



Relatorio de actividades

2018 - 2020

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1. Research activities

1.1 Overview of research and related activities 2018-2020:

From 1.9.2017-30.5.2018 I was on sabbatical leave from IST as Guest Professor at Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium. A detailed report on this sabbatical has been presented to DECN on 28.11.2018.

From 1.1.2019-31.12.2019 I took unpaid leave from IST, acting as Guest Professor with a Senior Fellowship at Instituut voor Kern- en Stralingsfysica (later at Quantum Solid State Physics group), KU Leuven, Belgium.

This activity report covers also these time periods during which my research activities were still closely related to IST and I continued to act as supervisor of two PhD students from IST.

During 2018-2020 my activities have been centered on two topics:

a) Emission channeling lattice location experiments with radioactive isotopes at the ISOLDE/CERN facility, which occupied ~80% of my time;

b) New systems and analysis methods for position-sensitive detection of ion beam and electron channeling (~20%).

Activity line a) was performed within the “Emission Channeling lattice location experiments with Short-Lived Isotopes” (EC-SLI) collaboration, which at the end of 2020 integrated 3 members from IST (Investigador Principal Dr. João Guilherme Correia, our former PhD student Dr. Eric Bosne, and myself), 1 member from Durban University of Technology in South Africa (Prof. Krish Bharuth-Ram), 1 member from CERN-TE (Dr. Ângelo Costa), 1 member from CICECO Universidade de Aveiro (retired Prof. M.R. da Silva), as well as 4 members from KU Leuven in Belgium (Prof. Lino Pereira, Prof. André Vantomme, Dr. Malven Tunhuma, and the PhD student Janni Moens).

Experimental work on this activity line involving beam times of radioactive isotopes was only possible until November 2018, when CERN entered its Long Shutdown 2 (LS2) for the major upgrade of the LHC, which was planned to last until April 2021, currently foreseen to be prolonged until June 2021, due to the Corona virus pandemic.

Until May 2020 the EC-SLI collaboration had two CERN experiments active: IS634 “Emission channeling with short-lived isotopes (EC-SLI) of acceptor dopants in nitride semiconductors”, and IS648 “Emission Channeling with Short-Lived Isotopes: sublattice displacement in multiferroic Rashba semiconductors”, for both of which L. Pereira and myself were jointly spokespersons. Both experiments were brought to a successful conclusion in 2020.

The task of the CERN experiments spokesperson is to prepare and defend the experimental proposals towards the ISOLDE program committee INTC, to negotiate the scheduling of beam time with the ISOLDE technical coordinator at the beginning of each year, and generally to represent the experiment in all organizational matters towards CERN. Since 2013 I have also acted as team leader of all IST scientists performing experiments at ISOLDE. As team leader

my task is the exchange of information with CERN on administrative matters concerning the team members, and in particular assuring that all of them are aware of CERN staff and safety rules and procedures.

Besides finishing work on a book chapter [B1] co-authored together with L. Pereira and A. Vantomme from the Quantum Solid State Physics group, one of the goals of my stay at KU Leuven in 2019 was to develop new strategies for future emission channeling and related experiments with radioactive probes at ISOLDE, with the potential for large scientific impact. In that respect, we identified two major fields of work for the future. The first concerns the study of quantum colour centers in diamond. In that respect it was possible to use already available data on the lattice location of ^{121}Sn ($t_{1/2}=27$ h) implanted in diamond and combine it with photoluminescence measurements on $^{121\text{m}}\text{Sn}$ (55 y), which showed the formation of SnV complexes in the so-called “split-vacancy configuration” and related luminescence with exceptionally narrow linewidth. This has resulted in a publication in Phys. Rev. Lett. [P7] and a number of conference contributions [C6, C15, C16, C17, C19]. A scientific proposal on “Quantum colour centers in diamond studied by emission channeling with short-lived isotopes (EC-SLI) and radiotracer photoluminescence”, with myself and L. Pereira as spokespersons, was accepted by INTC as CERN experiment IS668 on 25.6.2020. This experiment will be the workhorse of our future ISOLDE activities, with collaborators from IST, QSP-KU Leuven, CICECO Aveiro, CERN, and the universities of Torino in Italy and Warwick in the UK.

