Foster materials research
- Collaboration with industry
- Innovation

Intro into ion beams

- **Simple ion accelerator**



Vacuum 10^{-6} – 10^{-10} mbar (10^{-4} – 10^{-8} Pa)

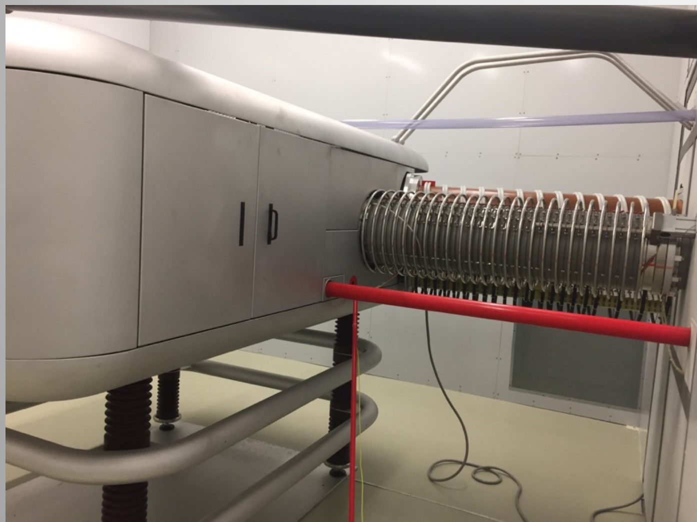
Mean free path of 1 MeV protons in air

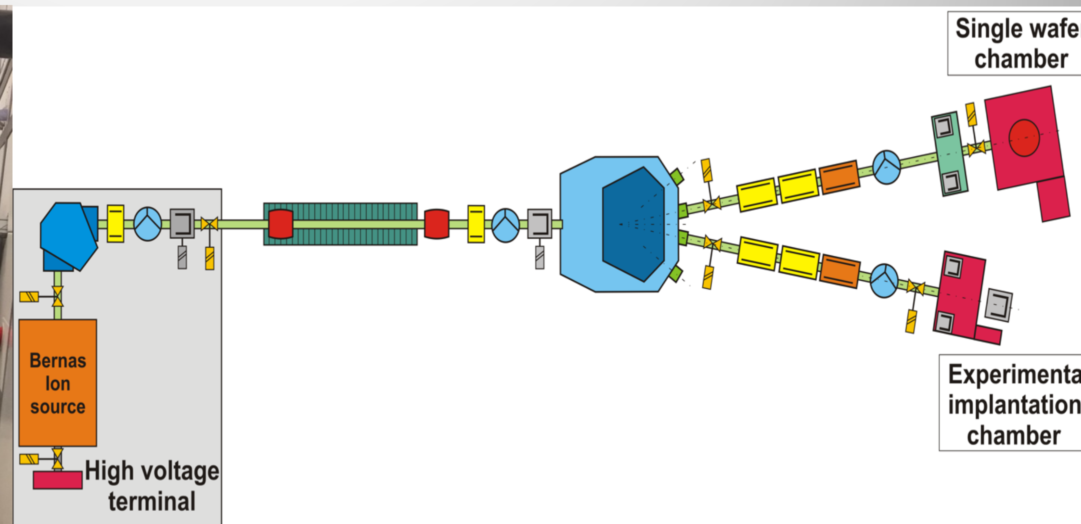
1 bar ~ 2 cm	10^{-6} mbar ~ 20 000 km
1 mbar ~ 20 m	10^{-10} mbar ~ 200 000 000 km

Where are ion beams useful

- **Physics research**
  - Exploring matter, its fundamental attributes and find answers to basic questions of physics using particle collisions
- **Materials modification**
  - Particle bombardment modifies the irradiated substrate in a highly controlled manner
- **Materials analysis**
  - Accelerated ions interact with the substrate and products of this interaction reveal valuable information
  - Accelerator mass spectrometry
- **Medicine – life sciences**
  - Radiopharmaceuticals, tracers for diagnostics, cancer therapy
  - Space travel
- **Etc...**

Research facilities - 500 kV ion implanter

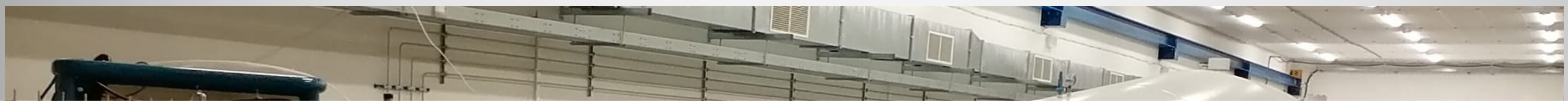


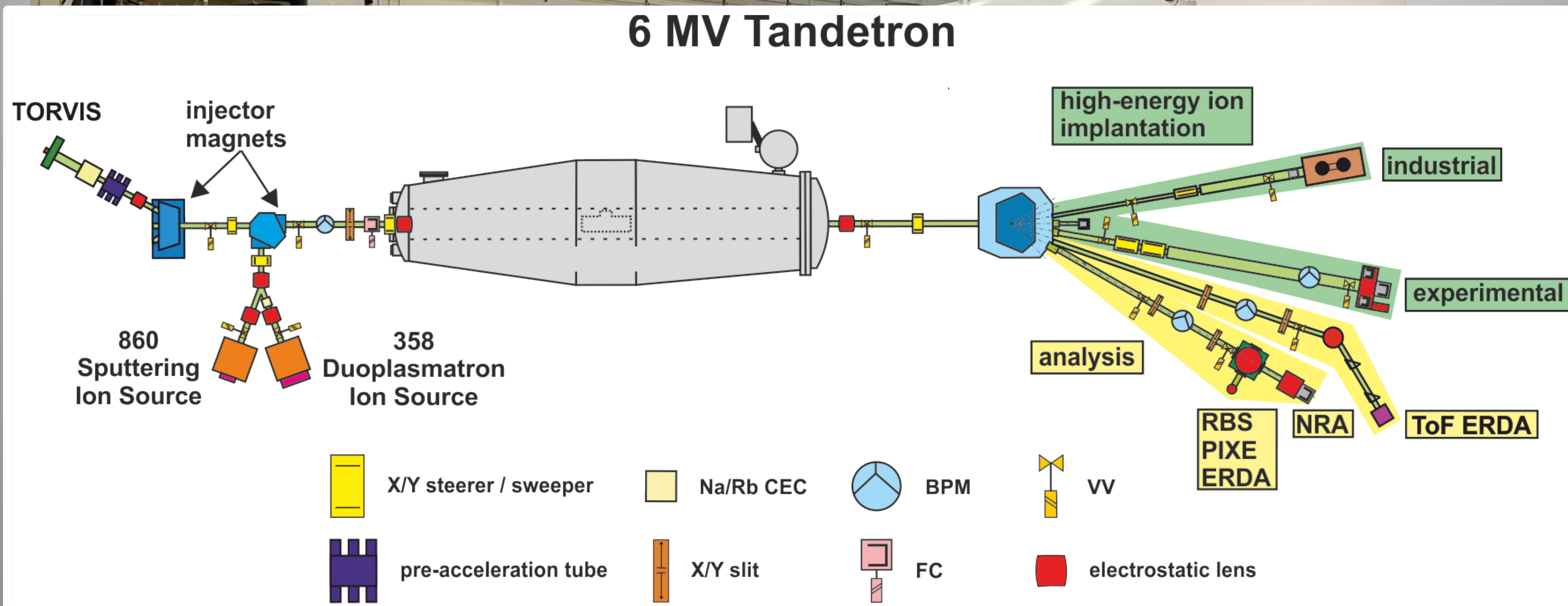


- Energies up to 500 keV
- Beam currents up to 2 mA depending on species
- Ion beam of any element possible

- Substrates up to ⌀200 mm, ⌀40 with heating up to 1000°C, water or LN2 cooling
- ISO Class 5 cleanroom possibility

Research facilities - 6 MV Tandem accelerator

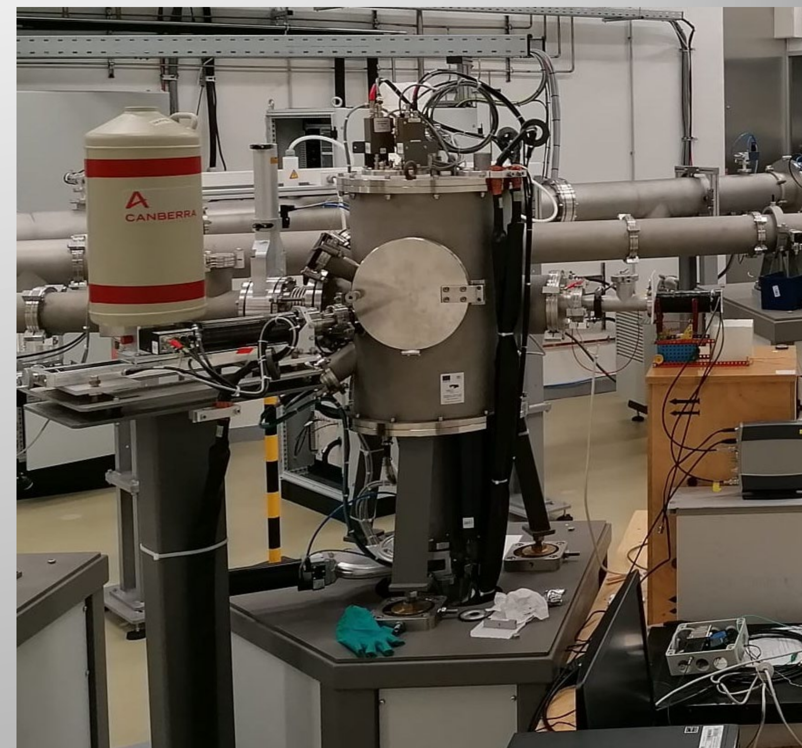




6MV Tandetron® tandem accelerator

- Ion beams of any element except Ne and heavier noble gases
- Energies (with reasonable currents) up to around 100 MeV
- Currents up to tens of μA (protons 50 μA, alphas 8 μA)

