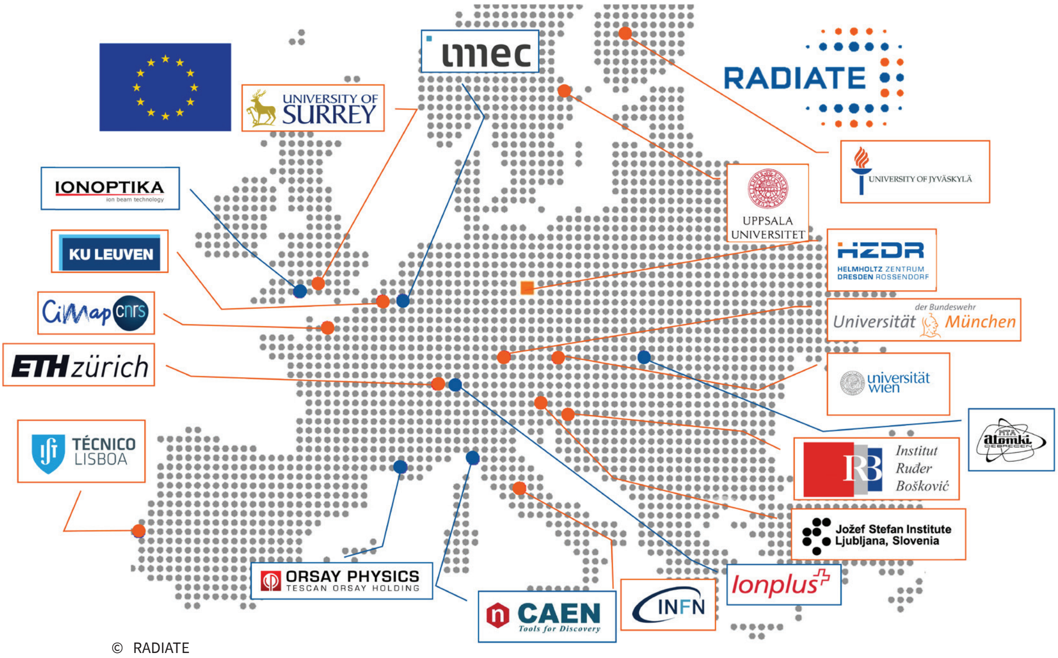
Issue # 5 - August 2021

Newsletter

RADIATE



RADIATE: how far have we come?

Research And Development with Ion Beams – Advancing Technology in Europe (RADIATE) has been running since 2019. At the latest Extraordinary Meeting of the RADIATE General Assembly, which took place in January 2021, the status of the project was discussed.

A total of 151 proposals have been submitted for Transnational Access (TA) since the project's inception. Despite the pandemic, the number of beam hours requested and delivered in 2020 (5040 and 3868, respectively) were not shockingly lower than those recorded in 2019 (4825 and 3864, respectively). This is a testament to all our users and partners who despite the many hurdles imposed by COVID-19, continued to work on their scientific projects. Also relating to TA, the number of facilities offering TA was recently extended to include our newest partner Uppsala University (Sweden) and original partners CIMAP-CNRS (France) and IST (Portugal).

RADIATE's Joint Research Activities (JRA) on topics such as Ion Sources and Beams, Detectors and Electronics and Software and Data Handling continue to successfully progress as reported in previous version of this newsletter.

Despite our best efforts, dissemination and outreach activities have slowed down as a result of the pandemic. Nonetheless, we have hosted two RADIATE schools – one on Ion Beam Analysis methods (held in France in 2019) and another on Ion Beam Modification of Materials (held virtually in 2021).

As we look forward to the future, we hope that RADIATE continues to be a successful and productive project for all our partners and users.

Catia Costa

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NEWSLETTER EDITORIAL

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Uppsala University joins RADIATE

Uppsala University joined the RADIATE project on 1 April 2021 as a full project partner and is supporting the consortium's transnational access activities. The Tandem Laboratory at Uppsala University will provide approximately 600 hours of transnational access.

For more information on Uppsala's facilities see https://www.ionbeamcenters.eu/radiate-uppsala-university/

Graduation!

The University of Surrey was able to host in person graduations for the first time since the pandemic for 2 weeks in July 2021. Matthew Sharpe (Research Assistant at Surrey Ion Beam Centre, working on RADIATE's joint research activities) attended his PhD graduation on the 13th July in Guildford Cathedral, which was originally planned for April 2020. His PhD thesis was titled 'Development of Novel Semiconductor Based Photodetector Devices', supervised by Prof. Stephen Sweeney and Prof. Richard Curry. Measures were still in place to ensure safety, but they didn't detract from the day and it was great to finally be able to celebrate the achievement with family, friends and colleagues after having to wait so long.

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WASP: a modular and reusable software platform for ion beam analysis

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Introduction

The demand for ion beam analysis at imec is increasing year by year. The service at imec is realized by operating a 2MV NEC tandem accelerator with analog control. It is equipped with end-stations for Rutherford backscattering spectrometry and ToF-E heavy ion elastic recoil detection analysis [1]. To improve the productivity, much can be gained by optimizing the data acquisition. A disruptive method to boost the measurement speed and the sensitivity of Rutherford backscattering spectrometry (RBS) is by adopting the multi-detector technology [2]. Yet, the advancement of measurement efficiency is only exploited if the transitioning from one sample to the next is not much slower than the time needed to measure a single sample. Therefore, with the introduction of multi-detector RBS also comes with the need to develop an efficient and integrated data acquisition, sample exchange and goniometer control.

© imec

A modular software framework for the control of measurements at an accelerator was developed at imec and published in 2017 [1]. The essential building blocks of the WASP architecture are the device daemons, each of which controls a single hardware device. The device daemons are designed to act as a service, providing a standardized gateway for requests from the user or supervisory program to the device, and to report the status of the device back to the user. In the first versions of the WASP implementation [1], the communication was maintained through the exchange of files. In the new release, we have developed the original WASP software framework to enable, besides of other flavours of ion beam analysis, also multi-detector RBS. The WASP framework proves to be robust, modular, re-usable and easily adaptable.