The second major topic to be followed in future ISOLDE experiments, will be ^{229}Th implanted into CaF_2 as a possible system for the realization of nuclear clocks. The ^{229}Th nucleus can be excited to a nuclear isomer state with extremely low energy (8.1 eV), within the range of current laser technologies, which makes it an ideal candidate for optical resonant nuclear clock applications. With two decay channels towards the ground state, the ^{229}Th isomer decays either by photon emission ($t_{1/2}=10^3$ - 10^4 s) or through internal conversion (IC, $t_{1/2}=7$ μs) that dominates over the photon decay channel due to the much shorter half-life. The radiative decay of the isomer can only be studied when the IC channel is blocked, i.e. when there will be no electrons available for the IC process to occur. According to theoretical predictions, this can be achieved by inserting ^{229}Th atoms into a CaF_2 crystal. If thorium occupies substitutional Ca sites, the isomer’s impurity energy level is located within the band gap of CaF_2 and no electronic states are available at the isomer energy, hence IC is not possible. In Nov. 2018 experiments were performed at ISOLDE using laser ionized beams of actinium feeding the ^{229}Th isomer state. First results were published [P4], presented at conferences [C4, C18, C19, C20], and originated a new proposal fully approved by INTC on 25.6.2020 as CERN experiment IS658 “Study of the radiative decay of the low-energy isomer in ^{229}Th ”. This work is performed in collaboration with the nuclear physics group of P. van Duppen of IKS Leuven, who also acts as spokesperson of IS658.

Besides the scientific leadership as CERN experiment spokesperson, I have been engaged in active participation in beam times at ISOLDE, supervision of experiments with long-lived isotopes at ISOLDE using remote access, the simulation of emission channeling data by means of quantum-mechanical “manybeam” calculations using CERN’s computing facilities, data analysis and publication of results for specific samples, and also the training and supervision of students.

With regards to the last aspect, the PhD thesis of Ângelo Costa (IST) on “Lattice location of impurities in silicon carbide” [T1] was successfully concluded on 5.6.2018, the one of Tiago Lima (KU Leuven) on “Local structure of Mn-doped ferromagnetic semiconductors” [T2] on 12.9.2019, and the one of Eric Bosne on “Emission channeling lattice location studies in semiconductors using highly pixellated TimePix detectors” [T3] on 14.10.2020. Currently ongoing theses where I act as promotor or co-supervisor are since June 2018 Janni Moens (PhD,

KU Leuven) on “Investigating the local structure of Th dopants in CaF_2 ” [T4], and since October 2020 Afonso Lamelas (Masters, Faculdade de Ciências da Universidade de Aveiro) on “Centros de cor quânticos em diamante (Quantum colour centers in diamond)” [T5].

In 2018 the EC-SLI collaboration performed 4 successful on-line beam times with the radioactive isotopes ^{27}Mg , ^{11}Be , ^{56}Mn , and ^{229}Ac at ISOLDE, usually with 7-9 participants from the different institutes, among those 3-4 from IST. I have attended all of the runs [W1, W3, W4, W5]. The results achieved during the ^{229}Ac beam time in Nov. 2018 have already been described above.

A major effort was dedicated to determining the lattice location of the short-lived radioactive probes ^{27}Mg ($t_{1/2}=9.5$ min) and ^{11}Be (13 s) in the nitride semiconductor GaN, for which beam times were undertaken in May 2018 [W1] and September 2018 [W4]. The ^{27}Mg run fully confirmed our earlier results [U. Wahl *et al*, PRL 118 (2017) 095501] that Mg acts as an amphoteric dopant in GaN, i.e. ^{27}Mg not only occupies substitutional Ga sites but also interstitial positions, with the interstitial fraction being highest in *p*-type and lowest in *n*-type GaN. Moreover, it was possible to measure the lattice location preference of implanted ^{27}Mg in GaN over four decades of implanted fluence, ranging from $5 \times 10^{10} \text{ cm}^{-2}$ to $5 \times 10^{14} \text{ cm}^{-2}$. For the technologically relevant fluence regime around 10^{14} cm^{-2} , we found that the fraction of implanted Mg that remains on interstitial sites is at maximum a few per cent, which is an encouraging result since it shows that the large majority of Mg is incorporated on electrically active Ga sites. For ^{11}Be , it was found to behave in a similar way as ^{27}Mg , only the interstitial fractions were considerably higher, confirming theoretical predictions that the Be dopant suffers to a larger extent from self-compensation than Mg. The work on Mg and Be has already led to several conference contributions [C1, C2, C8, C13], workgroup seminar presentations [S1, S2], and internal reports [O1, O2] A major publication aimed at the high impact journal “Advanced Electronic Materials” is on its way [P10].

The beam time with ^{56}Mn (2.6 h) took place in Sept. 2018 [W4] and concluded the lattice location studies of implanted Mn in the Multiferroic Rashba Semiconductors (MUFERS) GeTe, GeMnTe, and PbTe. In MUFERS, ferroelectricity and its coupling to ferromagnetism are intrinsically related to a rhombohedral distortion and a displacement between cation and anion sublattices, which breaks crystal inversion symmetry. We were able to establish the local structure of the Mn sublattice in (Ge,Mn)Te with Mn concentration up to 21%, and observed a smaller displacement for the Mn sublattice than for the host Ge sublattice. Besides being one of the topics of the PhD thesis of T. Lima, the results were presented at two conferences [C7, C12].