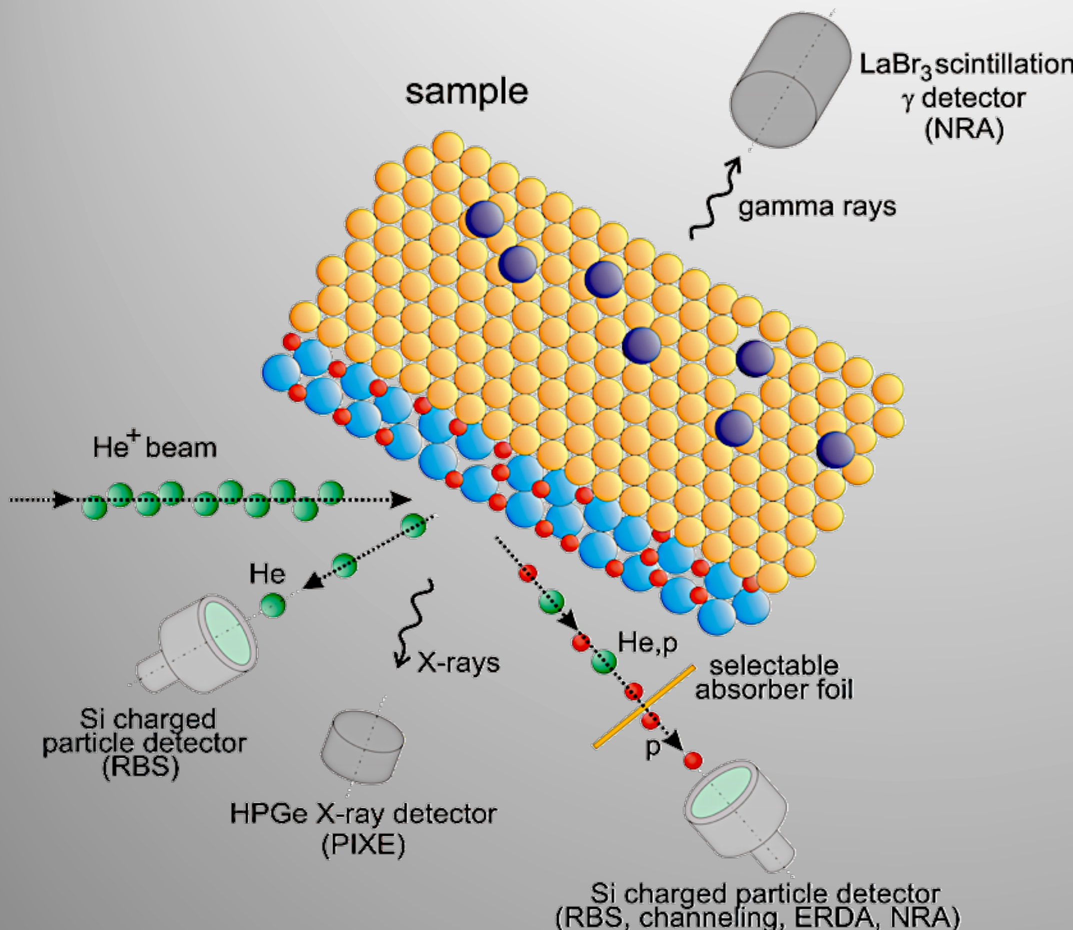
Tandetron beamlines and end-stations



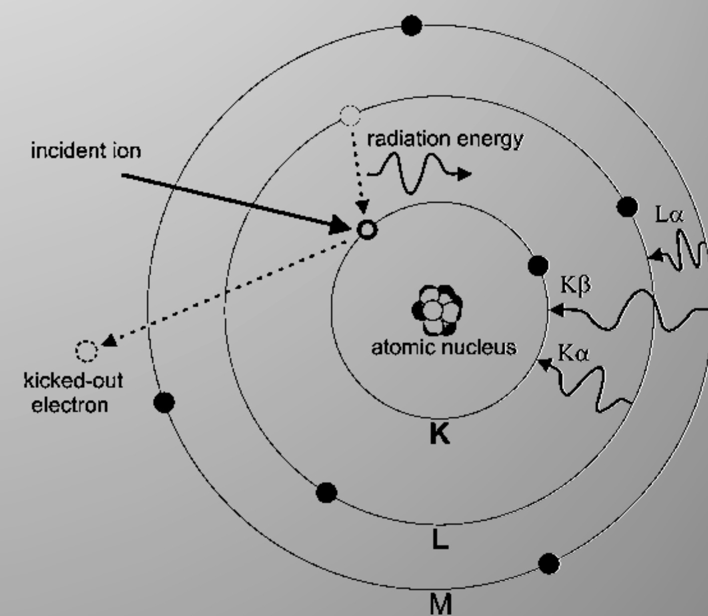
Analysis

Covering methods: RBS, PIXE, NRA, ERDA

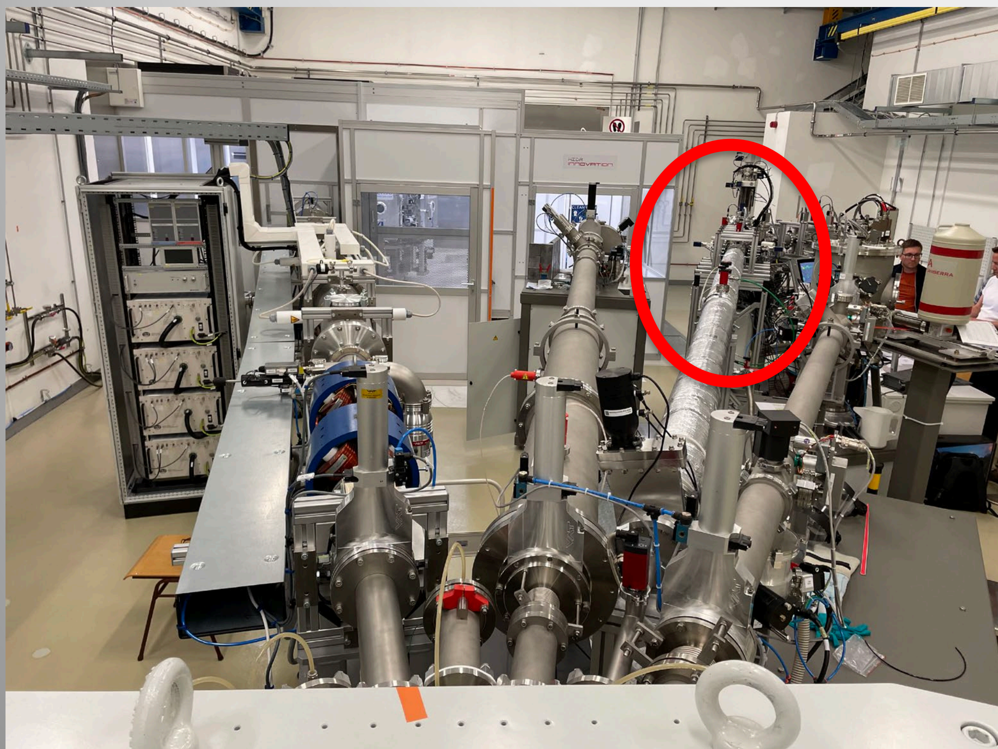
Ion Beam Analysis

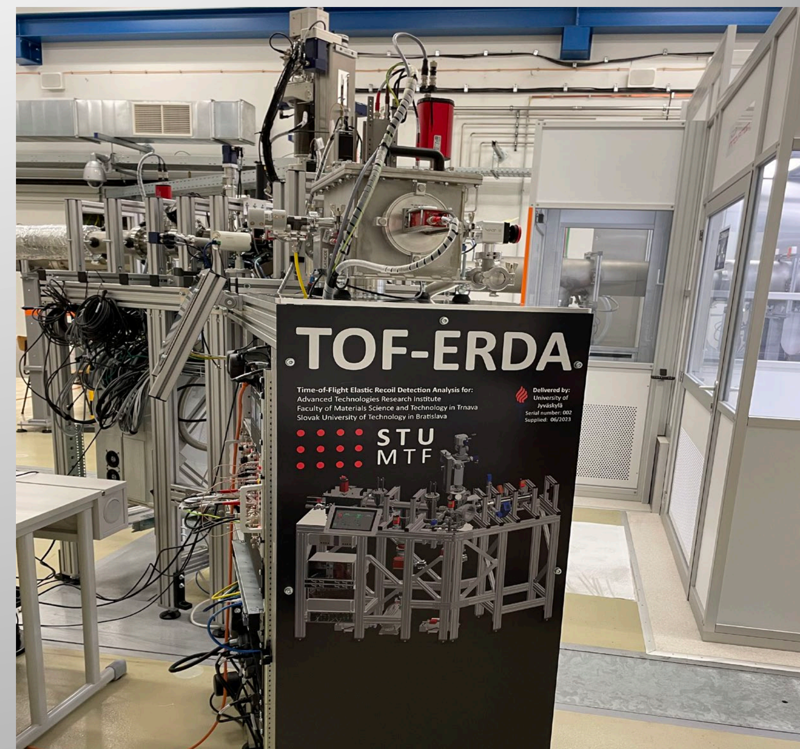


- Non destructive
- Trace element analysis
- Depth profiling
- Isotope resolution



