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Rethinking surface engineering – Conclusions from the 100th IUVSTA workshop dedicated to responsible surface engineering

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ABSTRACT

The global challenge of climate change can only be solved by substantial reduction of CO_2 and water footprints, enhancement of energy efficiency and mitigation of biodiversity loss. At the same time, economic growth ensures well-being of the society. Responsible surface engineering comprises the sustainable use of resources such as raw materials, energy and water for the production of advanced materials. To orchestrate the research and development efforts toward responsible use of resources, changes in education as well as research and innovation strategies are urgently required.

Rethinking of surface engineering has been the theme of the 100th IUVSTA workshop *How sustainable are thin films and thin film processing? Pathways towards responsible surface engineering*, which took place in Ludwigsburg, Germany, between 27th and 31st of October 2024. This workshop has been the first public, international activity of the *Sustainable Development Working Group* (*Sustainability Division* since 2025) formed within the International Union for Vacuum, Science, Technique and Applications (IUVSTA). The main outcomes of the discussions during the workshop on education, research and innovation strategies are summarized in this article, with the aim of strengthening awareness and driving the necessary shift toward responsible surface engineering. This interpretation represents the view of the authors of this article and is not necessarily agreed upon by all workshop participants. We intend to provide a perspective on the current challenges and how to anchor responsible surface engineering into different frameworks such as education, research and innovation, publications as well as conferences.

1. Scope of the workshop

The 100th IUVSTA workshop *How sustainable are thin films and thin film processing? Pathways towards responsible surface engineering* took place in Ludwigsburg, Germany, from 27th to 31st October 2024. The workshop was sponsored by the International Union for Vacuum, Science, Technique and Applications (IUVSTA), which comprises 30 national member societies worldwide and represents ~15,000 physicists, chemists, materials scientists, engineers and technologists [1]. IUVSTA is one of the drivers and innovators in science, research and development for the implementation of sustainability-related aspects in vacuum techniques such as used for advanced surface engineering. Guidance is provided by the United Nations (UN) Sustainable Development Goals (SDGs). These key elements of the *2030 Agenda for*

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Sustainable Development address how to mitigate climate change and biodiversity loss with an urgent call for action [2,3].

Therefore, IUVSTA established the *Sustainable Development Working Group* in 2022,[1] which organized the 100th IUVSTA workshop as the first public, international activity. The primary goal of the workshop was to exchange, nucleate and promote research and development toward responsible surface engineering and thin film deposition. The workshop hosted 31 participants (32% female) from 11 European countries as well as Canada, representing academia (71%) and applied industrial research (29%). The diversity of workshop participants is illustrated in Fig. 1.

With this size and venue, the workshop was ideally suited to foster discussions and create awareness of the economic, societal and environmental impact of vacuum process technologies, materials and products. 13 invited (62% female gender) and 10 contributed talks (20% female gender) covered a broad range of IUVSTA-related themes:

- hydrogen economy and energy storage materials [4],
- semiconductors [5],
- surface engineering and coating solutions for green aircraft [6],
- scalable low-dimensional functional materials [7],
- ceramic data storage media [8],
- metal-polymer interfaces for space applications [9],
- energy-saving processes and coatings [10],
- machine learning [11],
- antimicrobial coatings for high-touch surfaces [12],
- lead-free dielectric thin films [13],
- life cycle analysis of coatings [14] and
- how to bring advanced materials faster to the market [15,16].

An outstanding feature of the workshop were the discussions, which evidently benefited from the diversity of the participants in view of gender, age, background and education (Fig. 1). While sustainability-related aspects of physical vapor deposition (PVD) were in focus, chemical vapor deposition (CVD) [17], atomic layer deposition (ALD) [18] as well as additive manufacturing (AM) [19] were also critically discussed.

The envisioned interplay between academia and industry toward responsible surface engineering is presented in Fig. 2. Partnership is required, as firm ground for both stakeholders and responsible surface engineering enables innovation. The framework is defined by economic, ecological, societal and legal boundaries and responsible surface engineering relates to the responsible use of resources, comprising raw materials, energy and water [20]. In the following, we present the main outcomes of the discussions at the 100th IUVSTA workshop concerning the topics education, research and innovation, publications as well as conferences. This interpretation represents the view of the authors of this article and is not necessarily agreed upon by all workshop participants. We intend to provide a perspective on the current challenges and how to anchor responsible surface engineering into different frameworks.