WASP: the framework

The WASP toolkit consists of three layers: the device daemons, the middle layer, and the dashboard graphical user interface.

A *device daemon* is developed for each electronic module that has a digital communication interface. At present we have daemons for panel meters, stepper motors, pulse counters, data acquisition boards, pA current meters, etc. In the new release, all daemons have been re-developed to meet a standard structure and documentation. Identical to the earlier design of the framework is that each daemon is configured by a configuration file at startup. The main differences compared to the earlier approach are:

1. The daemons are headless applications
2. The daemons are developed using GCC. It is ensured that the daemons compile and operate well in a Windows and in a LINUX operating system environment.
3. The application programming interface between the daemons and the user or supervisory layer is carried out through http.
4. The daemons are implemented as a RESTful API. The communication format is JSON.

Besides of the daemons a *middle layer* is developed in Python. The middle layer serves two purposes:

1. It gives easy control over the various instruments through well-documented Python functions. The user may import the existing python functions to develop new python functions with custom functionalities.

2. Predefined complex functionalities that involve multiple daemons are developed and available to be imported.

Lastly, a *dashboard webserver* is implemented in Python based on the FastAPI library. The theming used for the dashboard webserver is bootstrap, an open-source JS/CSS library made by twitter. The dashboard allows the user to monitor and control the various daemons in a web-environment. It is also possible via the web-interface to request the documentation which is embedded in the daemon applications.

WASP implementation of multi-detector RBS

At first, we implemented the daemons for the devices that are necessary to execute a multi-detector RBS experiment and to schedule consecutive experiments on the various samples that are on a sample holder. The multiple daemons run independently and continuously in the background; it is considered a micro-services architecture. The following digitally controllable devices are used in our setup for multi-detector Rutherford backscattering spectrometry:

- Multiple AML stepper motor drivers (SMD210) to drive the goniometer
- MOTRONA panel meter (DX350) used as a charge counter and gate
- CAEN digital pulse processor boards (V1725 and V1782) for the data acquisition

Secondly, we developed a middle layer to ease the programming and interfacing with the device daemons using the python scripting language. The middle layer offers a relatively simple set of functions to control the hardware without having to worry about the internals. A few examples of functions used for RBS are shown in Figure 1. The end user can make any combination of activities in a custom python script by calling the basic python functions. The middle layer also offers multiple predefined recipes, for example to perform the full process of

```
f move_aml_both(request_id, url, positions)
f clear_start_motrona_count(request_id, url)
f pause_motrona_count(request_id, url)
f motrona_counting_done(url)
f stop_clear_and_arm_caen_acquisition(request_id, url)
f stop_caen_acquisition(request_id, url)
f get_caen_histogram(base_url, board, channel)
```

Figure 1: An example subset of the functions that are implemented in the middle layer © imec

searching for the channeling direction and to acquire the channeling and rotating-random spectra. Each recipe has an associated JSON representation.

The user may define the sequence of the samples to be analyzed by specifying the recipe and arguments in a list of JSON datasets. The JSON input is verified when uploaded, to avoid errors to happen during the unattended execution. For convenience, we also developed a csv-to-JSON converter to allow that people define the experimental sequence in a spreadsheet programme.

Conclusion and outlook

We present an updated version of the WASP toolkit to facilitate the control of ion beam analysis experiments at an accelerator. The various device daemons on which it builds have been re-developed for the present release. The main advancements are that the daemons are developed as RESTful entities, and that the inter-process communication is caried out over http and the JSON format. On top of the device daemons operates a middle layer which is developed in python. The user can define new scripts in this environment by calling upon existing elementary or advanced scripts, without having to bother about the peculiarities of the hardware devices. Finally, a front-end is made using web technologies. The various components are developed to be Operating System independent.

The WASP toolkit is shown to support the scheduling of unattended multi-detector RBS experiments at imec. For now, it controls the stepper motors of the goniometer and the electronics of the data acquisition. It also ensures the organized archiving of the experimental data.

The WASP framework has a modular and re-usable architecture. Each electronic device is controlled by a micro-service, and therefore instances can dynamically be added or removed without the need for a software restart or re-compilation. Once a device daemon has been created, it can be shared between different institutions and be deployed for different infrastructures. In the middle-layer, the user can build on the available functions and develop more advanced scripts as needed. The python libraries are easily shared between infrastructures. It is hoped that the framework may support the ion beam analysis community by making it easier to realize multi-detector RBS.

Acknowledgments

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References

[1] J. Meersschaut and W. Vandervorst, Nuclear Instruments and Methods in Physics Research B 406 (2017) 25–29

[2] G. Laricchiuta, W. Vandervorst, I. Zyulkov, S. Armini and J. Meersschaut, Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films 36 (2018) 02D407

A study of the formation of isotopically pure ^{28}Si layers using conventional ion implantation

E. Schneider, J. England, L. Antwis, A. Royle, R. Webb, R. Gwilliam

https://doi.org/10.1088/1361-6463/ac0a07

In the article recently published in Journal of Physics D: Applied Physics, researchers from Surrey Ion Beam Centre analysed and modelled historical experiments, carried out in 2016, to determine whether conventional ion implantation could be used to fabricate isotopically pure ^{28}Si layers by implanting directly into a natSi substrate. To be of use to quantum computers, implanted layers must have a high ^{28}Si enrichment and essentially no contamination.