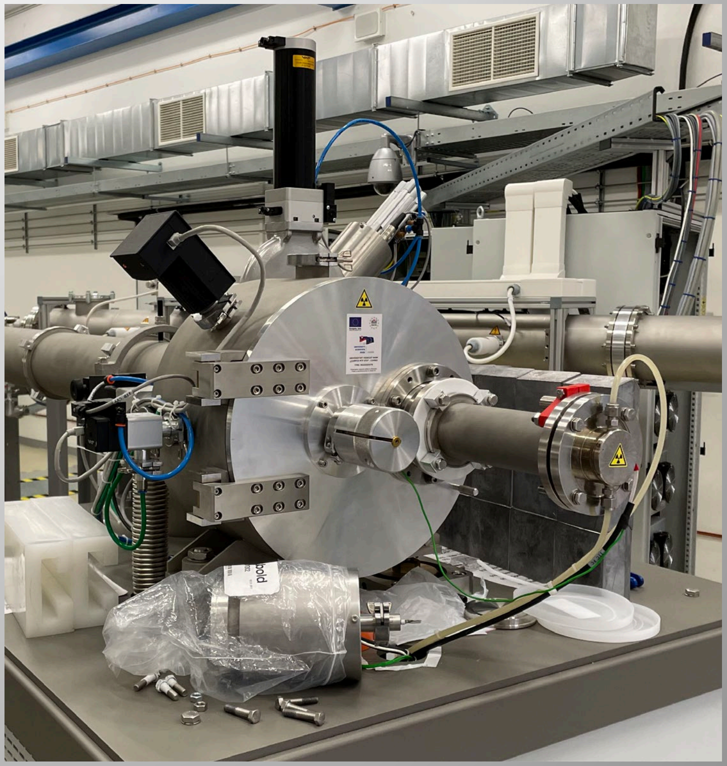
Tandem beamlines and end-stations





Highly sensitive, isotope-resolving elemental analysis methods
Covers also light elements down to hydrogen, ppm levels and depth profiling
For most techniques, no reference materials required

Tandem beamlines and end-stations



Ion implantation

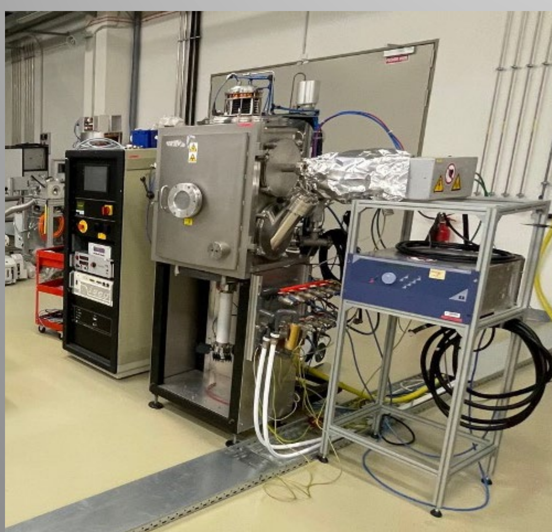
Substrates up to ⌀100 mm, ⌀40 with heating up to 1000°C, water or LN2 cooling
ISO Class 5 cleanroom possibility

Tandetron beamlines and end-stations

Wafer handler

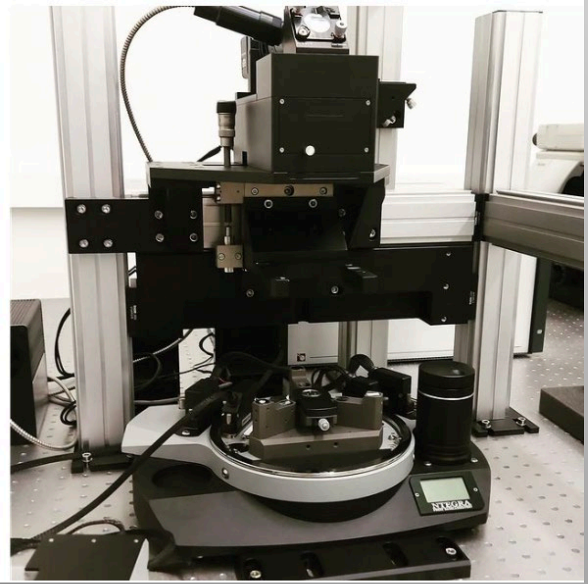
Plasma technologies

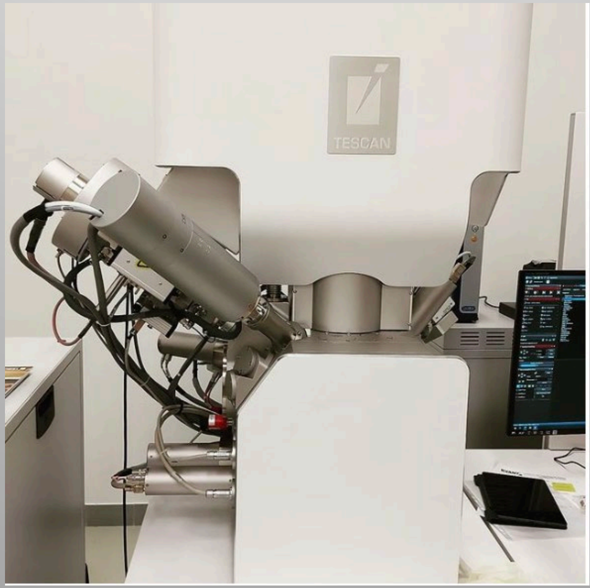
- **Magnetron deposition cluster tool** (2 chambers with 3 heads and 3 reactive gas dosing systems, HiPIMS under construction)
- **Plasma Immersion Ion Implantation** system
  (very high ion fluxes, yet no mass separation – being extended with 2xHiPIMS and powerful RF source)
- **RF sputtering deposition system** (in-house built combined system for ion beam synthesis – deposition + PIII)



Analytical equipments

- **NT MDT Spectra II AFM-Raman** system
- **Tescan Solaris dual beam FIB/SEM** system with EDX
  (EBSD and picoindenter stage under procurement)
- **PREVAC X-ray/UV photoelectron spectroscopy** including angle resolved measurements, ion scattering spectroscopy, UHV FTIR





The beginning…

- **01.03.2013 – Start of the realization**
- **30.06.2015 – Finishing of the construction workss**
- **4. December 2015 – Opening of the University Science Park CAMBO**
-

Funding: 42M EUR - UNIVERSITY SCIENTIFIC PARK “CAMPUS MTF STU” CAMBO – The European Regional Development Fund, project No. ITMS: 26220220179

Funding scheme:
85% EU structural funds
10% state budget
5% university budget

9M EUR – Slovak Centre of Excellence in Ion Beam and Plasma Technologies for Materials Engineering and Nanotechnology – SlovakION - The European Regional Development Fund, projects No. ITMS2014+:

- Increasing the long-term competitiveness of the Slovak Republic in the field of materials research based on ion and plasma technologies.
- Education and training of scientific and technical personnel for University Scientific Park CAMBO - materials research workplace.

The first five years, 2016-2020

The aim of the science park projects in Slovakia was to create an ecosystem for technology transfer and innovation and were primarily focused on completing the missing infrastructure.

The support was therefore mainly aimed at building infrastructure capacities. Personal costs, wages accounted for less than 10% of all expenses.

- Not clearly defined what science parks actually were
- No funding scheme for sustainable operation and further development – the home institutions were to take care of all this at their own expense.
- Issue of generating income – cooperation with industry and companies practically impossible
- No opportunity to create spinoff companies on university campuses that could bring financial income

The first five years, 2016-2020

- Implementation of the new technologies
- Hands on experience, broadening of the knowledge, building up research capacities
- Seeking contacts with industry, research centers, universities, Ion-beam facilities
- Cooperations through domestic research schemes (APVV, VEGA) and European projects (H2020)

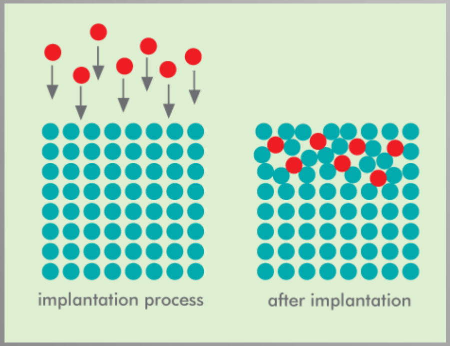
2021-Present

HZDR INNOVATION

Industrial cooperation

STU-HZDR Innovation GmbH. since 2021 – 500+kEUR/year
– R&D and processing of power semiconductors
– Development of ion sources

Semiconductors



- **Ion implantation:**
- **Doping**

  Circumventing the mutual solubility limit of elements we alter the substrate by forcing the dopant into its crystal lattice

- **Defect engineering**
- Tayloring properties of bulk and interfaces

2021-Present

Research
HydroGenIV - The European Regional Development Fund, project No. ITMS2014+: 313011BUH7

The European Commission under the EURATOM programme, grant No.: HORIZON-EURATOM-2021-NRT-01/101061241

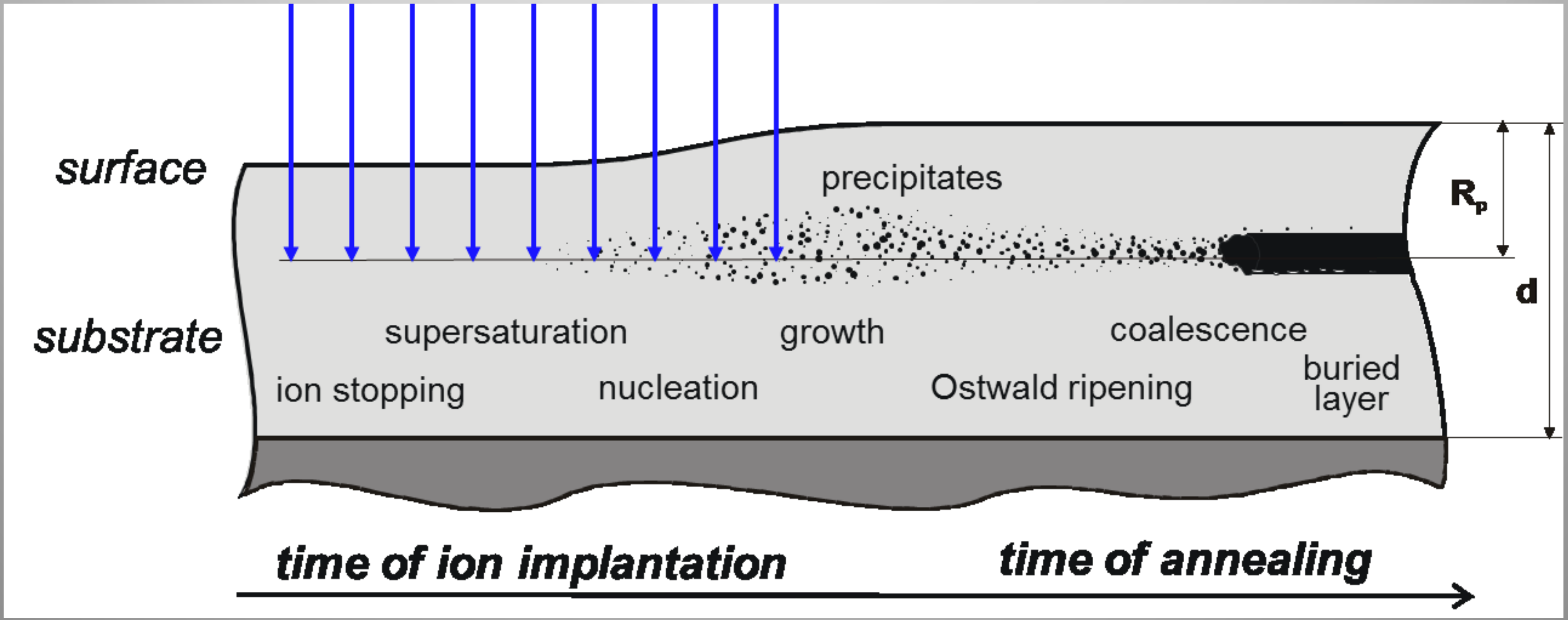
Ageing and Dynamic effets in Lithium-ion batteries - ADEL - EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under project No. 09104-03-V02-00046 (1139kEUR) together with INOBAT a.s.