2. Methods

The schedule of the 100th IUVSTA workshop is presented in Fig. 3 to illustrate the opportunities for exchange among individuals as well as within the whole group of participants. Intense discussions were enabled through 60 min time slots for invited talks as well as 30 min for contributed talks. First ideas of the expectations from the participants with respect to responsible surface engineering were gathered in an opening discussion. The panel discussion at the end of the second workshop day was moderated by one of the workshop organizers and during this group debate the key topics discussed in this article (education, research and innovation, publications as well as conferences) were identified. The main outcomes were summarized during the closing discussion on the last workshop day and the decision was made to disseminate these findings through a joint publication, including the commitment of all authors of this article. While the majority of workshop participants contributed to the discussions, the authors of this article are responsible for the interpretation of the findings as well as synthesis of conclusions.

3. Education

The United Nations Educational, Scientific and Cultural Organization (UNESCO) coordinated the International Year of Basic Sciences for Sustainable Development from July 2022 to July 2023, with IUVSTA as a key partner, to highlight the past and future essential contributions of fundamental science and education to achieving the SDGs. The advancement of basic sciences and the education of students in e.g. mathematics, chemistry, physics and materials science should be perceived as sustainability in its purest form, since each generation contributes to a growing reservoir of knowledge that future generations can draw upon to address the challenges they will face [21]. Although often not recognized, vacuum and vacuum-based processing is present in a large variety of daily life products and had a substantial role for the invention of e.g. light bulbs, television, computers and microelectronic devices [22]. It is reasonable to expect that vacuum science and vacuum technologies will have profound impact on future processes, materials and products. Consequently, IUVSTA places strong emphasis on educating and training the next generation of technicians, engineers and scientists, equipping them with the comprehensive competences needed to support a sustainable world [23]. We are convinced that academia will play the most significant role in delivering this impact on society.

SDG 4 *Quality Education* aims at providing inclusive, equitable, lifelong learning opportunities to everyone [3]. Education strategies were also intensely discussed at the 100th IUVSTA workshop. Consensus among workshop participants was obtained that current and future students, technicians, engineers and researchers in surface engineering (and related programs) need to understand and address sustainability-related challenges to drive innovation. However, embedding sustainability into curricula in a coordinated and impactful way requires multiple, integrated approaches across different domains [24] as visualized in Fig. 4. This framework has been based on previously identified main drivers and barriers, information gaps and tested prominent assumptions on implementing sustainability curricula in higher education [25].

Hence, meaningful embedding of sustainability at a university must happen on different levels. At the highest level, sustainability needs to be anchored in the university strategy, while curricula changes are driven at the faculty and department level. Within specific courses, the success of the embedding depends on the authenticity as well as credibility of individual teachers. It is obvious that the credibility of teachers is correlated with research efforts and publications in sustainability-related aspects. Currently, there are individual groups in surface engineering concerned with sustainability, e.g. [17,18,20,26–29], while a broader adaptation within the entire surface engineering community is lagging behind. Finally, the collective education of not only students, but also staff enables building of a community.

More specifically, it has been argued during the discussions at the workshop that surface engineering curricula have to be updated with respect to the transition from fossil fuel-based toward green energy sources, covering aspects of life cycle assessment and life cycle engineering, CO_2 footprint, water footprint, energy efficiency and biodiversity loss. The interlinkages and interdependencies between biodiversity, water, food, health and climate change have been evaluated by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) using nexus approaches [30]. Since the

[1] For the IUVSTA 2025–2028 triennium, the *Sustainable Development Working Group* was upgraded to the *Sustainability Division*: https://iuvsta.org/sustainability/ (accessed on 29 May 2026).

