IOP Institute of Physics
Ion and Plasma Surface
Interactions Group

Newsletter March 2023

Ions and Plasma Surface Interactions Group

Join the IPSI group:
https://www.iop.org/physics-community/special-interest-groups/ion-plasma-surface-interactions-group

Welcome from the IPSI Chair

Dear members,
Welcome to the 2023 Newsletter of the Ions and Plasma Surface Interactions Group.
First of all, I would like to welcome Luke Antwis and Gianfranco Claudio as new Ordinary Member and Co-opted Member of the committee, respectively. At the same time, we have said goodbye to Robert Sanjari and John Colligon. Their contributions over the years are much appreciated. In particular John will be missed as a long-standing and passionate IPSI member who was always keen to organise IPSI events. We will be holding elections for new Committee members in Summer 2023. Please consider standing in these elections and be part of the work that IPSI does for our community.

Over the last year we have organised three main events: Advances in Photovoltaics happened twice in 2022 (23 March 2022 and 7 December 2022). The first one was delayed from 2021 for COVID-related reasons. The other main IPSI event was Plasmas, Surfaces and Thin Films (9 June 2022). We are very pleased that all these events were again in-person, having to either cancel or move these events online over the last few years. Personally, I am very pleased to be able to meet in person again. Reports on these meetings can be found later in this newsletter.

The second major activity of the IPSI group is to recognise excellent contributions to the field through our Poster Prize and Outstanding PhD Thesis Award. It is always nice to see

enthusiastic people talking about their new and excellent work. I believe we have 2 excellent winners of these prizes: Rémi Delaporte-Mathurin for the thesis award and Joshua Ellingford for the poster prize. More details about their work can be found in this newsletter.

Finally, looking ahead at the year to come, we are planning to again organise our two main workshops, Advances in Photovoltaics and Plasmas, Surfaces and Thin Films as well as sponsor several other events that are organised by others. In addition, the poster prize will be awarded at our PSTF event while nomination for the PhD Thesis Award are now open. Details can be found on the IPSI website: https://www.iop.org/physics-community/special-interest-groups/ion-plasma-surface-interactions-group.

We always welcome new ideas and new people to our group, so please do get in touch with suggestions or if you would like to contribute to the newsletter.

Erik Wagenaars
IPSI Chair - University of York

Forthcoming IPSI meetings

Advances in Photovoltaics	IOP London	March 2023
Annual Plasma Surfaces & Thin Films meeting	IOP London	15th June 2023
International Conference on Fundamentals and Industrial Applications of HIPIMS	Venlo, NL	12-15th June 2023
12th Vacuum Symposium	Daresbury	13-14th June 2023
EVC-17 IUVSTA European Vacuum Symposium	Manchester	24-28th June 2024
IBMM International conference on ion beam modification of materials.	Queen Mary London	1st-5th July 2024

IPSI Thesis Prize

The 2022 IPSI Outstanding PhD Thesis Award was won by Rémi Delaporte-Mathurin of CEA Cadarache (France) for his thesis entitled "Hydrogen transport in tokamaks: Estimation of the ITER divertor tritium inventory and influence of helium exposure". His supervisor was Christian Grisolia.

The extended abstract of his thesis is:

Future fusion reactors will use a mixed fuel of deuterium and tritium, fusing into helium and releasing energy in the process. As a radioactive isotope of hydrogen, tritium can represent a nuclear safety hazard and its inventory in the reactors materials must be controlled. For instance, in the experimental reactor ITER, the tritium in-vessel safety limit is 700 g.

This PhD was focused on answering the following questions:
Are we able to predict tritium retention in fusion reactors?
Will the tritium inventory remain within the safety limits over their lifespan?
How will helium impurities influence this retention?

We focused on the ITER divertor, the reactor's component responsible for exhausting heat and particles. The tritium inventory of the ITER divertor was numerically estimated with the FESTIM code, which was specifically developed to simulate hydrogen transport in materials. A FESTIM model of tungsten monoblocks (bricks composing the divertor) was developed and a parametric study was performed varying the exposure conditions (surface temperature and surface hydrogen concentration). Using machine learning on these simulations results, we were able to obtain a monoblock behaviour law. This method provided an extremely rapid way of estimating the tritium inventory of a monoblock exposed to any heat and particle flux.