Within activity line b) “New systems and analysis methods for position-sensitive detection of ion beam and electron channeling”, the PhD thesis of Eric Bosne was successfully concluded in Oct. 2020, as was already mentioned. In this thesis, a highly pixelated Timepix-quad detector developed by the Medipix collaboration based at CERN was studied with the aim of using it as a replacement for the pad detectors that are currently applied in EC experiments. The Timepix detector causes a large increase in details of measured channeling patterns due to its array of 512×512 pixels with $55 \times 55 \mu\text{m}^2$ area each, much finer than the one of the pad detector composed of 22×22 pixels with $1.3 \times 1.3 \text{ mm}^2$ area. However, due to the large number of small pixels, the number of events/pixel is drastically reduced, which required the development of a new fitting software, PyFDD, that can use a chi-square or a maximum likelihood parameter optimization and has proven essential for fitting patterns with a low number of counts per pixel. The results yielded two publications [P6, P9] and two conference presentations [C11, C14], and the PyFDD software was made publicly available in June 2019.

1.2 Work visits:

- W1** 3.-11.5.2018: CERN stay for ^{27}Mg beam time of experiment IS634 at the ISOLDE facility.
- W2** 6.6.2018: Participation in the Prisma Strategy Meeting on the “Use of large scale facilities for condensed matter research”, Bundesministerium für Bildung und Forschung (BMBF, German Federal Ministry for Education and Research), Bonn, Germany.
- W3** 1.-7.9.2018: CERN stay for ^{11}Be beam time of experiment IS634 at the ISOLDE facility.
- W4** 10.-17.9.2018: CERN stay for ^{56}Mn beam time of experiment IS648 at the ISOLDE facility.
- W5** 6.-13.11.2018: CERN stay for ^{229}Ac beam time of experiment LOI198 at the ISOLDE facility and attendance of INTC meeting.
- W6** 3.-7.12.2018: CERN stay for ISOLDE Workshop participation.
- W7** 2.-6.12.2019: CERN stay for ISOLDE Workshop participation.

2. Research projects

2.1 Participation in research projects:

1.7.2018–31.12.2020: Participating scientist (50%) in the research project CERN/FIS-PAR/0005/2017 on “Portugal at ISOLDE: Materials and Nuclear Physics Research with Radioactive Isotopes and Techniques”, principal investigator J.G. Correia, funded by FCT with € 170000.

1.1.2021– anticipated 31.12.2022: Participating scientist (50%) in the research project CERN/FIS-TEC/0003/2019 on “Material’s Research with Radioactive Isotopes and Nuclear Techniques at ISOLDE-CERN”, principal investigator J.G. Correia, funded by FCT with € 170000.

2.2 CERN collaborations:

CE1 CERN experiment IS580: “Emission Channeling with Short-Lived Isotopes: lattice location of impurities in semiconductors and oxides”,
L.M.C. Pereira (spokesperson), L.M. Amorim, J.P. Araújo, V. Augustyns, K. Bharuth-Ram, E. Bosne, J.G. Correia, A. Costa, P. Miranda, D.J. Silva, M.R. da Silva, K. Temst, A. Vantomme, and U. Wahl,
approved with 15 shifts by the INTC on 24.10.2013, current status: experiment completed 7.5.2020.

CE2 CERN experiment IS634: “Emission channeling with short-lived isotopes (EC-SLI) of acceptor dopants in nitride semiconductors”,
U. Wahl, L.M.C. Pereira (spokespersons), V. Augustyns, J.G. Correia, A. Costa, E. David Bosne, T.A.L. Lima, G. Lippertz, M.R. da Silva, K. Temst, and A. Vantomme,
approved with 24 shifts by the INTC on 8.2.2017, current status: experiment completed 24.4.2020.

CE3 ISOLDE Letter of intent I198: “Characterization of the low-energy $^{229\text{m}}\text{Th}$ isomer”,
P. Van Duppen (spokesperson), M. Huyse, L. da Costa Pereira, A. Vantomme, M. Verlinde, E. Verstraelen, R. Ferrer, M. Laatiaoui, S. Sels, Yu. Kudryavtsev, S. Cottenier, U. Wahl, J. G. Correia, P.G. Thirolf, L. v.d. Wense, B. Seiferle, S. Raeder, M. Block, I. Moore, S. Geldhof,

M. Reponen, L. Gaffney, V. Fedosseev, B. Marsh, Th. Stora, J.P. Ramos, S. Rothe, E. Peik, U. Köster, L.M. Fraile, approved with 3 shifts by the INTC on 29.6.2017, current status: completed.