Slovak Technical Ecosphere Platform – STEPHANIK - EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under project No. 09I02-03-V01-00038 (15,8M EUR, cca 400 kEUR for CAMBO)

Submitted project proposals to extend testing and development capabilities for the Space industry, sensors for orbital satellites.

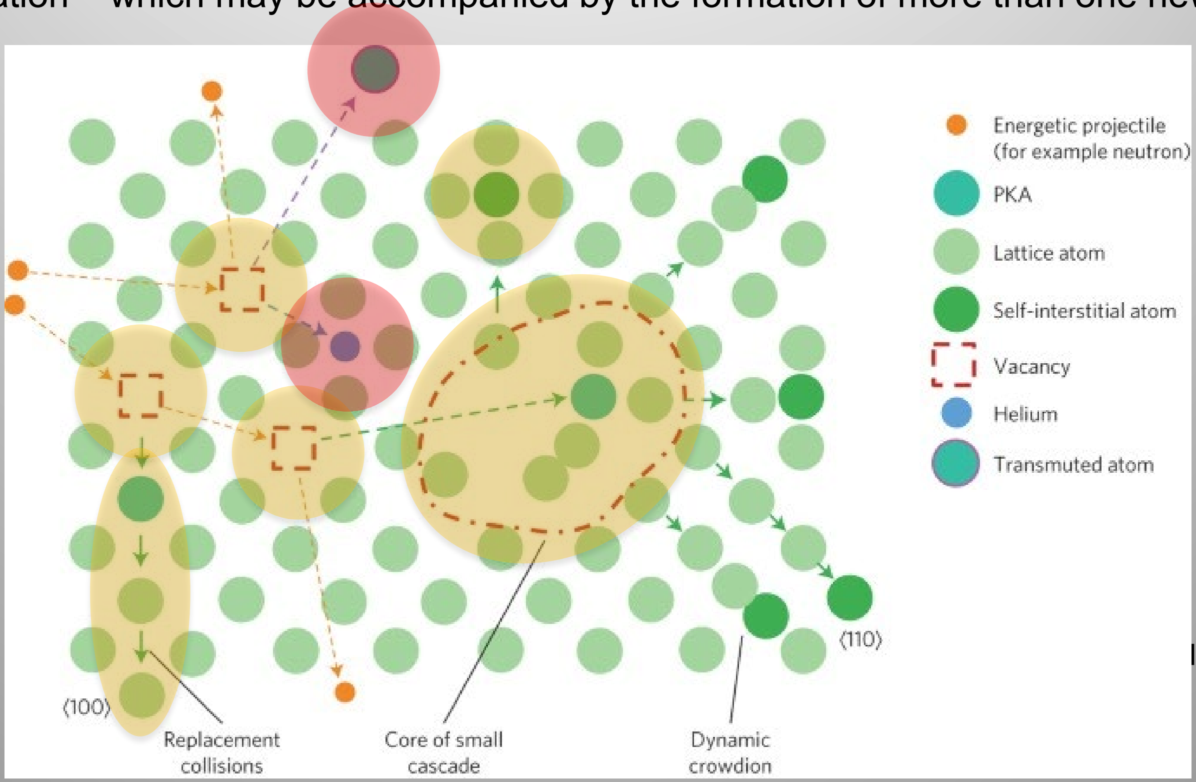
Ion beam synthesis

- **Add more, and the implanted elements start clustering**
  - various structures are formed



Extreme conditions - radiation environments

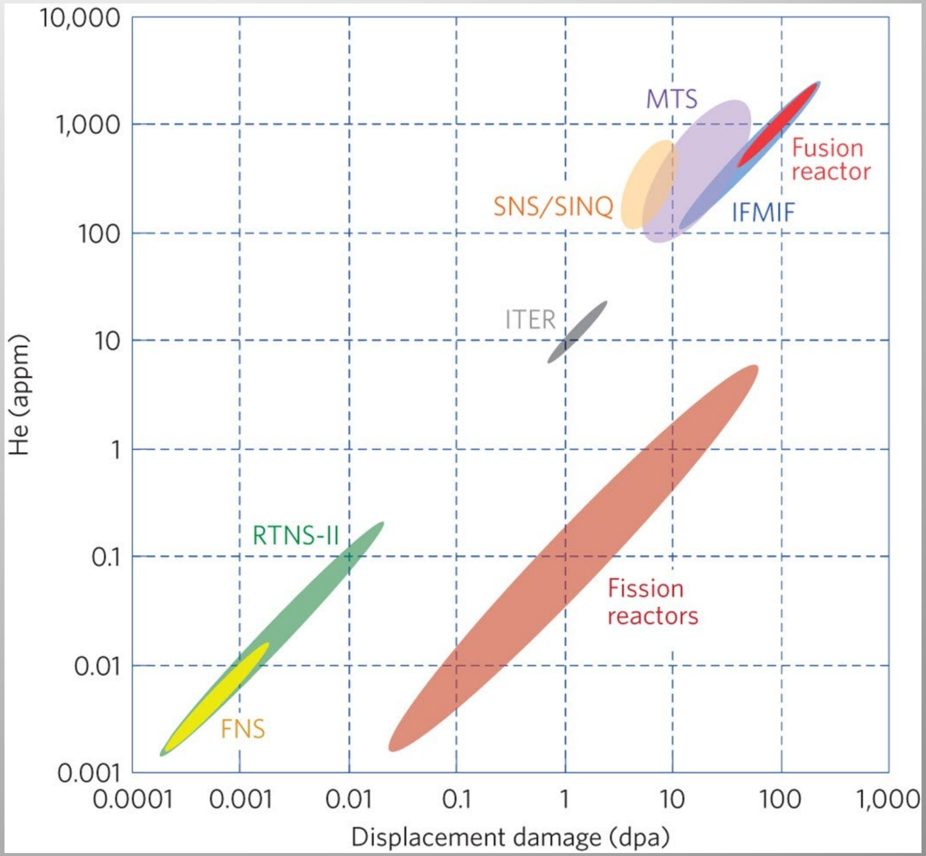
- **Particle irradiation (wherever it happens) may cause**
  - Changes to the structure - defects, phase change, swelling etc.
  - Transmutation – which may be accompanied by the formation of more than one new nucleus



12 (2016) 424.

Extreme conditions - radiation environments

- **The case of structural materials in nuclear systems**
  - Fission: **up to 1** appm He/dpa
  - Fusion: **10 – 15** appm He/dpa
  - Spallation: **10 – 100** appm He/dpa



J. Knaster, A. Moeslang, T. Muroga, Nature Physics 12 (2016) 424.

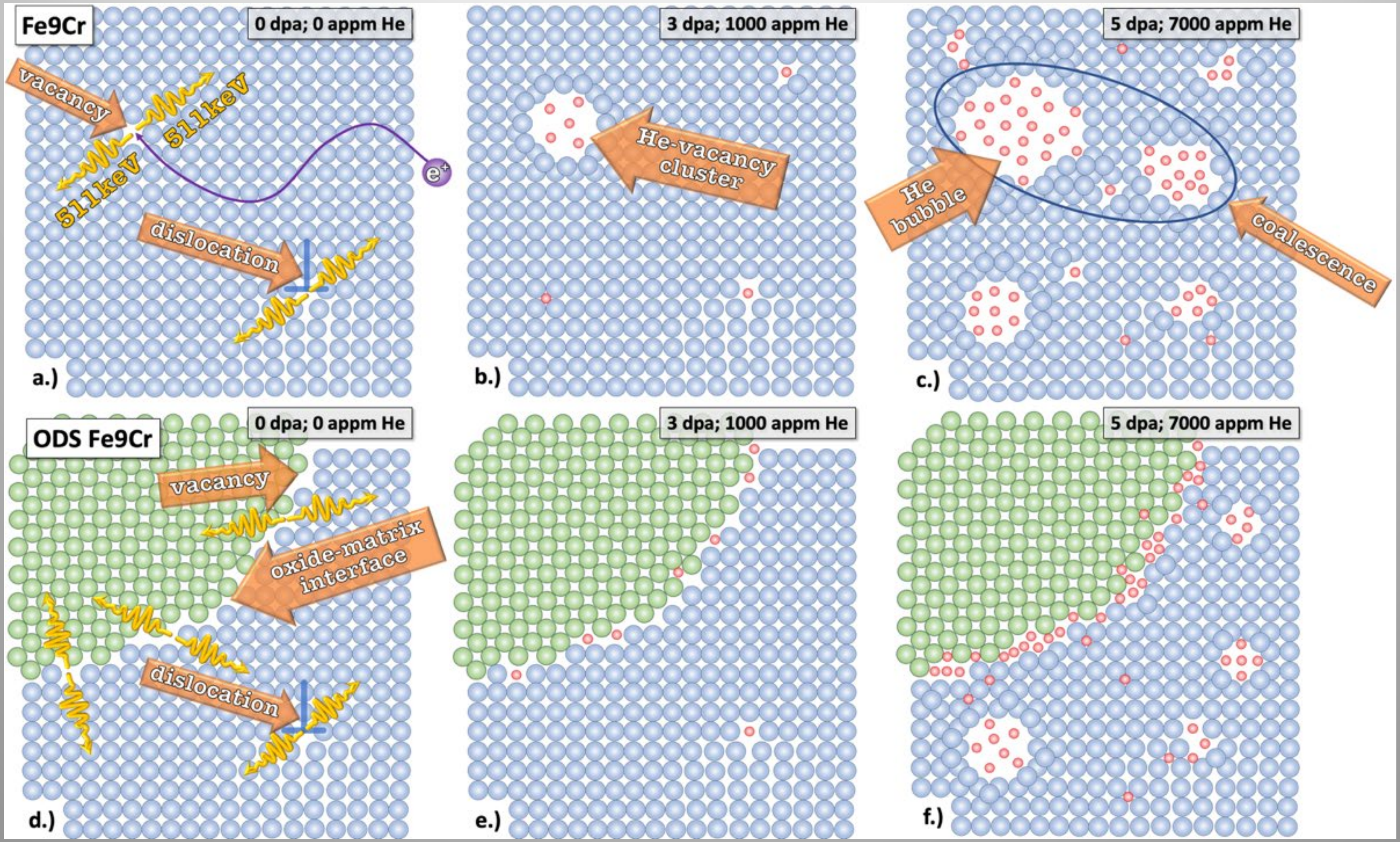
- **We know to live with dpa**
  - When not too much at once
- **With transmutation products**
  - When not too much in total
- **New generation systems are demanding**