$^{28}Si^+$ implants at 800 eV and 2 keV were carried out into regions of a 100 mm Si wafer using a deceleration method on the Danfysik 1090 Implanter ("DF") at the University of Surrey Ion Beam Centre. The highest Si beam currents possible were achieved by extracting, mass analysing and scanning the beam at 20 keV (for 800 eV) and 26 keV (for 2 keV) followed by an electrostatic deceleration to the final ultra-low energy immediately in front of the wafer. Within 35 hours, fluences of $1.6x10^{17}$ cm^{-2}, $2.2x10^{17}$ cm^{-2}, $3.8x10^{17}$ cm^{-2} were achieved. Implanted substrates were then measured with channelled 1.5 MeV He^+ Rutherford Backscattering Spectroscopy (RBS) on the Surrey Ion Beam Centre's High Voltage Engineering Europe 2MV Tandem Accelerator ("Tandem").

Ultra-low energies (800 eV and 2 keV) were initially chosen to concentrate the ^{28}Si at the surface of the sample, essentially depositing it. However, it was found that, at these ultra-low energies, ^{28}Si ions can easily react with oxygen in the residual (~10^{-6} mbar) vacuum present in the beamline and wafer endstation as the implanted ^{28}Si was heavily oxidised. The 2 keV implant also contained N^{-2} isobar contamination. Channelling revealed that an amorphous Si layer had also build up below the deposited ^{28}Si.

With this unexpected result, the dynamic binary collision approximate modelling program TRIDYN (Dynamic TRIM) was used to model both the 2 keV and 800 eV experiments. 0 keV oxygen was included in the models simulate the vacuum conditions. Modelling showed that 20 keV and 26 keV neutral contamination is what caused the buried amorphous layers to build up below the surface.

To investigate the effect of an improved vacuum, some limited implant tests were performed using the Tandem whose beam line and wafer environment vacuum levels (~10^{-8} mbar) were significantly better than the DF Implanter. As high fluences were not achievable experimentally, TRIDYN was used predict the result of a $4x10^{18}$cm^{-2} 20 keV experiment (Figure 1). It showed that due to self-sputtering, the enrichment is limited at 99.2%. However, this can be avoided by selecting a different ion energy.

The University of Melbourne have demonstrated that high ^{28}Si enrichment and an improvement in the lifetime of P atoms can be achieved using higher energy 45 keV ions to reduce sputtering. Negative ions were also cleverly used to eliminate isobaric interferences. [1]

In conclusion, this study has shown the challenges that arise when using conventional implanters for ^{28}Si enrichment by direct implantation. The authors are now working on a layer exchange enrichment technique with conventional ion implantation to overcome these challenges.

[1] D Holmes, et al., Phys. Rev. Materials, 5, 014601 (2021)

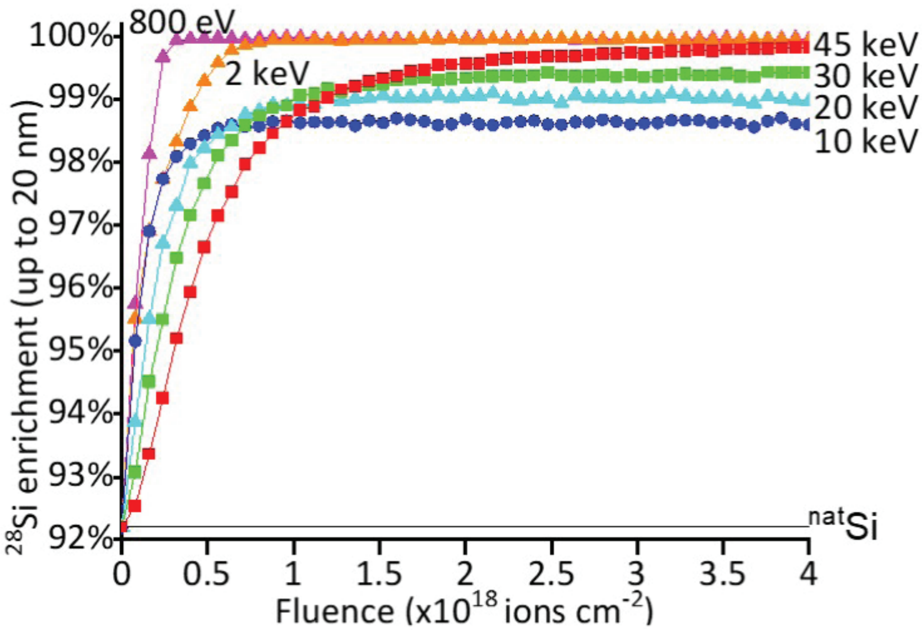


Figure1: ^{28}Si enrichment fraction in a layer 20 nm thick at the surface as a function of fluence for TRIDYN models of the ^{28}Si implants at 800 eV, 2 keV and 20 keV. No oxygen was included in any of these models © University of Surrey

Multiphysics simulations of negatively charged ions in a gas filled rf-quadrupole

Philipp Gaggl, Faculty of Physics – Isotope Physics, University of Vienna, Austria

Ion Laser Interaction Mass Spectrometry (ILIAMS) is a powerful method to eliminate the enormous unwanted background of isobars when measuring very rare radioisotopes by accelerator mass spectrometry (AMS). The first setup of its kind is implemented at the low energy side of the Vienna Environmental Research Accelerator (VERA) at the University of Vienna. Here we present some insight into the simulation model of its centerpiece, the ion cooler for anions. The model was developed within the scope of the Master thesis by Philipp Gaggl (supervised by R. Golser and M. Martschini) with the aim to describe the ion dynamics and the gas flow inside the cooler unit and out of it. It uses COMSOL, a Multiphysics simulations program capable of coupling different fields of physics within a unified model.