CE4 CERN experiment IS648: “Emission Channeling with Short-Lived Isotopes: sublattice displacement in multiferroic Rashba semiconductors”,

L.M.C. Pereira (spokesperson), T.A.L. Lima, H. Jin, E. Bosne, A. Costa, J. MacNulty, G. Lippertz, P.C. Lin, M.R. da Silva, K. Temst, A. Vantomme, J.G. Correia, G. Springholz, and U. Wahl,

approved with 4 shifts by the INTC on 9.11.2017, current status: experiment completed 30.4.2020.

CE5 CERN experiment IS658: “Study of the radiative decay of the low-energy isomer in ^{229}Th ”,

S. Kraemer, K. Beeks, M. Block, T. Cocolios, J.G. Correia, S. Cottenier, H. De Witte, K. Dockx, R. Ferrer, S. Geldhof, U. Köster, M. Laatiaoui, R. Lica, P.-C. Lin, V. Manea, J. Moens, I. Moore, L. M. C. Pereira, S. Raeder, M. Reponen, S. Rothe, T. Schumm, B. Seiferle, S. Sels, P.G. Thirolf, P. Van Den Bergh, P. Van Duppen (spokesperson), A. Vantomme, M. Verlinde, E. Verstraelen, and U. Wahl,

approved with 11 shifts by the INTC on 24.6.2020, current status: in preparation.

CE6 CERN experiment IS668: “Quantum colour centers in diamond studied by emission channeling with short-lived isotopes (EC-SLI) and radiotracer photoluminescence”,

L.M.C. Pereira and U. Wahl (spokespersons), J.G. Correia, A.R.G. Costa, E. David Bosne, T.A.L. Lima, J. Moens, M.R. da Silva, M. Tunhuma, and A. Vantomme, V. Amaral, P. Aprà, S. Ditalia Tchernij, J. Forneris, B. Green, K. Johnston, A. Lamelas, and P. Olivero,

approved with 20 shifts by the INTC on 24.6.2020, current status: in preparation.

3. Academic supervision activities

3.1 Supervisor and promotor of PhD and Masters theses:

T1 Nov. 2012 – June 2018: Supervisor of the PhD thesis of Ângelo Costa (Instituto Superior Técnico, Universidade de Lisboa) on “Lattice location of impurities in silicon carbide”, 170 pages, finished with defense on 5.6.2018 (supervisors U. Wahl, J.G. Correia), funded by FCT (SFRH/BD/86386/2012).

<http://cds.cern.ch/record/2624048>, CERN-THESIS-2018-072.

T2 Nov. 2014 – Sept. 2019: Promotor for the PhD thesis of Tiago Abel de Lemos Lima (Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium) on “Local structure of Mn-doped ferromagnetic semiconductors”, 207 pages, finished with defense on 12.09.2019 (promotors L. Pereira, A. Vantomme, and U. Wahl).

<http://cds.cern.ch/record/2696319>, CERN-THESIS-2019-179.

T3 Jan. 2014 – Oct. 2020: Supervisor of the PhD thesis of Eric David Bosne (Instituto Superior Técnico, Universidade de Lisboa) on “Emission channeling lattice location studies in semiconductors using highly pixellated TimePix detectors”, 130 pages, finished with defense on 14.10.2020 (supervisors U. Wahl, J.G. Correia), funded by FCT (SFRH/BD/95865/2013).

<http://cds.cern.ch/record/2748141>, CERN-THESIS-2020-239.

T4 Since June 2018: Promotor for the PhD thesis of Janni Moens (Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium) on “Investigating the local structure of Th dopants in CaF_2 ” (promotors L. Pereira, A. Vantomme, and U. Wahl).

T5 Oct. 2020 – ongoing: Co-supervisor (orientador externo) of the Masters thesis of Afonso Lamelas (Faculdade de Ciências da Universidade de Aveiro, Portugal) on “Centros de cor quânticos em diamante (Quantum colour centers in diamond)” (supervisor V. Amaral, co-supervisors U. Wahl, T. Monteiro).

3.2 List of trained PhD students

In 2018-2020 the following PhD students or post-docs have actively participated in emission channeling experiments at CERN and have received training by me on the application of this method for lattice location studies. **The ones marked in bold are using emission channeling data as part of their theses.**

- 1) 2011-2020: **Eric David Bosne**, PhD student from Instituto Superior Técnico, Universidade de Lisboa, promotor U. Wahl, J.G. Correia.
- 2) 2014-2019: **Tiago Lima**, PhD student from Instituut voor Kern- en Stralingsfysica, KU Leuven, promotors L.M.C. Pereira, A. Vantomme, U. Wahl.
- 3) 2018: Renan Villareal, post-doc from Instituut voor Kern- en Stralingsfysica, promotor Prof. L.M.C. Pereira.
- 4) Since 2018: **Janni Moens**, PhD student from Instituut voor Kern- en Stralingsfysica, promotors Prof. L.M.C. Pereira, A. Vantomme, U. Wahl.