Ion beams as a surrogate for neutron irradiation

- **Orders of magnitude faster damage rate**
  - Hour to days instead of months to years
- **Low to zero activation of the studied materials**
  - Analysis/damage assessment possible immediately after irradiation, no hot cells required
- **Versatility**
  - By multi-ion irradiation/implantation one can simulate any real-world irradiation condition including transmutation products

- **Only thin layers are affected**
  - Need near-surface analysis techniques
  - Hard to extract bulk properties such as Yield stress, Ultimate strength, Young‘s modulus
- **Question of transferability of results**
  - Neutrons vs. Ions – issue of charged vs. neutral, chemical alteration of the substrate
  - Damage is usually created by heavier ions for fast damage accumulation, extrapolation to reactor-relevant dose-rates is challenging

The role of transmutation helium



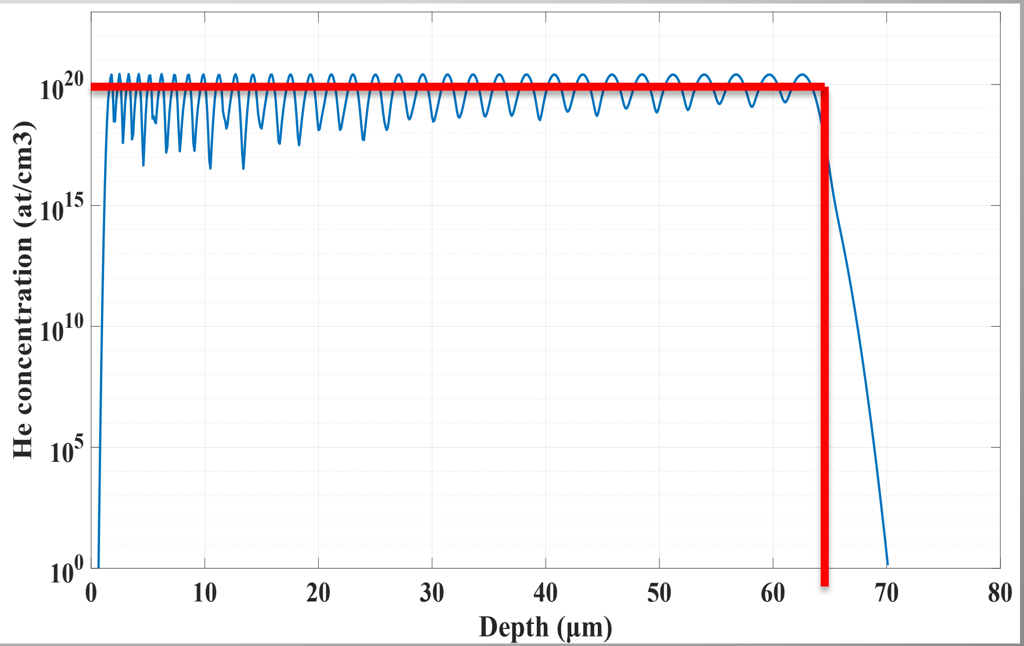
V. Kršjak et Al., J Mater Sci Technol. 105 (2022) 172-181.

Assessing the bulk properties

- **Irradiation with higher energies**
  - Deeper penetration, (range of 17 MeV He ions is 65 μm)
  - Homogeneity becomes an issue – overcome by multi-step irradiation
  - Activation slightly higher, yet dominated by short-lived isotopes
  - Damage accumulation, however, much slower

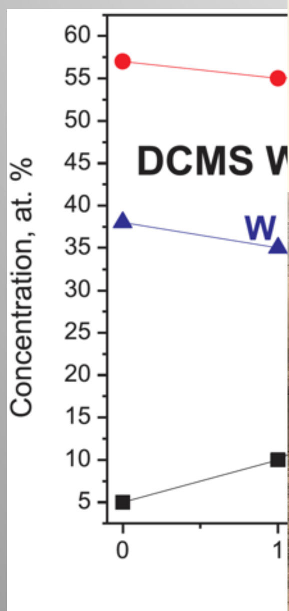
- **„Thick“ affected layer**
  - Micromechanical testing not limited to nanoindentation
  - Extraction of bulk material properties possible

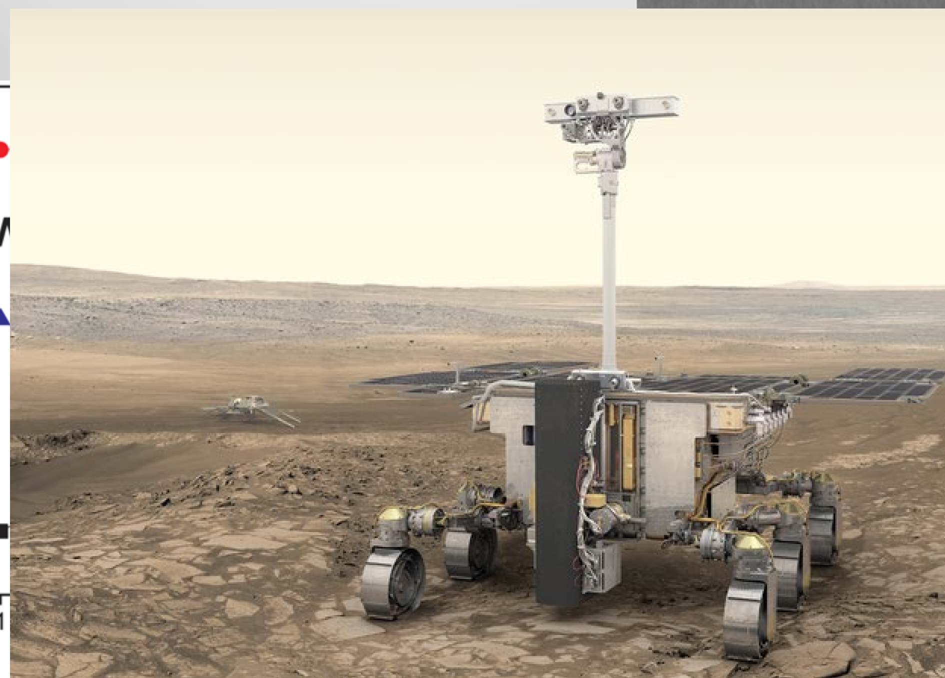
- **Transferrability**
  - Direct comparison with reactor-irradiated samples of the same batch of material is underway