By overlapping a beam of negatively charged ions with a laser beam of suitable wavelength the differences in electron affinities between the isotopes of interest and the unwanted isobaric ions (atomic or molecular ions with almost the same mass) can be utilized to selectively suppress the isobars. When the photon energy is chosen right, isobaric background with electron affinity lower than the photon energy gets neutralized via photo detachment whereas the isotopes of interest with higher electron affinity are left unaffected for injection into the subsequent AMS-system. The ion cooler increases the interaction time between photons and ions from microseconds into the range of several milliseconds and thus allows for high detachment efficiencies despite rather low detachment cross sections on the order of 10^{-17} cm^2. It consists of a 950 mm long quadrupole (linear Paul trap) that keeps the ions near the (laser) axis and four guiding electrodes that create a drift field of a few volts per meter to direct the ions towards the extraction side. The cylindrical housing is filled with low pressure buffer gas (typically Helium below 0.1 mbar) to slow down the ions via elastic collisions till they reach near-thermal energies. The electrodes are held in position by six ceramic spacers, equally distributed within the cylindrical tube. A differential pumping system comprising three turbomolecular pumps ensures high vacuum before and after the 3 mm apertures of the cooler unit to avoid ion losses outside the quadrupole region.

Depending on gas pressure and containment geometry one deals with so-called molecular gas flow if the mean free path of the gas particles exceeds the characteristic geometric length of the containment (e.g. the inner diameter of a cylinder; Knudsen criterion). In this regime, the frequency of collisions between particles becomes negligible when compared to particle-wall collisions. One can thus avoid solving the Navier Stokes equations but is limited to rarified-gas situations. COMSOL's Molecular Flow Module calculates (rarified) gas flows and particle distributions by summing up the flux arriving at a particular point from all surfaces in the line of sight.

To assess the proper input parameters an experiment has been performed with He, N_2 and Ar that correlates the measured gas flow into the cooler with the gas pressure measured at the gas inlet (outside of the vacuum vessel). The gas flow data and a very detailed 3D-model of the geometry have been combined into a COMSOL model that calculates stationary solutions of buffer gas pressure, density and flow inside the cooler tube and out of its openings. The results show the importance of including the ceramic spacers within the model, as gas density and pressure change there almost stepwise, see Figures 1, 2. Please also note the significant pressure drop between the inlet (outside of the vessel) and the center of the ion cooler.

Computed and measured pressures immediately above the main vacuum pump agree quite well. For He and N2 the simulated results are lower than experimental values by 8% to 11%. When increasing the mass or the flux of the buffer gas, mean free path lengths decrease and the nature of gas flow may change from molecular flow to so-called transitional flow. Here, the deviations between our simulations (based on molecular flow) and measured values begin to grow, e.g. to about 43% for N2 and 53% for Ar as buffer gas. In the transitional flow regime proper simulations are currently unfeasible due to the immense computational resources required by the respective COMSOL module.

To model the (purely) elastic collisions between ions and buffer gas particles, a variable-hard-sphere model has been applied. Here we replace the constant hard-sphere collision cross section by an

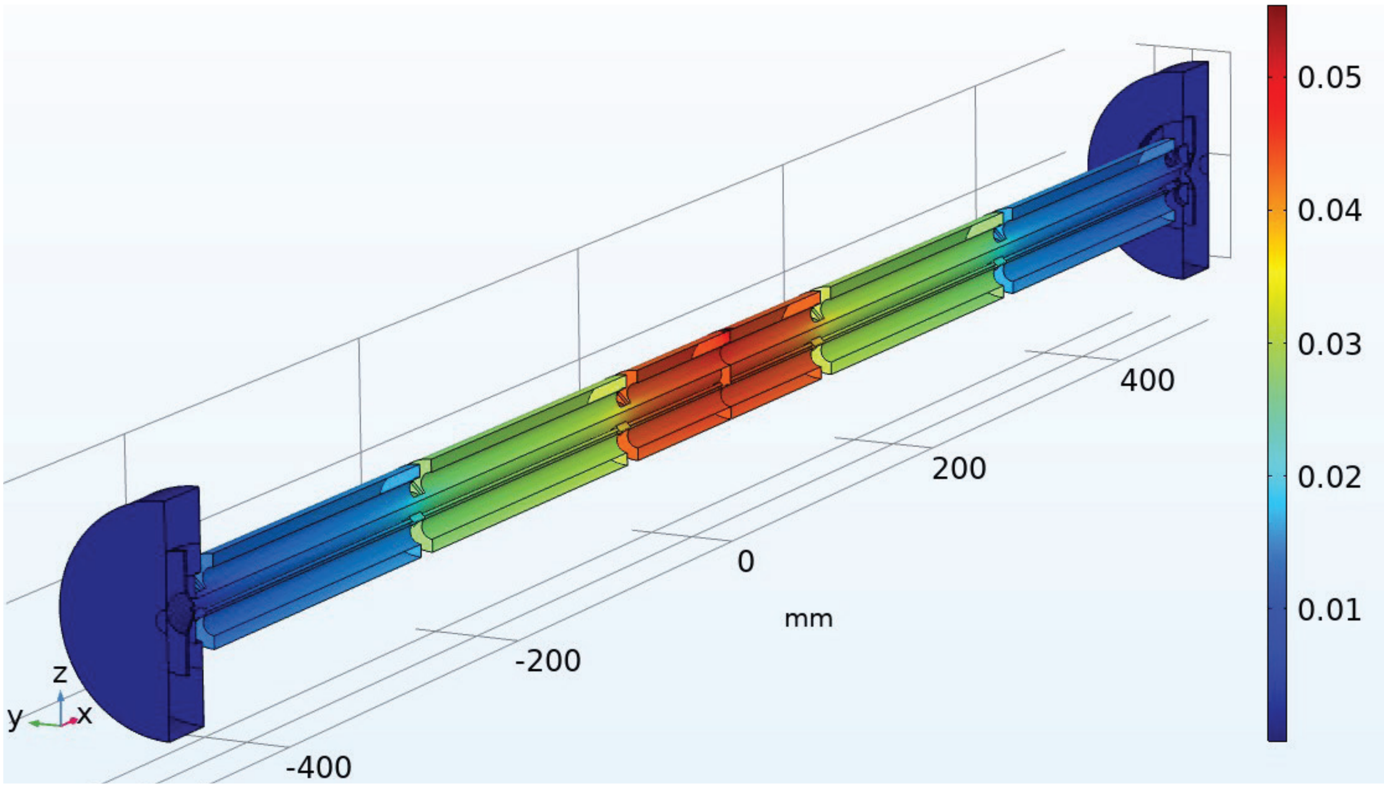


Figure 1: Pressure distribution in mbar along the ion cooler calculated for Helium gas at 0.25 mbar inlet pressure (shown without solid parts). The gas is fed in at 0 mm, and flows out into the pumped volumes at 0.00 mbar (dark-blue) © University of Vienna