3.3 Academic jury memberships:

5.6.2018: Jury member in the PhD defense of Ângelo Costa (Instituto Superior Técnico, Universidade de Lisboa) on “Lattice location of impurities in silicon carbide”, 170 pages, finished with defense on 5.6.2018 (supervisors U. Wahl, J.G. Correia).

12.09.2019: Jury member in the PhD defense of Tiago Abel de Lemos Lima (Instituut voor Kern- en Stralingsfysica, KU Leuven, Belgium) on “Local structure of Mn-doped ferromagnetic semiconductors” (promotors L. Pereira, A. Vantomme, and U. Wahl).

14.10.2020: Jury member in the PhD defense of Eric David Bosne (Instituto Superior Técnico, Universidade de Lisboa) on “Emission channeling lattice location studies in semiconductors using highly pixellated TimePix detectors” (supervisors U. Wahl, J.G. Correia),.

4. Services to the community

4.1 As member of committees or commissions

Jan. 2013 –Jan. 2019: Member of the board of referees on the “Use of large scale facilities for condensed matter research” of the German Federal Ministry for Education and Research (Mitglied des Gutachterausschusses “Erforschung kondensierter Materie an Grossgeräten” des Bundesministerium für Bildung und Forschung BMBF). The federal funding approved by this board amounted to a total of 73 MEUR for the years 2013-2016 and 71 MEUR for the years 2016-2019.

4.2 As journal referee

In 2018-2020 I have refereed two manuscripts submitted to Journal of Applied Physics, and one manuscript submitted to Diamond and Related Materials.

5. Scientific divulgation activities

Open access publications: as is indicated by the web links in my publication list, **reprints** of my CERN-related publications are freely available to the general public on the CERN document server.

6. Participation in conferences and meetings

(this section lists the conferences, meetings and workshops which I have personally visited or attended on-line with inscription)

- V1 15th Congreso Nacional de Materiales and 1st Iberian Meeting on Materials Science, Salamanca, Spain, 4.-6.7.2018.
- V2 2018 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland, 5.-7.12.2018.
- V3 IAEA Technical Meeting on Novel Multidisciplinary Applications with Unstable Ion Beams and Complementary Techniques, Vienna, 10.-14.12.2018.
- V4 24th International Conference on Ion Beam Analysis (IBA), Antibes, France, 13.-18.10.2019.
- V5 2019 1st ISOLDE EPIC Workshop on “Exploiting the Potential of ISOLDE at CERN”, CERN, Geneva, Switzerland, 3.-4.12.2019.
- V6 2019 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland, 5.-6.12.2019.
- V7 2020 2nd ISOLDE EPIC Workshop on “Exploiting the Potential of ISOLDE at CERN”, CERN, Geneva, Switzerland (on-line participation), 24.-25.11.2020.
- V8 2020 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland (on-line participation), 26.-27.11.2020.

7. Seminar and similar presentations

- S1 Work group seminar, KU Leuven, Instituut voor Kern- en Stralingsfysica, Leuven, Belgium, 9.2.2018, “Influence of Fermi-level on the lattice location of ²⁷Mg in GaN”.
- S2 Work group seminar, KU Leuven, Instituut voor Kern- en Stralingsfysica, Leuven, Belgium, 8.2.2019, “First results on the temperature dependence of the ¹¹Be lattice location in GaN”.
- S3 Work group seminar, KU Leuven, Solid-State Quantum Physics, Leuven, Belgium, 29.11.2019, “Direct structural identification and quantification of the split-vacancy configuration for implanted Sn in diamond”.

8. Communications at conferences and meetings

(lists the conference contributions where I have been main author or co-author, my name is underlined in those presentations which were given by myself)