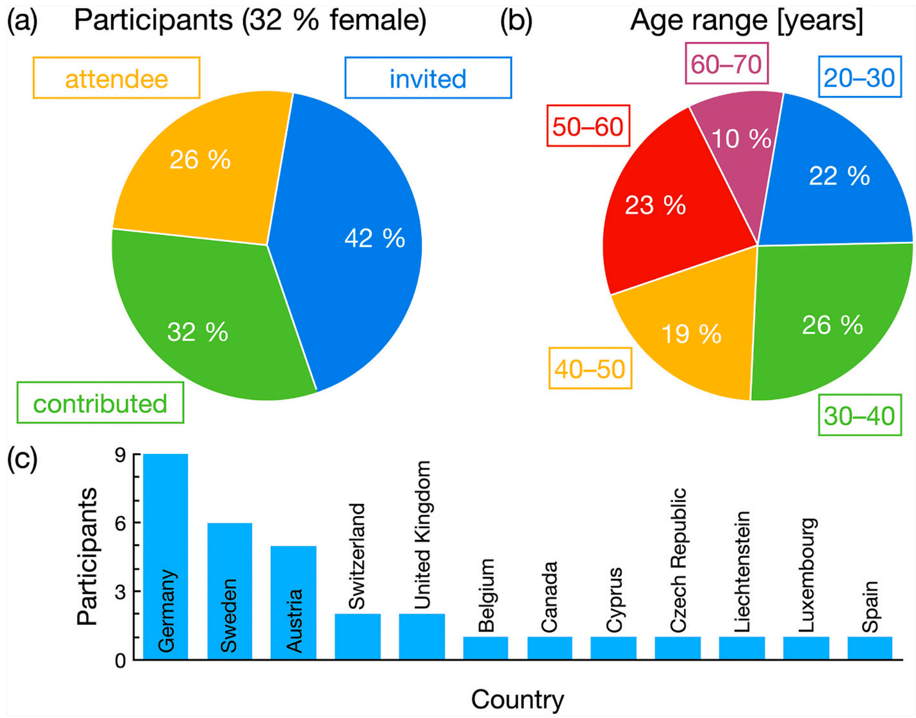

Fig. 1. Diversity of workshop participants. (a) Type of workshop registration (invited, contributed, attendee), (b) age range and (c) country.

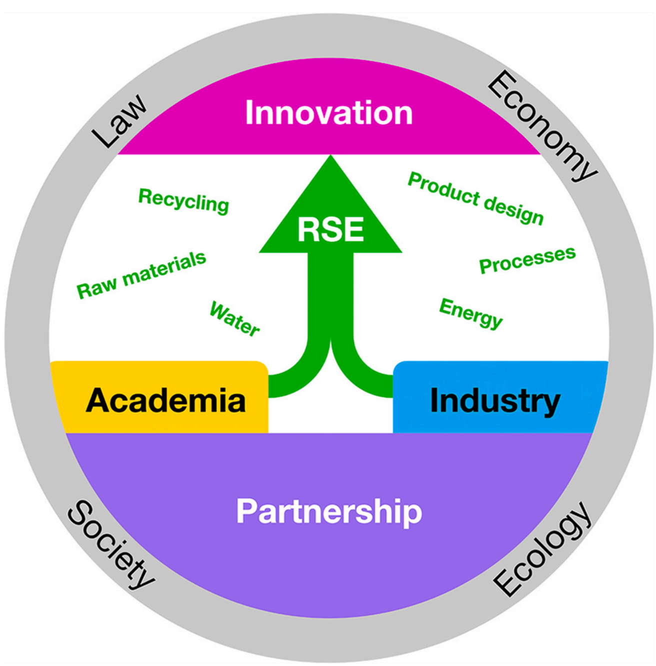

Fig. 2. Ecosystem illustrating the academia-industry partnership fostering innovations through responsible surface engineering (RSE) in the framework of economic, ecological, societal as well as legal boundaries. Sustainability-related aspects include, but are not limited to, usage of energy, water and raw materials as well as recycling, efficient processing and sustainable product design.

associated challenges are highly complex, interconnected, hard to digest and need to be addressed on a global scale, they are usually perceived as a burden rather than an opportunity and several workshop participants confirmed this perception. Therefore, promotion and branding of surface engineering-based solutions for sustainability needs to be improved to turn frustration about the current situation into motivation toward actively shaping the future. In addition, workshop participants emphasized that creativity of the students must be fostered. While the relevant theory is commonly taught in lectures, emphasis should be placed on training practical skills in the lab. Based on the feedback of university students it is clear that their learning curve is steeper, if they are given a problem and solve it by themselves working in the laboratory. It was discussed during the workshop that teaching approaches like inverted classrooms, blended learning as well as (real-life) problem- and challenge-based learning can help to introduce sustainability topics into existing curricula and may at the same time increase excitement and creativity of teachers and students. We have also realized during the workshop that we need to gain credibility ourselves, when teaching others about sustainability.

Moreover, the participants of the workshop agreed that most current curricula are designed for standardization and predictability; they are tied to measurable outcomes, e.g. by providing 'correct answers'. Creativity, as needed to address sustainability-related solutions, requires flexibility, risk, uncertainty and sometimes failure, which is much harder to grade.