energy dependent cross section based on experimental parameters. The computed transit times for $^{63}Cu^-$ anions through the cooler with injection energies of 50 eV and He buffer gas at 0.25 mbar inlet pressure are in the range of 4.5 ms to 18.5 ms with a peak at 9.05 ms. This compares favorably well with our experimental data at low beam currents, e.g. for 32 pA of $^{63}Cu^-$ transit times peak at 8.2 ms. Furthermore, an additional velocity contribution dependent on the inlet pressure and the areal cross section at each position along the cooler axis has been added to the ion motion to study the influence of the directional gas flow towards the cooler openings. These simulations, however, show no significant effect on the ion transit times.

To summarize, a first realistic model of the cooler unit including buffer gas dynamics, applied electric fields and ion-particle collisions shows good agreement with experimental data. Improvements of the model are still ongoing with emphasis on including space charge effects. Our goal is to model both the observed lessening in transmission and the significantly shorter transit times with increasing beam current.

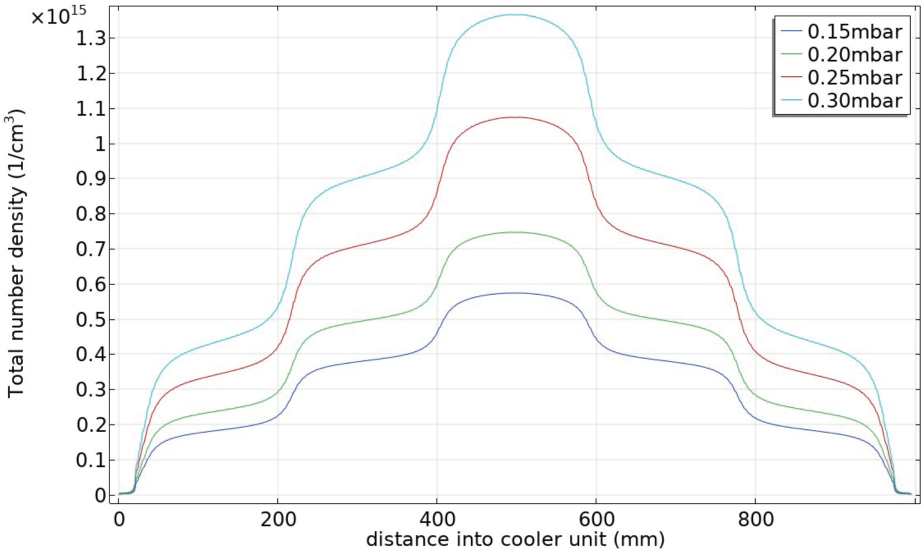
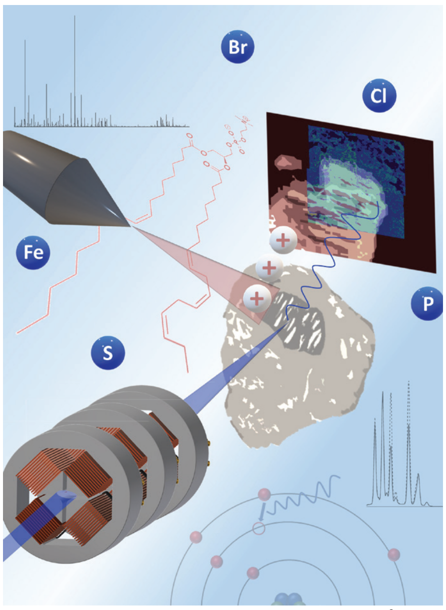


Figure 2: He buffer gas density along the beam axis for different inlet pressures © University of Vienna

Correlative Imaging of Trace Elements and Intact Molecular Species in a Single Tissue Sample at the 50 Micron Scale

Catia Costa, Janella de Jesus, Melanie Bailey, University of Surrey

Article will be soon available online in Analytical Chemistry



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Studying the spatial distribution of elements and molecules is critical in many fields. In biology and medicine, understanding the elemental and molecular landscape of biological samples (e.g. tissue sections) can provide vital information about disease state and ultimately assist in the development and/or improvement of treatments.

Mass spectrometry imaging (MSI) techniques are well-established and documented in the literature for their ability to provide spatially-resolved maps of small metabolites, lipids and even large proteins. Several MSI techniques are commercially available, but desorption electrospray ionisation (DESI) and matrix assisted laser desorption ionisation (MALDI) have become routinely used for molecular mapping of tissue sections. The juxtaposition of Ion Beam Analysis (IBA) with MSI techniques offers a unique approach for multimodal imaging of elemental and molecular markers on biological samples.