Total number of conference contributions 2018-2020: 20

Personally presented invited oral contributions: 1

Personally presented oral contributions: 3

Personally presented poster contributions: 3

- 21st International Conference on Ion Beam Modification of Materials (IBMM), San Antonio, Texas, 24.-29.6.2018,
- C1** poster contribution, U. Wahl, J.G. Correia, A. Costa, E. David-Bosne, T.A.L. Lima, G. Lippertz, M.R. da Silva, M.J. Kappers, K. Temst, A. Vantomme, and L.M.C. Pereira: “Lattice sites of implanted Mg in different doping types of GaN”.
- 15th Congreso Nacional de Materiales and 1st Iberian Meeting on Materials Science, Sociedad Española de Materiales, Salamanca, Spain, 4.-6.7.2018,
- C2** invited talk, U. Wahl, J.G. Correia, A. Costa, E. David-Bosne, T.A.L. Lima, G. Lippertz, M.R. da Silva, M.J. Kappers, K. Temst, A. Vantomme, and L.M.C. Pereira: “Emission channeling lattice location of Mg in GaN”.
- C3** oral contribution, A. Redondo-Cubero, E. David-Bosne, U. Wahl, P. Miranda, M.R. da Silva, J.G. Correia, and K. Lorenz: “Ion channeling patterns as a tool for strain measurement in lattice-matched AlInN/GaN bilayers”.
- 676th W.E. HeraeusSeminar, Novel Optical Clocks in Atoms and Nuclei, Bad Honnef, Germany, 9.-12.7.2018,
- C4** poster contribution, J. Moens, S. Cottenier, L.M.C. Pereira, M. Huyse, R. Ferrer, S. Kraemer, Y. Kudriavtsev, M. Laatiaoui, S. Sels, P. van Duppen, A. Vantomme, M. Verlinde, E. Verstraelen, U. Wahl, and S. Zadornaya: “Investigating the local structure of Th dopants in CaF₂ using channeling techniques”.
honored with the Best Poster Award.
- ENSAR_NEXT preparatory meeting, Catania, Italy, 6.10.2018,
- C5** oral contribution, L.M.C. Pereira, U. Wahl, and J.G. Correia: “Nuclear probes with non-conventional isotopes”.
- 2018 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland, 5.-7.12.2018,
- C6** invited talk, L.M.C. Pereira, U. Wahl, and J.G. Correia: “Unraveling the atomic structure of quantum materials using radioactive ions”;
- C7** oral contribution, T.A.L. Lima, J. Moens, R. Villareal, E. Bosne, A. Costa, J.G. Correia, M.R. da Silva, G. Springholz, U. Wahl, K. Temst, A. Vantomme, L.M.C. Pereira: “Sub-lattice displacement in multiferroic Rashba semiconductor (Ge,Mn)Te (IS648)”;
honored with the CAEN Best Young Scientist Oral Award.
- C8** poster contribution, U. Wahl, A. Costa, T.A.L. Lima, J. Moens, J.G. Correia, M.R. da Silva, K. Temst, A. Vantomme, L.M.C. Pereira, and M.J. Kappers: “IS634: First results on the temperature dependence of the ¹¹Be lattice location in GaN”.
- IAEA Technical Meeting on Novel Multidisciplinary Applications with Unstable Ion Beams and Complementary Techniques, Vienna, 10.-14.12.2018,
- C9** oral contribution, U. Wahl, J.G. Correia, and L.M.C. Pereira: “Portuguese and Belgian experiments with radioactive probes in solids at ISOLDE/CERN”.

- 2nd Workshop C²TN: Radiation for Science and Society, Instituto Superior Técnico, Bobadela, Portugal, 11.12.2018,
- C10** poster contribution, J.G. Correia, U. Wahl, K. Lorenz, E. Bosne, A. Costa, R. Teixeira, and D. Pereira: “Radioactive local probe techniques at ISOLDE”.
- Ciência ‘19, Encontro com a Ciência e Tecnologia em Portugal, Centro de Congressos de Lisboa, Lisbon, Portugal, 8.-10.7.2019,
- C11** poster contribution, E. David Bosne, U. Wahl, and J.G. Correia, “2-dimensional position sensitive radiation detectors for lattice location studies with α and β particle channeling”.
- 24th International Conference on Ion Beam Analysis (IBA), Antibes, France, 13.-18.10.2019,
- C12** oral contribution, T.A.L. Lima, U. Wahl, J.G. Correia, E. Bosne, A. Costa, R. Villarreal, J. Moens, P.C. Lin, M.R. da Silva, A. Vantomme, L.M.C. Pereira: “Sublattice displacement in multiferroic Rashba semiconductor (Ge, Mn)Te”;
- C13** poster contribution, U. Wahl, A. Costa, T.A.L. Lima, J. Moens, J.G. Correia, M.R. da Silva, M.J. Kappers, A. Vantomme, and L.M.C. Pereira: “Lattice location of Be and Mg in GaN: Exploring the acceptor doping limits”;
honored with the ELSEVIER Best Poster Award;
- C14** oral contribution, E. David Bosne, U. Wahl, J.G. Correia, T.A.L. Lima, A. Vantomme, and L.M.C. Pereira: “A generalized fitting tool for analysis of two-dimensional channeling patterns”;
- C15** poster contribution, U. Wahl, J.G. Correia, R. Villareal, A. Vantomme, and L.M.C. Pereira: “Unambiguous identification of the split-vacancy configuration of the SnV⁻ defect in diamond”.
- 2019 Fall Meeting of the Materials Research Society (MRS), Symposium EL05 on “Diamond and Diamond Heterojunctions - From Growth and Technology to Applications”, Boston, Massachusetts, 1.-6.12.2019,
- C16** oral contribution, A. Vantomme, U. Wahl, J.G. Correia, R. Villareal, E. Bourgeois, M. Nesladek, and L.M.C. Pereira: “Identifying the structure of the SnV⁻ defect in diamond - experimental evidence of the split-vacancy configuration”.
- 2019 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland, 5.-6.12.2019,
- C17** oral contribution, U. Wahl, J.G. Correia, R. Villareal, E. Bourgeois, M. Gulka, M. Nesladek, A. Vantomme, and L.M.C. Pereira: “Unambiguous identification of the split-vacancy configuration of the SnV⁻ defect in diamond”;
- C18** oral contribution, J. Moens, U. Wahl, J.G. Correia, T. Lima, S. Kramer, M. Verlinde, P. Van Duppen, A. Vantomme, and L.M.C. Pereira: “Lattice location of ²²⁹Th in CaF₂”.
- Advanced Materials Annual Workshop, C²TN, Instituto Superior Técnico, Bobadela, Portugal, 10.11.2020,
- C19** online oral contribution, U. Wahl, J.G. Correia, A. Costa, J. Moens, T. Lima, A. Vantomme, and L.M.C. Pereira: “Using radioactive ion beams to study the properties of quantum systems”.
- 2020 ISOLDE Workshop and Users Meeting, CERN, Geneva, Switzerland (via Zoom), 26.-27.11.2020,
- C20** online poster contribution, S.F. Kraemer, K. Beeks, M. Block, T. Cocolios, J.G. Correia, S. Cottenier, H. De Witte, K. Dockx, R. Ferrer, S. Geldhof, U. Köster, M. Laatiaoui, R. Lica, P.C. Lin, V. Manea, J. Moens, I. Moore, L. Pereira, S. Reader, M. Reponen, S. Rothe, T. Schumm, B. Seiferle, S. Sels, P. Thirolf, P. Van den Bergh, P. Van Duppen, A.