This behaviour law was then used and interfaced with output data from the edge-plasma code SOLPS-ITER in order to estimate the tritium inventory of the whole ITER divertor. Under conservative assumptions, the total tritium inventory was found to be well below the ITER tritium safety limit, reaching ≈ 14 g

after 25 000 plasma pulses of 400 s. This is a major result as it is the first time the tritium inventory in the tungsten divertor of ITER was assessed with this level of accuracy and at such a long timescale. A model for helium transport in tungsten was also developed to investigate the influence of helium exposure on these results. The physics of helium bombardment differ a lot from hydrogen transport as helium tends to cluster in materials and create bubbles. The results of this helium bubble growth model were in good agreement with published numerical results and experimental observations. A parametric study was performed to investigate the influence of exposure conditions (helium flux and temperature) on the bubbles density and size. To investigate the influence of helium bubbles on hydrogen transport, deuterium thermo-desorption experiments of tungsten pre-damaged with helium were then reproduced. The distribution of bubbles density and size was computed using this helium bubble growth model and the results were used in FESTIM simulations. It was found that exposing tungsten to helium could potentially reduce the hydrogen inventory by saturating defects, making it impossible for hydrogen to get trapped. Moreover, the effect of helium bubbles (creation of additional traps for hydrogen) is limited to the near surface region (small compared to the monoblock's scale). This result is of crucial importance as helium is often expected to have the opposite effect: increasing the hydrogen retention.

This PhD was extremely prolific both in terms of how much science was produced, but also in regard to the tools made available to the global community. Indeed, this work led to a dozen of publications (some in high ranking journals) as well as many contributions to conferences and communications on

nuclear fusion: a seminar at Cambridge University, a TED talk... The work was awarded several prizes, the most prestigious of them being the IUVSTA Medard W. Welch International award. Numerous international collaborations also span from this PhD: UKAEA, First Light Fusion (UK), Massachusetts Institute of Technology (USA), ENEA (Italy), CIEMAT (Spain), IPP Garching (Germany)... Moreover, FESTIM, developed specifically for this PhD, is open-source. This powerful code will therefore be accessible to anyone, and will greatly benefit from the feedback and contributions of the scientific community. The philosophy was not only to make this work reproducible, but to make hydrogen transport simulations easy for everyone. It should be noted that a major effort has been made to make this PhD thesis 100 % reproducible: all the scripts, data-sets, and figures are available online.

Plasmas, Surface and Thin Films meeting Poster Prize

The winner of the 2022 PSTF poster prize was Joshua Ellingford from Plasma Quest Ltd. The title of his poster was “A new plasma source design enabling co-sputter and large area applications of HiTUS (High Target Utilisation Sputtering)”.

The abstract of his work is:
HiTUS (High Target Utilisation Sputtering) is a low temperature i-PVD technique that is well regarded for producing high quality thin film coatings for an extensive range of materials, on delicate substrates. This is due to the large process space made available using a remote plasma source to generate the plasma for sputtering, as opposed to using the target for generation of plasma. Despite the extensive capabilities of HiTUS, there are some limitations that present a barrier to the large-scale adoption of the technique; notably practical limits on the size of the remote plasma source limiting the size of target and substrate, and only being able to sputter from a single target at a time. A recent advancement in plasma source design (patented, GB2593863) enables the Thwaites design remote plasma source to be used in a co-sputter configuration. An essentially planar high-density plasma is generated by locally

compressing the initial tubular shape of the plasma in one direction, yielding a much thinner plasma zone, whilst spreading the plasma generating zone in the orthogonal direction, thereby extending the area available for plasma processes, enabling the source to overcome the limitations on the usable processing space that is intrinsic to the initial tubular source.