In a recent article published in Analytical Chemistry titled 'Correlative Imaging of Trace Elements and Intact Molecular Species in a Single Tissue Sample at the 50 Micron Scale', de Jesus et al. describes the successful sequential analysis of a single tissue sample using MSI and IBA. Using tissue homogenates as a proxy, the article reports on the exploration of compatible sample substrates and on the appropriate workflow for the sequential measurements. No compatible substrate was found for IBA and MALDI, but PET frame slides (Leica) were suitable for successive IBA and DESI mapping experiments. Regarding the order of analysis, the proton beam used for IBA caused loss of intensity of intact lipids, presumably due to ion beam induced fragmentation. Thus, an IBA>DESI workflow is unviable as molecular information is lost. Using DESI first resulted in de-localisation of alkaline metals (e.g. Cl, K). However, elements like Fe and Zn remained undisturbed. Therefore, unless mobile elements are of interest, sequential DESI>IBA measurements can be performed on the same tissue section.

Through RADIATE's transnational access scheme (proposal 19001813-ST), the developed analysis protocol was applied to a tuberculosis (TB)-infected lung section, showing the interrelated distribution of the trace elements, Fe, S and Zn with inflammatory lipid profiles. This is a novel discovery and will help study and understand the inflammatory reactions in a series of diseases like Parkinson's and cancer.

Expansion of Transnational Access from April 2021

RADIATE expanded its transnational access activities in April 2021! Uppsala University (Sweden), IST (Portugal) and CNRS-INSP (France) are now offering beam time through Transnational Access. Additionally, JYU (Finland) is expanding its existing services.

Uppsala University will provide approximately 600 hours of transnational access. Services offered include RBS using multiple RBS-set-ups with options for handling large samples, ToF-ERDA analysis, NRA for high-resolution depth profiling of hydrogen, ToF-MEIS and TOF-LEIS for high-resolution depth profiling, in-situ IBA offering RBS, ERDA, PIXE & NRA in combination with thermal annealing, sputtering, thin film and irradiation station for MeV ions. Deposition and gas exposure

The Ion Beam Laboratory at IST will provide approximately 350 hours to users. Within RADIATE, the IST-IBL will offer the use of analytical techniques, namely, NRA, PIXE, RBS, (including RBS/channelling for structural analysis and lattice site location in single crystal), as well as broad beam ion implantation/irradiation.

INSP's SAFIR offers access to its full range of Ion Beam analysis (RBS, NRA, ERDA, MEIS, PIXE-Kossel, ion channeling), and the associated facilities for thin film growth and thermal treatments under isotopically controlled atmospheres, allowing users not necessarily equipped for isotopic tracing studies to benefit from the proximity of the isotopically specific preparation and analysis facilities available within the infrastructure. INSP will provide 250 hours of TA Access.

Use the QR code to go directly to RADIATE's Transnational Access website

Proposals can be submitted at any time. Find out more about it at https://www.ionbeamcenters.eu/radiate/radiate-transnational-access/

Report on the RADIATE Spring School 2021: Ion Beam Modification of Materials

RADIATE's Spring School 2021 was organised by the Instituto Superior Técnico, Portugal, using an online platform. The school was planned to happen just before the Ion Beam Modification of Materials (IBMM) in July 2020 but due to the pandemic, the conference was ultimately postponed to July 2022. Thus, the school was organised as an online event in the spring of 2021.
The school format and the programme were adjusted to compensate the experimental limitations of these type of presentations. The focus was on Ion-Solid interactions and being online we could invite leading scientists in the field to give tutorials covering the relevant aspects from fundamentals to applications. During the first day the talks focus on the physics underlying Ion-solid interactions including the simulation models, Binary Collisions (BC) and Molecular Dynamics (MD). The last two days were dedicated to explore the most significant applications on doping of semiconductors, production of nanostructures, real time in-situ ion solid interactions and current status of single ion implantation and its future in quantum technologies.

	28 April	29 April	30 April
9:00 - 10:00	Lecture 1 Fundamentals of ion-solid interactions (André Vantomme, KU Leuven)	Lecture 4 Tailoring material properties by ion implantation (Katharina Lorenz, Instituto Superior Técnico)	Lecture 7 Swift Heavy Ion irradiation of materials (Miguel Sequeira, University of Lisbon)
10:00 - 11:15	Lecture 2 Ion and defect distributions: Monte Carlo simulation (Wolfhard Moeller, HZDR)	Lecture 5 Empirical modelling of ion-beam induced damage formation (Elke Wendler, University Friedrich-Schiller Jena)	Lecture 8 Real time studies of ion-solid interactions (Stephen Donnelly, University of Huddersfield)
11:30 - 12:45	Lecture 3 Molecular Dynamics simulation of Ion-solid interactions (Flyura Djurabekova)	Lecture 6 Waveguide engineering by ion beams (José Olivares, Universidad Autónoma de Madrid)	Lecture 9 Towards Single Ion Implantation (Roger Webb, University of Surrey)

The Spring School was attended by ~ 48 participants from 16 countries. A large majority were PhD students (34 participants) , seven post Doc and 5 MSc. In addition, several senior researchers dropped in and out to attended particular tutorials.

Additional information about the school can be found at https://www.ionbeamcenters.eu/radiate/training/radiate-summer-school/spring-school-2021/

Summer School 2021 applications now welcome!

RADIATE is already planning its next virtual summer school since in-person meetings are still very difficult to organize. Organized by the University of Jyväskylä, the school focuses on Ion Beam Applications to Nanostructures.
Three half-days of lectures are planned to take place from 8-10 September 2021. Interested students (and others) can register for the school until 1 September. For the full program and registration form, visit

https://www.ionbeamcenters.eu/radiate/training/radiate-summer-school/

Mamour Sall joined the CIMAP laboratory in Caen, Normandy in December 2020 as a permanent researcher in the MADIR team (Materials, Defects, Irradiation). He has worked for more than 10 years in the field of ion / matter interaction for fundamental and applied research. He studied the modifications of different materials (III-N semiconductors, metallic multilayers for nuclear applications, magnetic stacks for MRAM applications, etc.) under ion irradiation in both electronic excitation regime and nuclear collision regime, as well as their synergy. He is an expert in transmission electron microscopy, which is the main technique he has used for the characterization of irradiation defects.