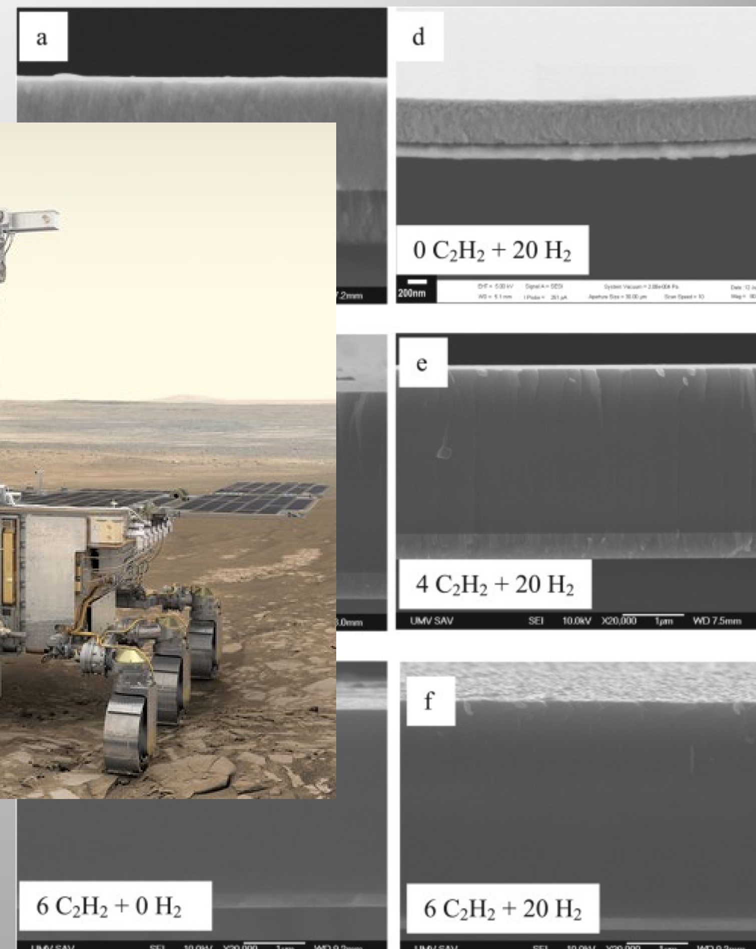


P. Noga et Al., Materials 14 (2022) 6443.

Hydrogen content analysis in W-C:H coatings







Institute of Materials Research SAV Košice

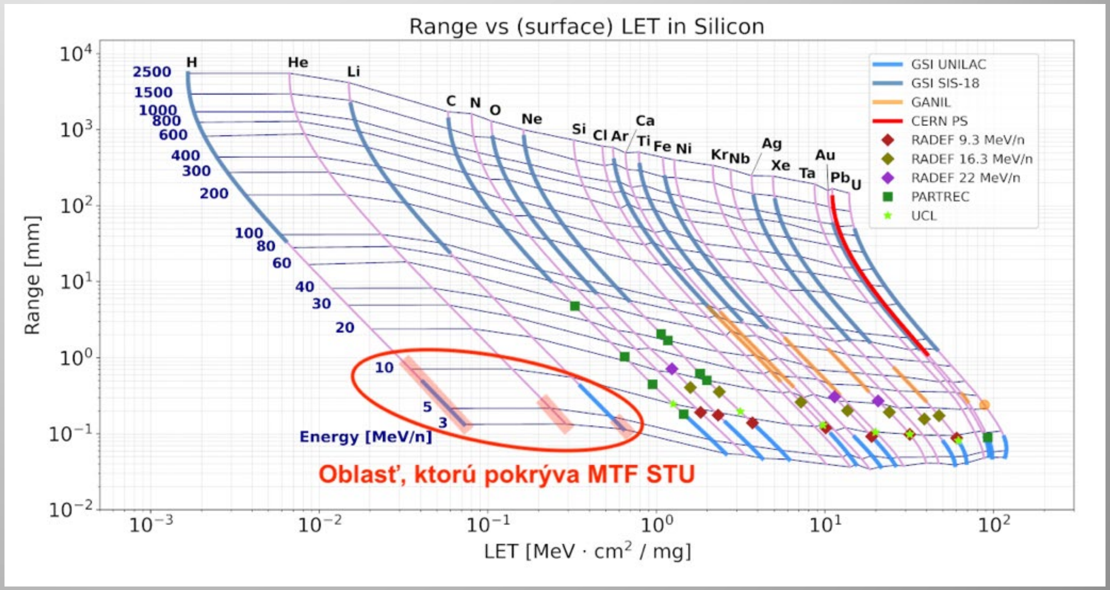
F. Lofaj et Al. Ceram. Int. 45 (2019) 9502–9514

Future plans

- **In-operando characterisation during charging-discharging processes**
  - In a functional battery layer, thin film batteries.
- **In situ characterization of material degradation**
  - Thermal ageing, radiation induced corrosion
- **In situ characterization during functional layer growth**
  - In cooperation with Uppsala University
- **Involve students and young researchers as much as possible**
  - Teaching activity, new study program incorporating accelerator technologies

Development and Testing of Materials and Components for Space Applications

- **Most relevant for Space applications and electronics**
  - **The orbit is not a good vacuum**
  - Van Allen belts
  - Mainly protons & electrons
  - Deteriorate electrical properties



R. García Alía et al., "The HEARTS EU Project and its Initial Results on Fragmented High-Energy Heavy Ion Single Event Effects Testing", in IEEE TNS, doi:10.1109/TNS.2025.3530502

How much does flux matter

- **Most relevant for Space applications and electronics**
  - **The orbit is not a good vacuum**
  - Van Allen belts
  - Mainly protons & electrons
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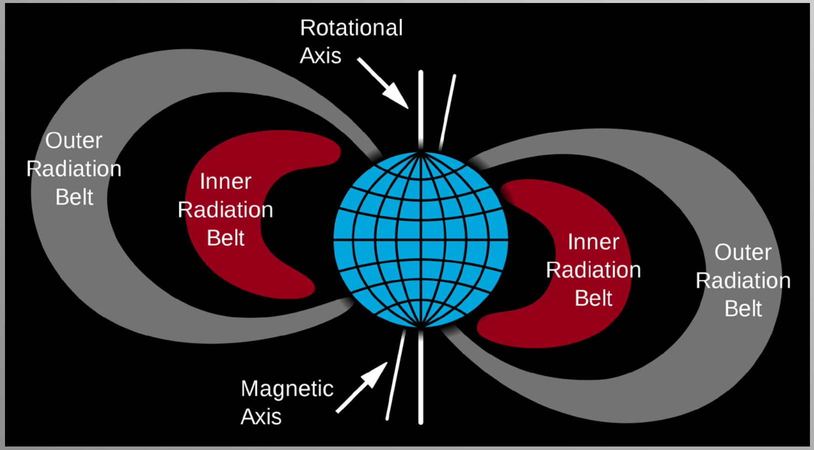
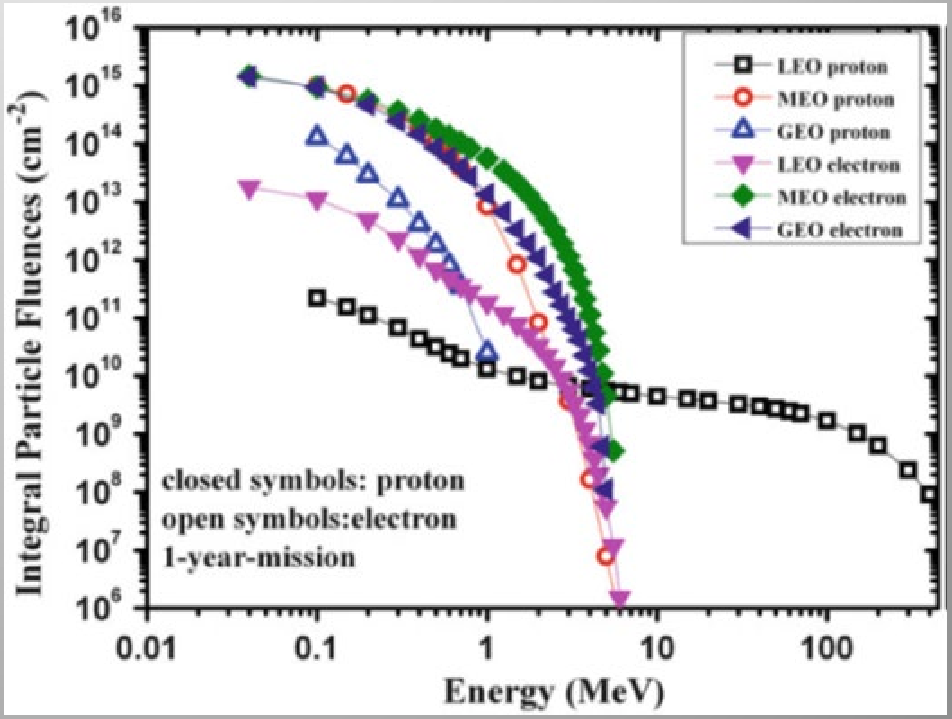
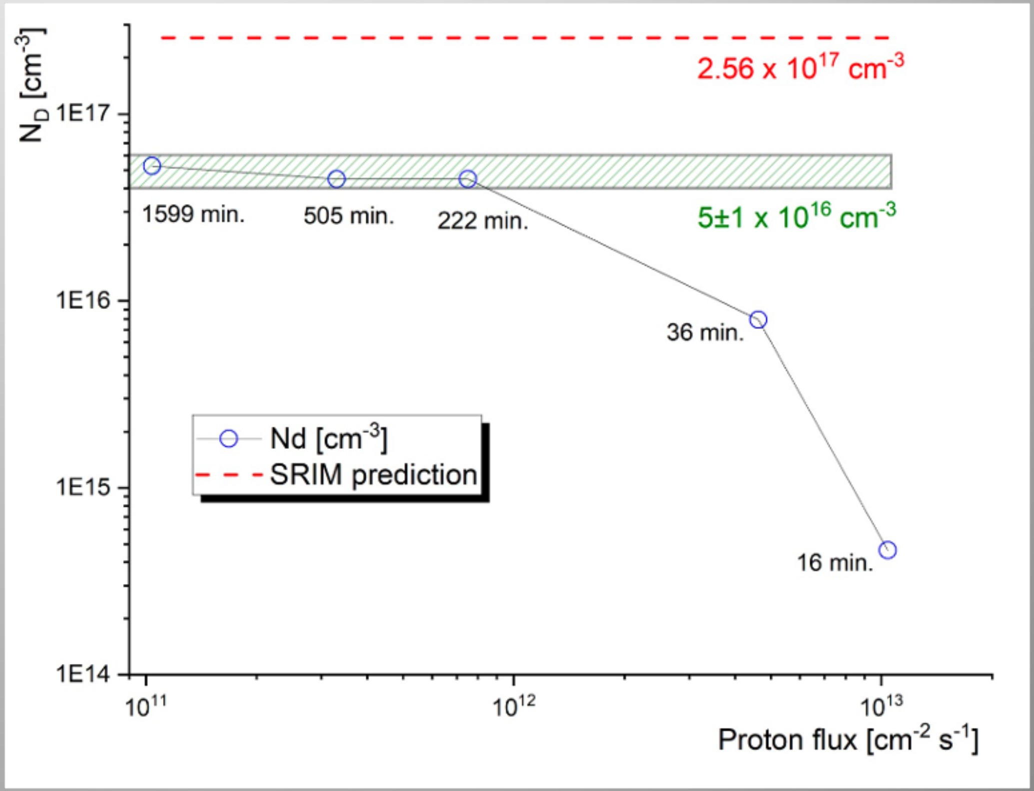




X. Gao, S. Yang, Z. Feng, Radiation Effects of Space Solar Cells, Chapter: High-Efficiency Solar Cells, Volume 190 of the series Springer Series in Materials Science pp 597-622, 2013