Vantomme, M. Verlinde, E. Verstraelen and U. Wahl: “Investigation of the radiative decay of $^{229\text{m}}\text{Th}$ using the beta decay of ^{229}Ac ”;
Winner of the CAEN Best Young Scientist Poster Award.

Accepted conference contributions that had to be canceled due to the Corona virus pandemic:

- 25th Hasselt Diamond Workshop 2020 (SBDD XXV), Hasselt, Belgium, 11.-13.3.2020, oral contribution, U. Wahl, J.G. Correia, R. Villarreal, E. Bourgeois, M. Gulka, M. Nesládek, A. Vantomme, and L.M.C. Pereira: “Identifying the structure of the SnV⁻ center in diamond - high formation yield and narrow optical linewidth”.
- IMEC Workshop on Defects 2020, Leuven, Belgium, 16.-17.4.2020, oral contribution, U. Wahl, J.G. Correia, R. Villarreal, E. Bourgeois, M. Gulka, M. Nesládek, L.M.C. Pereira, and A. Vantomme: “The SnV⁻ defect in diamond: experimental evidence of the split-vacancy configuration”.

9. Publications

9.1 Book chapter

- B1** L.M.C. Pereira, A. Vantomme, and U. Wahl: “Characterizing defects with ion beam analysis and channeling techniques”, chapter 11 in *Characterisation and Control of Defects in Semiconductors*, edited by F. Tuomisto (The Institution of Engineering and Technology, Stevenage, UK, 2019, ISBN-13: 978-1-78561-655-6), p 501-561.
 Published 30/09/2019
<http://dx.doi.org/10.1049/PBCS045E>

9.2 Publications listed in ISI Web of Science: 8

of which

Publications in type A journals (IST internal classification): 4

Publications in type B journals (IST internal classification): 4

- P1** A.R.G. Costa, U. Wahl, J.G. Correia, E. Bosne, V. Augustyns, D.J. Silva, M.R. da Silva, and L.M.C. Pereira: “Lattice sites of ion-implanted Mn, Fe and Ni in 6H-SiC”, *Semiconductor Science and Technology* 33 (2018) 015021/1-10.
 Published online 20/12/2017 IF 2.361 / Q 2
<http://dx.doi.org/10.1088/1361-6641/aa9f08>
- P2** A. Redondo-Cubero, E. David-Bosne, U. Wahl, P. Miranda, M.R. da Silva, J.G. Correia, and K. Lorenz: “Strain detection in crystalline heterostructures using bidimensional blocking patterns of channeled particles”, *Journal of Physics D: Applied Physics* 51 (2018) 115304/1-10.
 Published online 22/02/2018 IF 3.169 / Q 1
<http://dx.doi.org/10.1088/1361-6463/aaad8b>