2023 IPSI prizes

Outstanding PhD Thesis Award

The competition is open to IOP members who are also members of our group. The prize is £250 and a certificate. The winning entry is published on our website and in our newsletter. Your PhD thesis has to be examined in the period October 2022-October 2023. Full details on how to apply: https://www.iop.org/physics-community/special-interest-groups/ion-plasma-surface-interactions-group/thesis-prize
Deadline for applications: October 31st deadline 2023

IPSI Poster Presentation Prize

This will be awarded at the Plasma, Surfaces & Thin Films meeting in June 2023. To be considered you must register and present a poster at this event.

Plasma Surfaces & Thin Films 2022

9 June 2022, IoP Headquarters, London

After a COVID-related absence of a few years, the Plasma, Surface and Thin Films meeting was back in June. Organised by the Ion and Plasma Surface Interactions, Thin Films and Surfaces and Vacuum groups, this was a 1-day event at the IoP headquarters in London. For many of us, this meeting was the first opportunity to see colleagues again in person and talk about some exciting science.

The programme had 3 themed sessions with an invited speaker and a contributed talk as well as a poster session during lunch. As always, there was a nice mix of university and industrial contributions. The first session was on Ion Implementation with an invited talk by Mateus Masteghin of University of Surrey on "Strain Control in Suspended Thin Films via Ion Implantation: Towards Direct Bandgap group-IV Semiconductors". He showed work investigating the intentional use of strain to control film material properties.

Then there was a dedicated session on the emerging topic of the Application of Clusters and Heavy Ions. Naoko Sano from IonOptika Ltd. gave an invited presentation on "A Practical Guide for Choosing the Best Gas Cluster Ion Beam for SIMS Application", highlighting their experience on producing high-quality, reliable gas clusters for analysis.

After lunch, the last session was a session on Technology applications for quantum and solar. Ella Schneider of the Surrey Ion Beam Centre gave a presentation on "The Use of Ion Beams for Quantum Applications". The talk covered many of the potential as well as some of the material challenges for quantum

applications and how our research field can contribute to overcoming these.
During the lunch break, we enjoyed our lunch while talking to the presenters of posters. Topics ranged from laser ablation to thin film deposition and ion beam sputtering.
Overall, it was a relatively small but very successful event, hopefully marking the return to an annual and in-person event. Many thanks to Hayley Brown and Roger Webb for the excellent organisation. Finally, I hope to see you all again next year.

Erik Wagenaars
University of York

9th International Plasma Science and Entrepreneurship workshop 2022

21-22 November 2022, York

Organised by the University of York and Vision Dynamics, the 9th International Plasma Science and Entrepreneurship took place in York in November 2022. The aim of this series of workshops is to bring together leading international scientists from universities, institutes and firms & scientific entrepreneurs to discuss the achievements, challenges and opportunities for the scientific- and entrepreneurial community in the field of plasma science. Over 40 scientists from 7 different countries participated in this 2-day workshop. The keynote speakers were Professor Jas Pal Badyal FRS (Durham University) and Dr Dirk Hegemann (Empa,

Switzerland). A wide range of plasma-related topics were covered, from atmospheric-pressure plasmas and sparks to thin films and surfaces and low-pressure etching plasmas. There was also a dedicated session on industry perspectives and how industry and academia can work together most effectively. It was a good meeting, bringing together a large part of the UK plasma science community, as well as some of our European colleagues. Finally, it was decided that the next workshop in this series will take place in Kiel (Germany) in Nov/Dec 2023.

Erik Wagenaars
University of York

IPSI group membership - demographic overview

Note: A digital version of the report, including the figures can be found on: https://tinyurl.com/IPSI-demo

The Ions & Plasma Surface Interactions (IPSI) group has 480 members – a relatively small IoP group - and has grown ~5% over the 12 months to Nov-2022, which is middling growth for the IoP – see Figures 1, 2 and 3. Total IoP membership is now 21,110.

IPSI membership is 21% female, compared to 17% for all of the IoP; IPSI group is middling for %-female membership – see Figure 4 and 5.

IPSI group average age is 41 years, compared to 52 years for all of the IoP, with more membership in the younger age groups see table below and figures 1,2,4.

Age range	IPSI %	IOP %
15-19	6	2
20-29	33	15
30-39	15	13
40-49	13	16
50-59	15	17
60-69	6	13
70-79	8	11
80+	4	10

Figure 6 shows how gender split varies in different age groups and membership grades for the whole IOP membership – this data is not available on Tableau at group level.