How much does flux matter

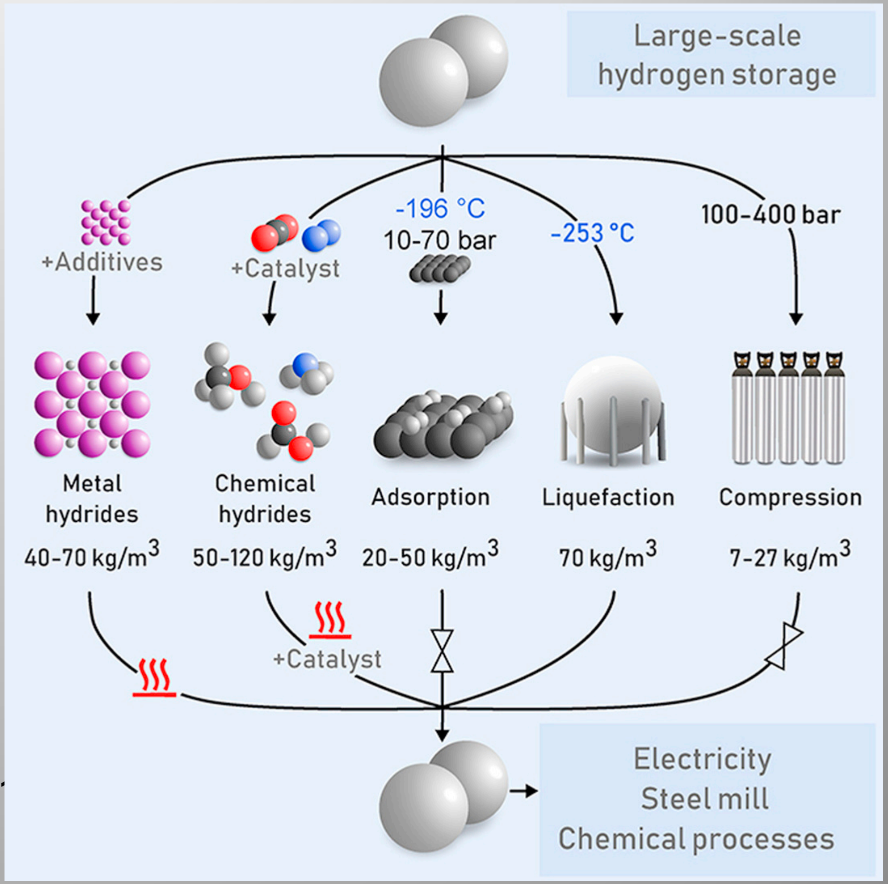
- **Most relevant for Space applications and electronics**
  - **Pilot study on GaAs semiconductor**
  - Investigating irradiation induced vacancies (transmutation happens, but no secondary nuclei)
- **Results**
  - Surviving vacancies lower than predicted
  - Self-annealing apparent
  - Above 10^{12} at.cm^{-2}s^{-1} irradiation annealing dominates
- **Be careful when testing electronics!**



Neuhold et Al. Materials 16 (2023) 1089.

Hydrogen storage & transport

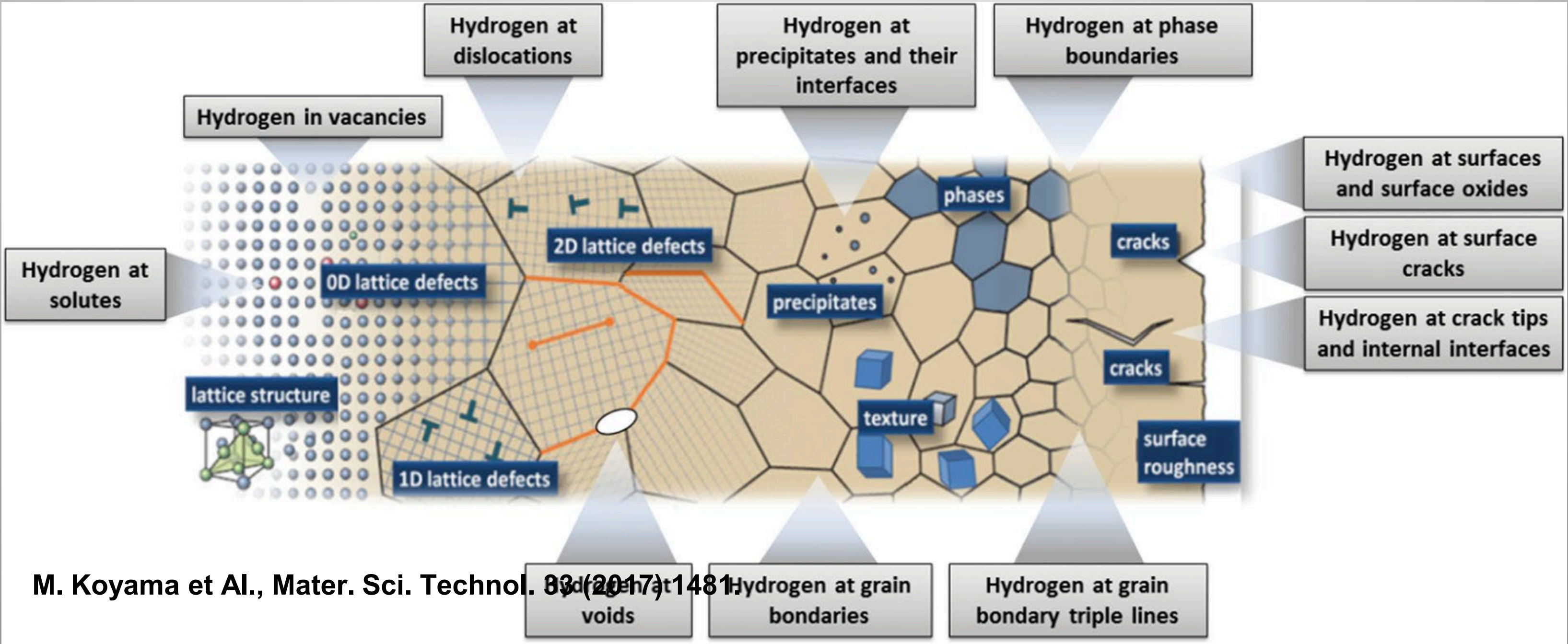
- **Effectivity and safety (of hydrogen storage materials and systems)**



J. Andersson, S. Grönkvist, Int. J. Hydrog. Energy 44 (20

Hydrogen storage & transport

- **Safety of transport systems**
  - **Hydrogen induced cracking (or hydrogen embrittlement)**
  - Atomic hydrogen diffuses into the material and coalesces to bubbles (in steels even methane)



M. Koyama et Al., Mater. Sci. Technol. 33 (2017) 1481.

  - Pipelines more-less OK, dynamically loaded parts (compressors) prone to failure (similar problem in titanium hip-joint replacements)

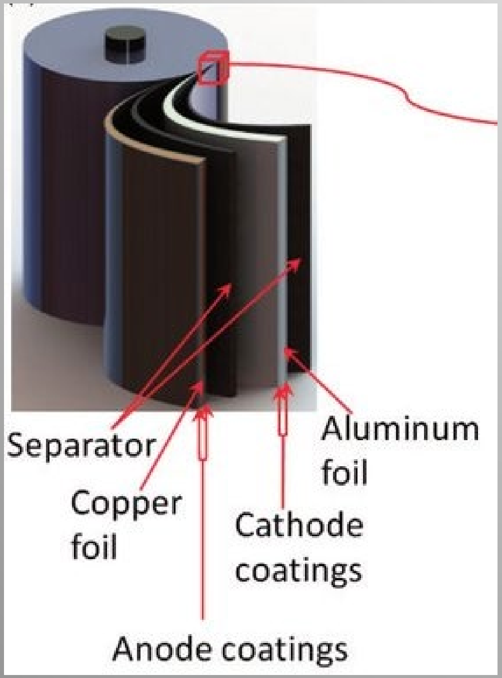
Hydrogen storage & transport

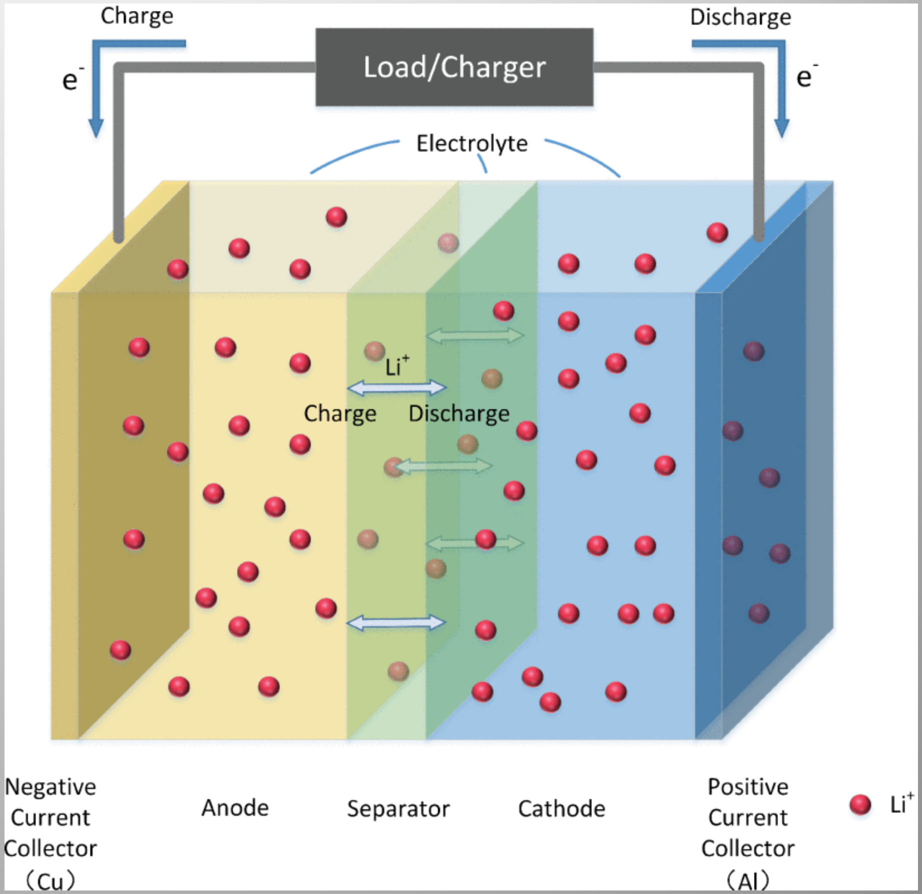
- **Safety of transport systems**
  - **Hydrogen induced cracking (or hydrogen embrittlement)**