- P3** A.R.G. Costa, U. Wahl, J.G. Correia, E. David-Bosne, V. Augustyns, T.A.L. Lima, D.J. Silva, M.R. da Silva, K. Bharuth-Ram, and L.M.C. Pereira: “Lattice location study of low-fluence ion-implanted ^{124}In in 3C-SiC”, *Journal of Applied Physics* 125 (2019) 215706/1-8.
Published online 05/06/2019 IF 2.286 / Q2
<http://dx.doi.org/10.1063/1.5097032>
http://cds.cern.ch/record/2678030/files/JAP_2019_125_215706_Preprint.pdf
- P4** M. Verlinde, S. Kraemer, J. Moens, K. Chrysalidis, J.G. Correia, S. Cottenier, H. De Witte, D.V. Fedorov, V.N Fedosseev, R. Ferrer, L.M. Fraile, S. Geldhof, C.A. Granados, M. Laatiaoui, T.A.L. Lima, P.C. Lin, V. Manea, B.A. Marsh, I. Moore, L.M.C. Pereira, S. Raeder, P. Van den Bergh, P. Van Duppen, A. Vantomme, E. Verstraelen, U. Wahl, and S.G. Wilkins: “An alternative approach to populate and study the ^{229}Th nuclear clock isomer”, *Physical Review C* 100 (2019) 024315/1-10.
Published online 12/08/2019 IF 2.988 / Q1
<http://dx.doi.org/10.1103/PhysRevC.100.024315>
- P5** T.A.L. Lima, U. Wahl, J.G. Correia, V. Augustyns, S.M.C. Miranda, K.W. Edmonds, B.L. Gallagher, R.P. Campion, J.P. Araújo, M.R. da Silva, K. Temst, A. Vantomme, and L.M.C. Pereira: “Thermal stability of interstitial and substitutional Mn in ferromagnetic (Ga,Mn)As”, *Physical Review B* 100 (2019) 144409/1-8.
Published online 07/10/2019 IF 3.575 / Q1
<http://dx.doi.org/10.1103/PhysRevB.100.144409>
- P6** E. David-Bosne, U. Wahl, J.G. Correia, T.A.L. Lima, A. Vantomme, and L.M.C. Pereira: “A generalized fitting tool for analysis of two-dimensional channeling patterns”, *Nuclear Instruments and Methods in Physics Research B* 462 (2020) 102-113.
Published online 15/11/2019 IF 1.270 / Q2
<http://dx.doi.org/10.1016/j.nimb.2019.10.029>
- P7** U. Wahl, J.G. Correia, R. Villareal, E. Bourgeois, M. Gulka, M. Nesladek, A. Vantomme, and L.M.C. Pereira: “Direct structural identification and quantification of the split-vacancy configuration for implanted Sn in diamond”, *Physical Review Letters* 125 (2020) 045301/1-7.
Published online 22/07/2020 IF 8.385 / Q1
<http://dx.doi.org/10.1103/PhysRevLett.125.045301>
- P8** U. Wahl, E. David-Bosne, L.M. Amorim, A.R.G. Costa, B. De Vries, J.G. Correia, M.R. da Silva, L.M.C. Pereira, and A. Vantomme: “Lattice sites of implanted Na in GaN and AlN in comparison to other light alkalis and alkaline earths”, *Journal of Applied Physics* 128 (2020) 045703/1-12.
Published online 24/07/2020 IF 2.286 / Q2
<http://dx.doi.org/10.1063/5.0009653>

Recently submitted or prepared for publication:

- P9** E. David-Bosne, U. Wahl, P.A. Miranda, M. Ribeiro da Silva, E. Alves, and J.G. Correia: “Use of a Timepix position sensitive detector for Rutherford backscattering spectrometry with channeling”, submitted to *Nuclear Instruments and Methods in Physics Research B*.
- P10** U. Wahl, J.G. Correia, A.R.G. Costa, E. David-Bosne, T.A.L. Lima, G. Lippertz, A. Vantomme, M.R. da Silva, M.J. Kappers, and L.M.C. Pereira: “Lattice location studies of the amphoteric nature of implanted Mg in GaN”, manuscript aimed at *Advanced Electronic Materials*.

9.3 Other publications (ISOLDE Newsletters)

- O1** U. Wahl: “Influence of Fermi-level on the lattice location of ^{27}Mg in GaN”, ISOLDE Newsletter Spring 2018 (2018).
http://isolde.web.cern.ch/sites/isolde.web.cern.ch/files/April%202018_2.pdf
- O2** U. Wahl: “ ^{11}Be lattice location in GaN as function of temperature and doping type”, ISOLDE Newsletter Spring 2019 (2019).
<http://isolde.web.cern.ch/sites/isolde.web.cern.ch/files/April%202019.pdf>

Lisboa, 11.2.2021



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