IOP membership worldwide distribution is shown in Figure 7 – this is highest in UK, USA, Australia, western Europe and Japan. Within the UK, IPSI group membership follows the IOP general pattern, being South-East UK weighted (24%), but IPSI has 15% of members in North-West-UK compared with IOP-wide 11%, Figure 2.

The most common other groups for IPSI members are, predictably, Plasma Physics, Thin Films & Surfaces, and Vacuum groups – the other most common group cross overs are shown in Figure 8.

Source: Physics Insights/Tableau 07/11/2022
Oliver Greenwood
Ceres Power Limited
IPSI Secretary

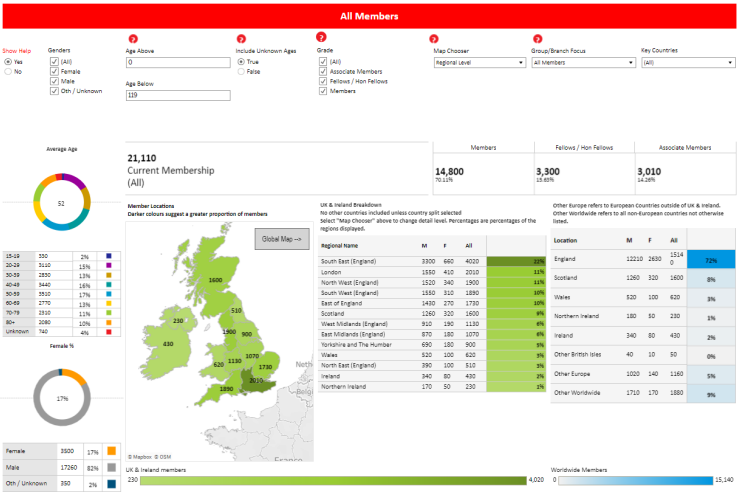


Fig 1. IOP-wide membership statistics

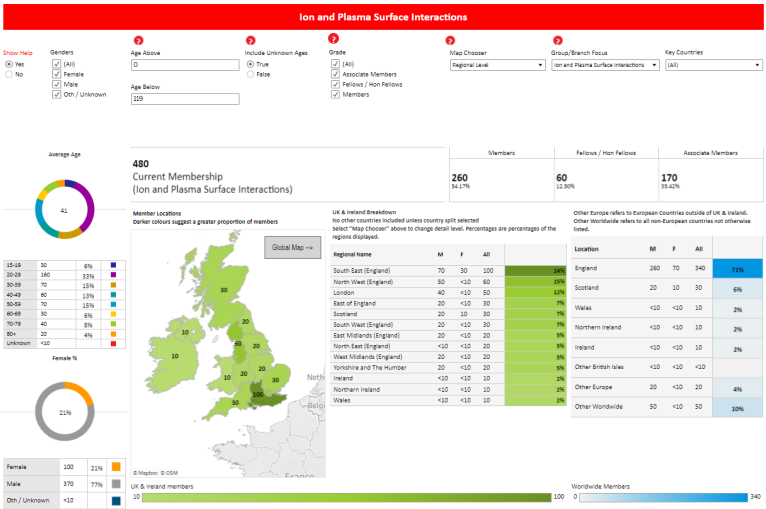
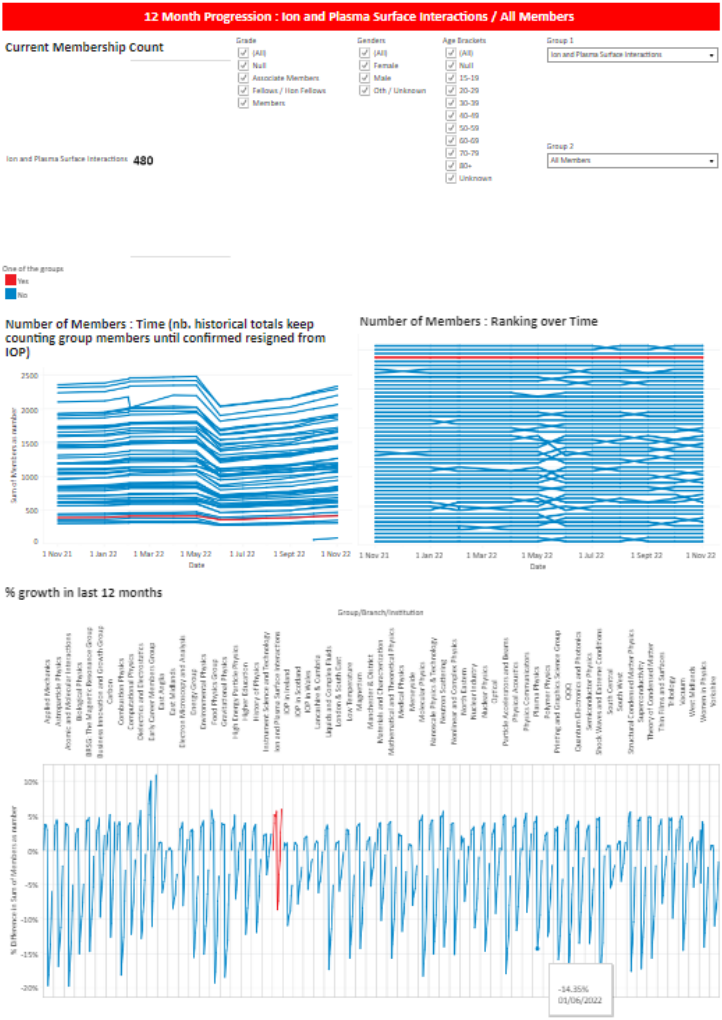