P. Adam, R. Bode, M. Groissboeck, Turbomachinery international, Jan. 21 2021

Batteries

- **Li-ion battery**
  - Cathode
  - Anode
  - Electrolyte
  - Separator
  - Li ions physically migrate between them

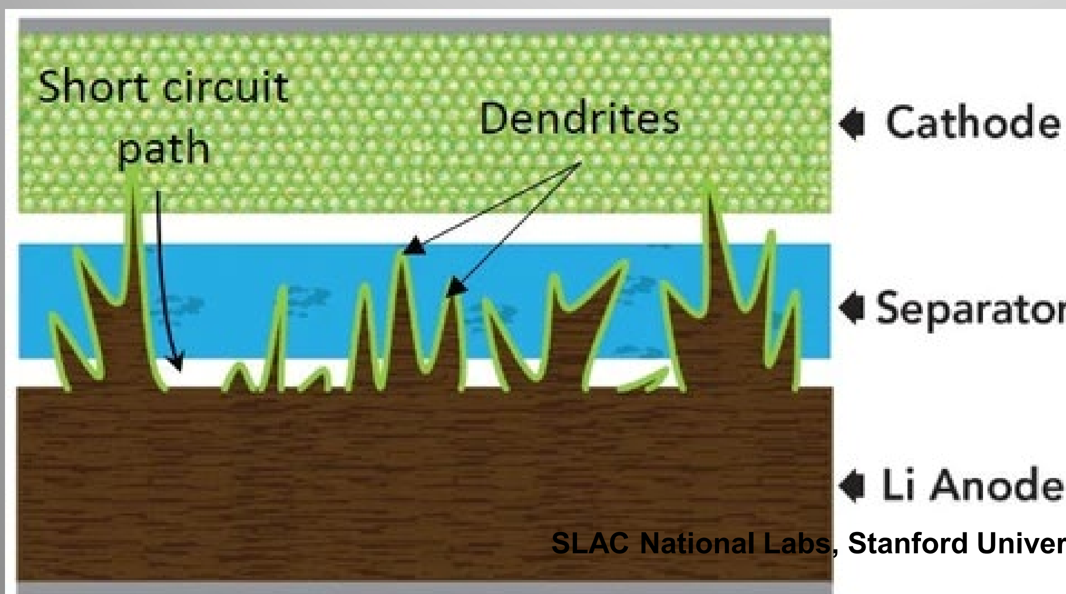


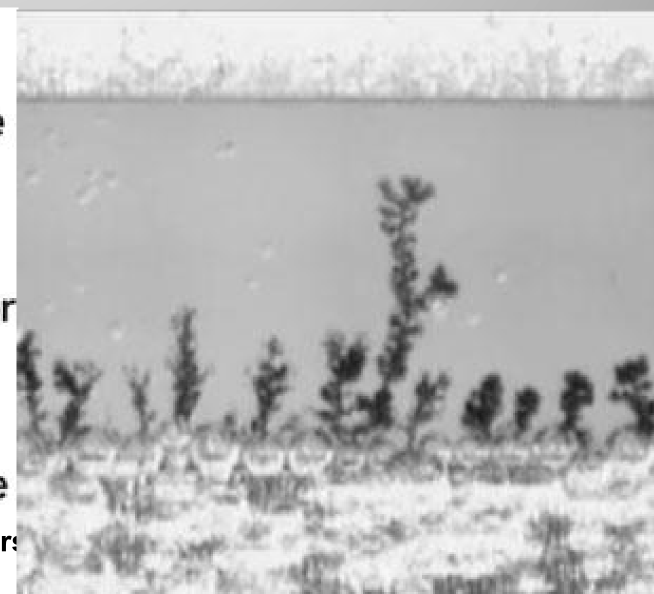


J. Zhang, L. Zhang, F. Sun, Z. Wang, IEEE Access 6 (2018) 23848

Batteries

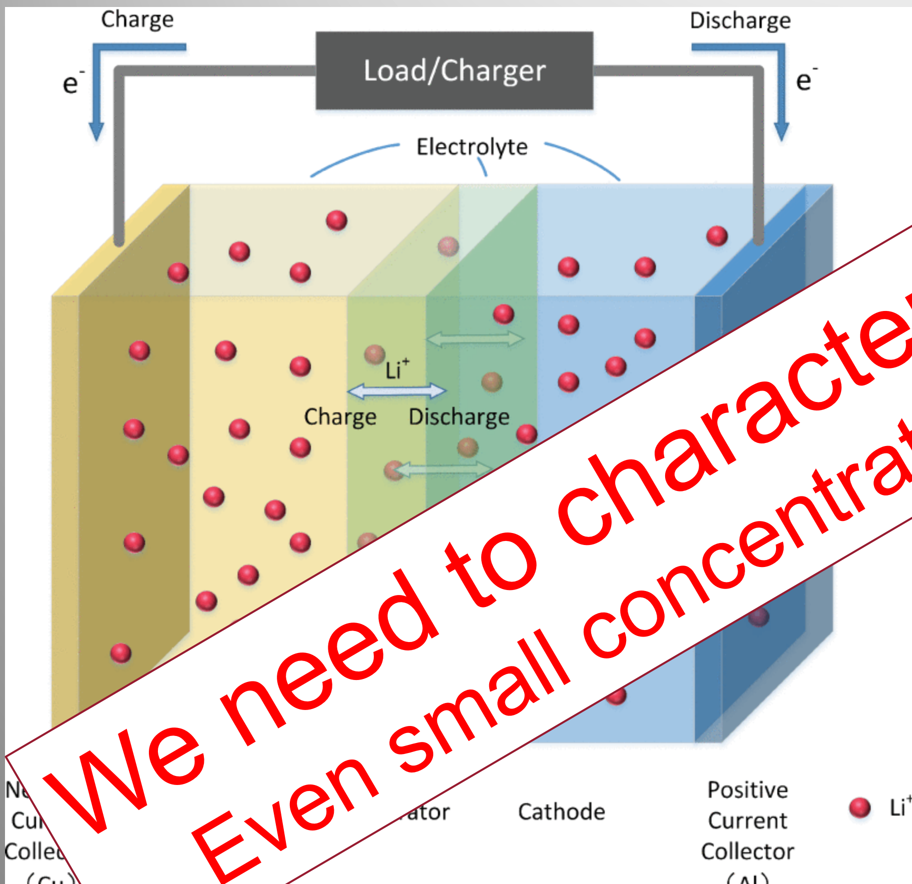
- **Increasing energy density sets more stringent requirements**
  - Efficient resource utilization – Remember the talk of Janusz Tobola
  - Safety
- **The issues**
  - Li is becoming scarce – replacement by Na highly potential
  - New approaches needed for extended lifetimes
  - Dendrite growth causing internal short circuit (Occuring with Li as well as Na)

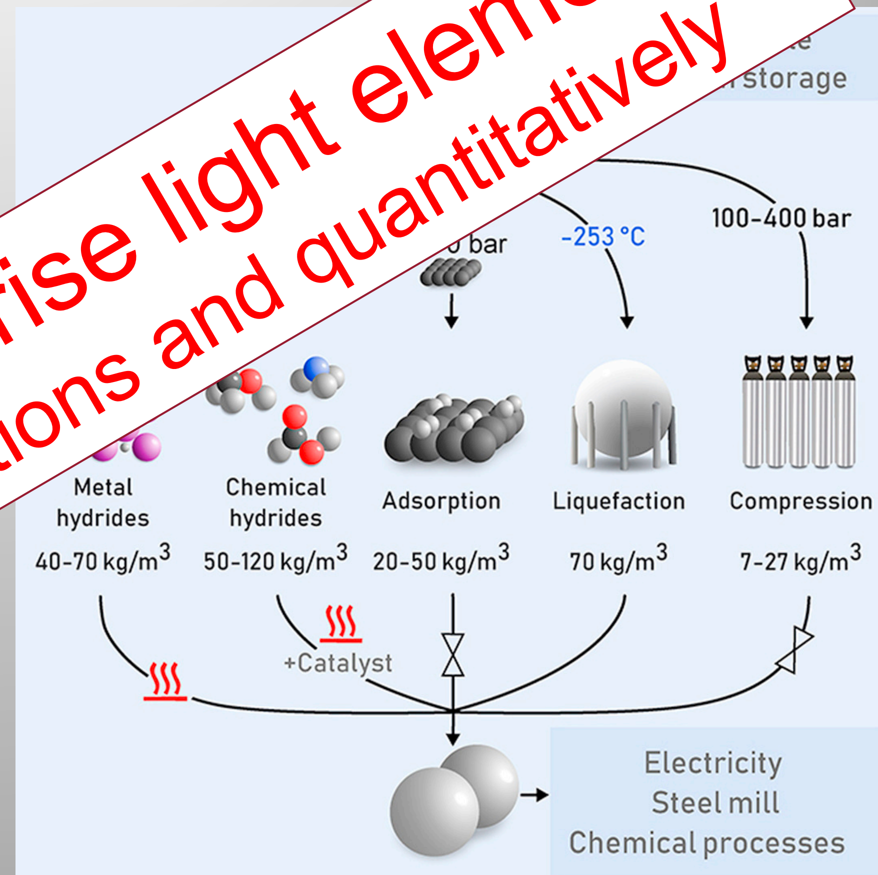




SLAC National Labs, Stanford Univers

Both cases dependent on light element characterisation





We need to characterise light elements

Even small concentrations and quantitatively

Research staff

Senior scientists 4 (full time)

Research staff 4

Technicians 10

PhD students 4

Undergraduates 6

University Technology Incubator

Aiming at supporting start-ups:

- Validating business ideas
- Legal entity formation
- Contacts and connections with industry experts
- Integration into the start-up community
- Networking opportunities with entrepreneurs and investors
- Advantageous lease of office space
- Support service packages
- Education events for the public

European Alliance for Innovation at STU

European Alliance for Innovation at STU – collaborative research community of ICT innovators, promoting research excellence, ICT innovation and education. (operations center)

Aims to ensure the transmission of the results of university science, technology and arts into the economic and social practice

Thank you for your attention!