4. Research and innovation

Another outcome of the discussions at the workshop was that surface engineering traditionally prioritizes performance, durability, functionality and cost, while sustainability introduces environmental, social and life-cycle constraints that are more complex to measure, evaluate and optimize. Thus, integrating sustainability into surface engineering research presents several challenges, including potential trade-offs between coating performance and environmental impact, the high energy consumption of vacuum-based deposition processes and the limited availability of standardized sustainability metrics as well as life cycle assessment data. Furthermore, regulatory constraints, interdisciplinary knowledge requirements and the difficulty of scaling sustainable solutions from laboratory to industrial implementation complicate their adoption. Addressing these challenges requires the development of alternative materials and processes, improved sustainability assessment methodologies and closer collaboration between materials scientists,

Time	Sunday 27th October 2024	Time	Monday 28th October 2024	Time	Tuesday 29th October 2024	Time	Wednesday 30th October 2024	Time	Thursday 31st October 2024
		09:00	Opening discussion	09:00	Invited talk	09:00	Invited talk	09:00	Invited talk
		09:30	Invited talk	10:00	Contributed talk	10:00	Contributed talk	10:00	Contributed talk
		10:30	Coffee & discussion	10:30	Coffee & discussion	10:30	Coffee & discussion	10:30	Coffee & discussion
		11:00	Invited talk	11:00	Invited talk	11:00	Invited talk	11:00	Invited talk
		12:00	Contributed talk	12:00	Contributed talk	12:00	Contributed talk	12:00	Closing discussion
		12:30	Lunch	12:30	Lunch	12:30	Lunch	12:30	Lunch
		14:00	Invited talk	14:00	Contributed talk	14:00	Contributed talk		*End of workshop*
		15:00	Invited talk	14:30	Invited talk	14:30	Invited talk		
				15:30	Contributed talk	15:30	Contributed talk		
		16:00	Coffee & discussion	16:00	Coffee & discussion	16:00	Coffee & discussion		
		16:30	Social program	16:30	Invited talk	16:30	Social program		
				17:30	Panel discussion				
	Arrival of participants								
18:30	Welcome reception	18:30	Dinner	18:30	Dinner	18:30	Dinner		

Fig. 3. Schedule of the 100th IUVSTA workshop, highlighting multiple opportunities for discussions per day (highlighted in orange).

Fig. 4. Strategy for coordinated and impactful embedding of sustainability into curricula (adopted from [24]).

environmental experts and industry.

SDG 12 *Responsible Consumption and Production* addresses sustainable consumption and production patterns [3]. The development of advanced and innovative functional materials as well as surfaces is an essential enabler for sustainability and requires targeted research for materials discovery, digitalization and re-engineering toward reduced energy and material consumption, sourcing and circularity [31].

Considering Fig. 2, the necessary innovations can be driven by academia, industry or, in the optimum case, by both stakeholders working together in a close partnership. The importance of partnerships between academia and industry is also emphasized by the *Code of practice on industry-academia co-creation for knowledge valorization*, which has been published by the European Union in 2024 [32]. The main recommendations focus on supporting an environment for co-creation as well as managing the process of co-creation to valorize knowledge. Such partnerships between academia and industry should be anchored in the strategies of involved organizations and awareness for mutual benefits (e.g. lifelong learning, formation of networks) has to be created among the staff [32]. With respect to management of knowledge valorization it is underlined that intermediaries between academia and industry are important to encourage co-creation as well as to promote the outcomes, which are facilitated by joint infrastructures [32]. Similar practices appear promising for fostering innovation through responsible surface engineering in partnerships between academia and industry, Fig. 2.

An example for such a successful partnership reported during the 100th IUVSTA workshop was the transfer of a sputtering process for thermochromic VO_2-based coatings from the laboratory to a large-scale roll-to-roll device [33]: the sputtering process has been developed at the University of West Bohemia, Plzeň, Czechia, and the scale-up was carried out at the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology (FEP), Dresden, Germany. An alternative approach to scale-up is the direct research and development within production equipment. While the thermal stability of (Ti,Al)N coatings is limited to ~1000 °C due to formation of the thermodynamically stable wurtzite AlN phase, an enhancement to ~1300 °C was achieved by addition of ~15 at.% O [34]. This coating development has been carried out in an industrial-scale cathodic arc deposition system with close collaboration between academia and industry [34,35]. Consequently, the recipe is directly transferrable to other coating equipment in production. Another example of a successful partnership was the transfer of reactive sputter deposition of MoO_x thin films from laboratory-scale to an industrial in-line coating system using a rotatable target, while maintaining control of film composition, microstructure and functional properties [36]. By adjusting the O_2/Ar ratio, the films could be tailored from electrically conductive, reflective to insulating, transparent MoO_3, highlighting the versatility of the process for large-scale production of optical films for display applications [36].