Fig2. IPSI Group Membership statistics



[Physics Insights] Source: Institute of Physics Member Data. Counts of members above 0 and less than 10 are shown as <10 and percentage figures aren't shown against them, though they are included in the total member counts. Other figures rounded to the nearest 10 and so percentages may not add up to 100%. Count of members is a count of distinct memberships where the member status is Active or Applied, and the relationship to the group, branch or institution selected is not out of date.

Fig 3. IPSI Group (red) growth 2021/2022

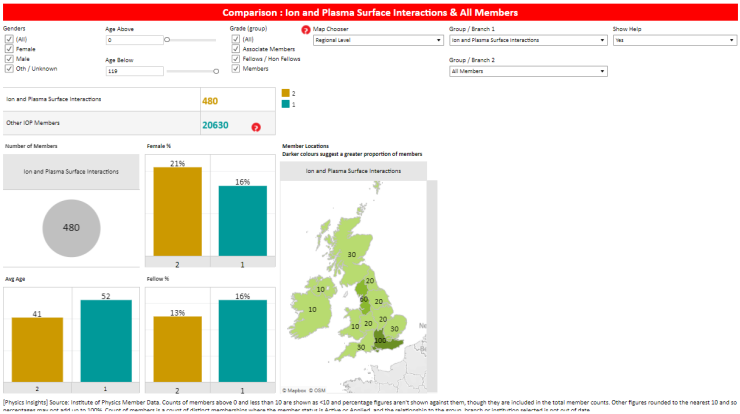


Fig 4. Comparison of IPSI group members' Age and Gender with all of the IOP

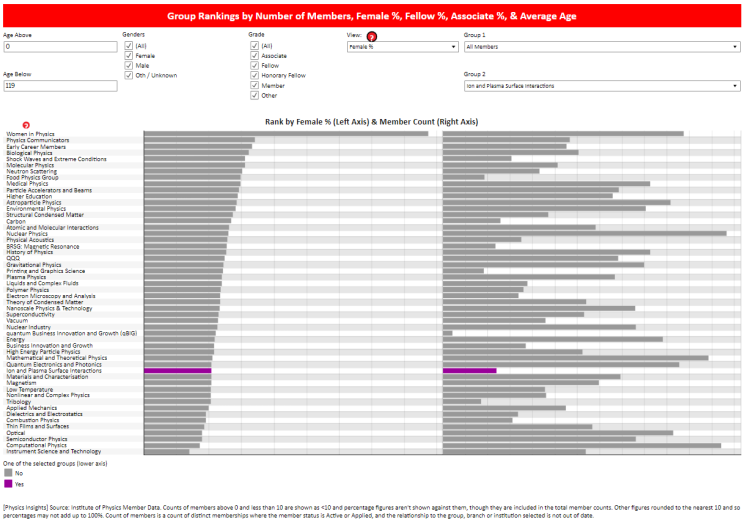


Fig5. IOP Groups gender split(left) and member-count(right); IPSI in purple (21% female)