He joined the MADIR team to strengthen activities related to the study of structural and microstructural modifications of inorganic materials under irradiation. He also participates in the MADIR team's mission to welcome interdisciplinary research with GANIL beams and will be an active member of our user facility.

M.C. Sequeira is the newer researcher of the Material Processing and Characterization group at IST. He recently finished his PhD thesis on the effects of Swift Heavy Ions on group-III nitrides semiconductors. Aimed at understanding this interaction, he has been combining Two Temperature Model – Molecular Simulations (TTM-MD) and experimental techniques such as Ion Beam Analysis, X-Ray Analysis or Transmission Electron Microscopy. By performing virtual simulations of such experiments on the TTM-MD cells, he showed that the model could describe the interaction with remarkable precision, resulting in an improved understanding of its dynamics at timescales inaccessible in the laboratory.

Mauricio Rodriguez came to the Laboratory for ion beam interactions at Ruđer Bošković Institute (RBI) in 2019 as a postdoc researcher before joining RADIATE in April this year. Mauricio obtained his M.Sc. in Physics from the University of Seville, Spain. In addition, he obtained his PhD diploma in Physics from the same university and during his PhD he worked in the characterization of scintillator-based ion detectors for diagnostic in nuclear fusion devices. He had worked at the National Accelerator Centre (CNA) in Seville and at the Max Planck Institute for Plasma Physics (IPP) in Munich. He further continued his research as a postdoctoral researcher at the same institution on the study of semiconductor detectors using the ion beam induced charge (IBIC) technique. Mauricio's most recent work revolved around the effects of irradiation with focused ions on the study and characterization of nuclear diamond detectors, exploring in particular the polarization phenomena in diamond samples. For RADIATE, he will be focused on the development of the single-ion detection technique and the characterization/application of the high-resolution PIXE detector.

Joint Research Activities

WP21 - Self-powered proton detectors based on GaN core-shell p-n microwires

D. Verheij, M. Peres, S. Cardoso, L. C. Alves, E. Alves, C. Durand, J. Eymery, J. Fernandes, K. Lorenz

https://doi.org/10.1063/5.0045050

GaN and related III-nitride semiconductors are considered for the next generation of high power and high frequency electronics. Furthermore, these semiconductors revealed extraordinary thermal, chemical and radiation resistance making them ideally suited for applications in extreme environments such as space. The same properties are also interesting for the development of particle detectors and radiation sensors. Moreover, the wide bandgap allows the incorporation of optically active dopants and defects, interesting for quantum applications such as single photon emitters and quantum sensors. If the radiation sensor is embedded in the semiconductor matrix (a so-called active substrate) it allows the detection of implanted ions in real time.

In the joined research activity Detectors and Electronics (WP21), the Radiate consortium investigates novel wide bandgap materials such as diamond, Ga_2O_3, and GaN as radiation sensors. Here, we report on the fabrication and characterisation of radiation sensors based on GaN core/shell p-n junction microwires. With their small size, high resistance to radiation and high crystalline quality, GaN microwires constitute highly interesting building blocks for radiation-hard devices. Through microfabrication steps, single-wire devices were processed with leakage currents as low as 1 pA in reverse bias. A scanning electron microscopy image of such a device is shown in Fig. 1. Irradiation with both UV light and protons results in photo/ionocurrent signals several orders of magnitude above the dark current and response times below 30 ms.
Fig. 2 shows transient measurements of the ionocurrent induced by 2 MeV proton irradiation for different biases. Interestingly, the device works in photovoltaic mode without any externally applied bias and it shows good resistance to radiation. Self-powered particle detectors have the potential to offer exceptional flexibility and compactness in applications where size limits and low power consumption are key requisites.

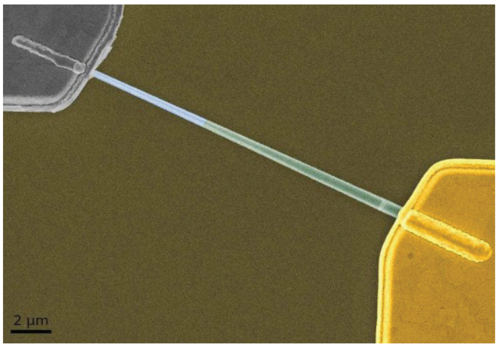

Figure 1: Scanning electron microscopy image of a single p-n-junction microwire device. © IST

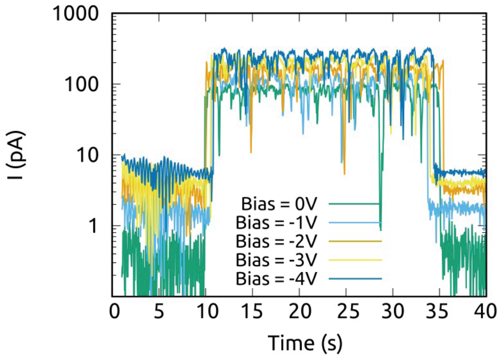

Figure 2: Transient ionocurrent measurements for irradiation with 2 MeV protons for different applied biases. © IST