More of such examples are needed within the near future, since European companies are losing global market share and industrial competitiveness according to the 2024 report from the European Round Table (ERT) [15]. One of the key weaknesses is the regulatory burden as well as administrative demands. Thus, simplification of the regulations is urgently required to obtain coherence of rules and to replace coercive targets with incentives [15]. A very similar picture of limited innovative power within Europe is drawn in the report *The future of European competitiveness* from the European Commission. Geopolitical dependencies in terms of energy supply have currently dramatic consequences for energy prices and Europe has not been able to keep pace of technological change such as in the recent developments with respect to digitalization and artificial intelligence [16].

While it is challenging to reduce the regulatory framework within individual nations or the European Union by surface engineers, our task for the near future is the transformation of innovative ideas into commercial products. The workshop participants agreed that sustainability has to be economically viable. However, this transformation also requires a change in mindset from academia and industry as the major drivers of innovation (Fig. 2). While academia and industry have distinct competences, responsibilities and roles in society, addressing sustainability-related challenges and enabling innovation requires close and continuous collaboration between them. Networks are widely recognized as key breeding grounds for innovation, enabling knowledge exchange, interdisciplinary collaboration and access to complementary expertise. Thereby, the development and implementation of new technologies and sustainable solutions is accelerated. Within such networks, partners develop a mutual understanding of their different needs and constraints, with academia gaining insight into industrial requirements and industry recognizing the importance of academic freedom and the obligation to widely disseminate knowledge and research findings.

Hence, it is evident that managing research and innovation of responsible surface engineering is a highly complex task, including geopolitical challenges. Nevertheless, we want to highlight two tangible recommendations from the discussions at the 100th IUVSTA workshop. Participants from industry advocated for *starting* instead of *perfectionism*. In other words, researchers from academia must be aware that the time to bring solutions through responsible surface engineering to the market is crucial. A faster transfer to industry would accelerate the commercialization of sustainable solutions, despite remaining challenges and open fundamental questions. In turn, participants from academia requested that industry needs to be more open for out-of-the-box thinking and creative innovations. Responsible surface engineering solutions can be effectively translated into real-world impact only through mutual openness, trust and a willingness to reconcile academic depth with industrial timeliness.

5. Policy on publication of research results

It has been also discussed that an essential aspect of advancing scientific knowledge is ensuring that all research outcomes, whether successful or not, are shared openly with the community. Workshop participants agreed that failure is very valuable toward success. However, the findings derived are often considered ‘negative’ and thus usually not published. The sole publication of positively biased datasets originates from the fact that only hypotheses could be provided why an idea may not have worked out as intended. This situation considerably limits scientific progress, since e.g. machine-learning supported data mining cannot benefit from unpublished ‘negative’ findings. Here, a necessary change in scientific publishing policy was discussed toward a more sustainable publishing model, enabling dissemination of negative datasets and hypotheses to avoid duplication of efforts, as it has been e.g. intended in the journal *Access Microbiology* with a new collection of negative results [37] to utilize the full potential of data mining approaches. Along these lines a values-based roadmap has been proposed, integrating the roles of funders, institutions, publishers and researchers, to promote knowledge sharing, research transparency and rigor [38].

For the surface engineering community the journal *Results in Materials* promotes the visibility of exploratory studies, preliminary/incremental results and negative results with scientifically sound explanation, welcoming articles in theoretical, experimental, computational and environmental materials science as well as education in materials science [39]. However, the discontinuation of journals dedicated to negative results, such as the *Journal of Negative Results* (ceased in 2023) and the *Journal of Negative Results in BioMedicine* (ceased in 2017), underlines the persisting publication bias toward novel, positive findings as well as the limited incentives for authors, reviewers and publishers to disseminate well-executed studies reporting null or negative outcomes.