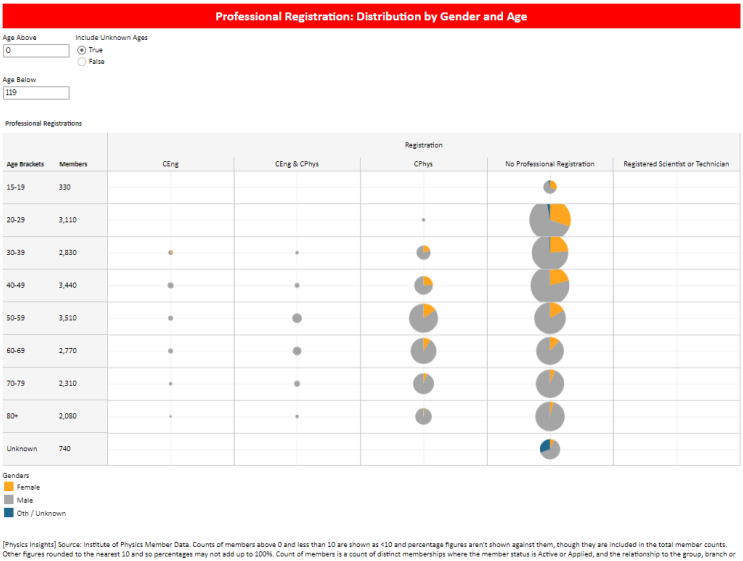


Fig6. All IOP – split by grade and gender

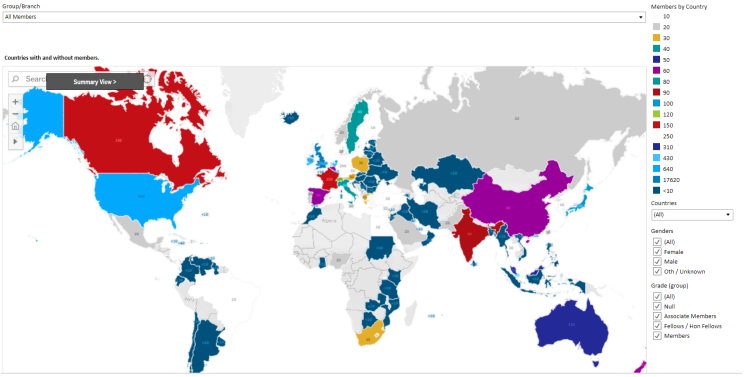


Fig7. Worldwide distribution of IOP members

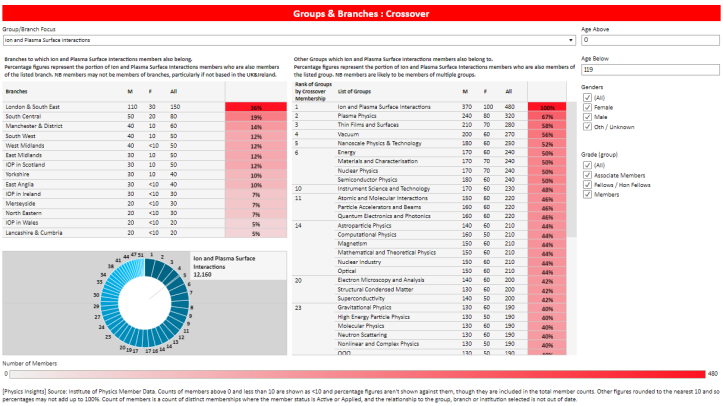


Fig8. IPSI group ‘crossover’ - membership of other IOP groups