Conference Report

IAEA quantum workshop

by Ella B Schneider

On 4 - May 2021, the International Atomic Energy Agency (IAEA) held a virtual training workshop on “Ion Beam Driven Materials Engineering: New Roles for Accelerators for Quantum Technologies,” aiming to provide early career researchers and PhD students with knowledge on the latest technological developments to engineer new material properties with ion beams, with a specific focus on novel detector applications using quantum technologies.
Amongst 70 delegates from 20 countries across the globe, I was very excited to attend this workshop (from the UK) and learn from world experts; the topics were very relevant to my PhD, which is on using ion implantation with layer exchange to enrich ^{28}Si for quantum computers.
Across the four days, a series of though-provoking lectures were given by David Jamieson (University of Melbourne). In the opening lecture, he introduced the, “quantum revolutions.” In the first quantum revolution, quantum physics was used to explain how the world behaves which has shaped modern technology developed in the 20th century. In the second quantum revolution (which we are currently in the middle of) we will engineer our own quantum systems for new technology and capabilities. The subsequent lectures covered essential physical principles for solid-state quantum technology and how ion beams are being used to enable it.
Roger Webb (Surrey Ion Beam Centre) gave an interesting talk on the motivations and statistics of deterministic ion implantation, how SIMPLE (Surrey’s single ion implanter) works and discussed ^{28}Si enrichment with ion implantation. Other interesting talks included Thomas Schenkel’s (Lawrence Berkley National Laboratory) on cutting-edge laser plasma accelerators and exotic qubits; Takeshi Ohsima’s (Japanese National Institutes for Quantum and Radiological Science and Technology) on Quantum sensing based on colour centre in wide bandgap semiconductors; and Paolo Olivero’s (University of Turin) on single photon sources for quantum communication in a safe global network. Andre Schleife (University of Illinois) and Flyura Djurabekova (University of Helsinki) also gave excellent lectures on computational modelling of materials and ion beam interactions.
Presenting my work in a virtual poster session on GatherTown (a platform where your avatar can walk around a virtual room) was a fun experience and the closest to a real-life poster session that I have experienced since the beginning of UK lock-down.
Overall, the workshop was a success and a very valuable experience. Some delegates even stayed up through the night to attend lectures. I have learnt a huge amount about a wide range of quantum technologies, their applications, and ion beams, which has given me knowledge and motivation for my own work. For me, it was particularly interesting to hear about the University of Melbourne’s ^{28}Si enrichment method that uses direct ion implantation. The workshop has resulted in a University of Surrey/ University of Melbourne collaboration, so it’s been very beneficial for building up connections.

RADIATE Summer School

The RADIATE Virtual Summer School 2021 on Ion Beam Applications to Nanostructures will take place on Zoom from 8-10 September 2021 and is organized by the University of Jyväskylä. The school will be spread over three days of half-day lectures from 9 am to 1 pm CET. Registration is open until 1 September. There is no participation fee. More information on the Summer School program can be found here: https://www.ionbeamcenters.eu/radiate/training/radiate-summer-school

	8 September	9 September	10 September
9:00 - 10:00	**Introduction to ion interaction with nanostructures** Richard Wilhelm, *Institute of Applied Physics, TU Wien, Austria*	**Probing 3D nanostructures buried in modern electronics devices** Claudia Fleischmann, *imec / KU Leuven, Belgium*	**Nanostructure formation by strong electronic excitations from slow highly charged ions and swift heavy ions** Richard Wilhelm, *TU Wien, Austria*
10:00 - 11:00	**Periodic patterning on the nanoscale by ion beam irradiation** Stefan Facsko, *HZDR, Germany*	**3D nanostructure fabrication by means of MeV proton beams (and other techniques)** István Rajta, *MTA Atomki, Hungary*	**Single ion implantation and qubits** Juha Muhonen, *University of Jyväskylä, Finland*
11:15 - 12:15	**Simulations of irradiation-induced effects in 2D materials** Arkady Krasheninnikov, *HZDR, Germany*	**Modelling of single ion effects on buried nanostructures** Flyura Djurabekova, *University of Helsinki, Finland*	**Nanopatterning and characterization by means of focused ion beams** Gregor Hlawacek, *HZDR, Germany*
12:15 - 13:15		**3D nanostructures analyzed by means of RBS** Johan Meersschaut, *imec, Belgium*	Final words and closing Timo Sajavaara, *University of Jyväskylä, Finland*

Conferences

- 25th International Conference on Ion Surface Interactions (ISI-2021) to be held in Yaroslavl, Russia, is planned as "hybrid" conference, with local and remote attendees. 23rd-27th August 2021. See http://project3329204.tilda.ws/con
- Geochronology Summer School On Dating Techniques In Environmental Research will be held in Zurich, Switzerland. 29th August-3rd September. See https://www.geo.uzh.ch/en/units/gch/geochronologysummerschool.html
- Applied Nuclear Physics (ANP) conference to be held in Prague, Czech Republic will take place in hybrid form, providing with local and remote attendees. 12-17th September. See https://www.anpc2021.cz/
- Joint EuFN and COST action FIT4NANO workshop will take place in Vienna, Austria. 27th-29th September 2021. See https://www.eu-f-n.org/eufn-and-fit4nano/
- 25th International Conference on Ion Beam Analysis & 17th International Conference on Particle Induce X-ray Emission & International Conference on Secondary Ion Mass Spectrometry will be held virtually. 11th-15th October 2021. See http://iba2021.iopconfs.org/home
- 15th International Conference on Accelerator Mass Spectrometry (AMS-15) will take place virtually. 15th-19th November 2021. See http://www.ams15sydney.com/
- 4th International Conference on Radiation and Emission in Materials (ICREM-4) is planned to run 15th-18th December 2021 in Thailand. See http://www.nano.kmitl.ac.th/icrem2021/
- 23rd International Conference on Secondary Ion Mass Spectrometry (SIMS23) has been postponed and will now take place in Minneapolis, USA from 18-23 September 2022. See https://sims23.avs.org/
- 23rd International Conference on Ion Implantation Technology (IIT) (postponed from 2020) is planned to take place 25th-29th September 2022 in San Diego, USA. See https://www.mrs.org/iit2021
- 26th Conference on Applications of Accelerators in Research and Industry (CAARI) & the 52nd Symposium of North Eastern Accelerator Personnel (SNEAP) scheduled to take place in Denton, Texas, USA, from 30 October to 2 November 2022. See https://caari-sneap.com/

Sign up for the RADIATE newsletter here:
https://www.ionbeamcenters.eu/radiate/radiate-newsletter/

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