Another issue for consideration is the quantity vs. quality of published papers. While ~1.92 million indexed articles were published in 2016, this number increased to ~2.82 million indexed articles in 2022, corresponding to an exponential growth of ~5.6% per year over this period [40]. In this context the major concern of a rising fraction of manuscripts generated by paper mills and articles from predatory publishing must be acknowledged [41]. While there are no comprehensive studies quantifying the prevalence of paper mills specifically within the field of surface engineering, there have been documented cases of article retractions, involving image manipulation, fabricated data, peer-review manipulation and suspected paper-mill activity in materials science and engineering journals, including those covering coatings, surface modification and tribology. Although the true prevalence remains unknown, publishers have reported increasing numbers of investigations and retractions across engineering journals, suggesting that the issue also affects the surface engineering community and warrants increased vigilance by authors, reviewers and editors. Recently, an editor of the journal *ACS Energy Letters* suggested to publish fewer, but higher quality papers, since today's publishing culture itself represents an unsustainable path [42]. Of course, the increasing number of scientific publications is driven by many factors such as grant agency requirements or the proliferation of new journals, hence, significant changes cannot be expected within the near future.

As a recommendation from the workshop, we see the urgent need to learn from both positive and negative research findings, making the publication of negative datasets and results essential for responsible surface engineering. However, the corresponding framework has to be still developed. Detailed questions to be solved at institutional levels involve e.g. the value of a published negative dataset for a Ph.D. thesis.

6. Promoting sustainability-related discussions at conferences

We have witnessed during the workshop that discussions after presentations tended to switch more toward materials science rather than sustainability. This observation is not surprising as we have been trained to question and discuss materials science (and other technical aspects), which corresponds to our comfort zone. Hence, it is evident that a change of mindset is required to critically evaluate and discuss sustainability-related aspects. Thereby, the problem of unsustainable publishing practices discussed in *section 5* could also be tackled by changing the expectations of presentations at conferences. We are convinced that discussions and networking could be enhanced by communicating more negative results at scientific meetings.

Challenges with integrating sustainability-related topics are faced by the majority of technical meetings. One example has been mentioned during the workshop: at the 50th *International Conference on Metallurgical Coatings & Thin Films* (ICMCTF) 2024 in San Diego, USA, e.g. only five abstracts (three invited and two contributed talks) were submitted to the new topical session *Circular Strategies for Surface Engineering*. Despite this low number of abstracts, the session was very well received by the audience with up to ~90 attendees per talk, corresponding to a 17% fraction of all attendees. Based on this example we interpret that the community would like to hear and learn about responsible surface engineering, while research on this topic is still limited. Consequently, this topical session has become part of ICMCTF also in 2025 and 2026. This observation may encourage the scientific community as well as other conference organizers to further integrate sustainability- and circularity-related topics into future scientific programs. We expect that highlighting sustainability-related topics prominently in the conference program – with dedicated symposia and sessions – will provide an important platform for fostering interdisciplinary exchange and stimulating research efforts toward more responsible and sustainable solutions. Such an integration of sustainability-related topics is already done at conferences with a strong focus on surface engineering. Examples are provided for the *European Materials Research Society* (EMRS) spring and fall meetings, ICMCTF as well as the *International Conference on Plasma Surface Engineering* (PSE) for the years 2024, 2025 and 2026 in Table 1.

To increase sustainability-related contributions and discussions during conferences related to surface engineering, it has been suggested during the discussions at the workshop to focus on current challenges without necessarily presenting a straight-forward solution. Such an approach would be contrary to the current culture of rather publishing and presenting (often only minuscule) advances instead of focusing on the sustainability-related challenges of mankind.

All of these suggestions have in common to exploit the greatest assets of a conference: discussion and networking. It is obvious that international conferences have significant carbon footprints, since attendees are flying around the globe, sit in air conditioned rooms and participate in banquets with a surplus of food. Consequently, the time spent at international conferences should be used as efficiently as possible to foster new ideas and partnerships and develop solutions with a reduced carbon footprint to compensate for the footprint of the meeting itself.

7. Summarizing remarks and outlook

In summary, the 100th IUVSTA workshop was a success due to intense discussions between participants from different communities on the topic of responsible surface engineering. Urgently required changes in education, research and innovation, publications as well as conferences were discussed and our interpretations thereof are summarized as recommendations in the following:

- Education: University curricula have to be updated, comprising aspects of life cycle assessment and life cycle engineering, CO_2 footprint, water footprint, energy efficiency and biodiversity loss. In addition, creativity, curiosity and courage can be nurtured in curricula to create an environment where teachers and students are encouraged to explore, experiment, take intellectual risks and learn to exploit failure, which is required for innovations.
- Research and innovation: While the management of research and innovation of responsible surface engineering is a highly complex task, two tangible recommendations could be synthesized from the discussions at the workshop.

  (1) *Starting* instead of *perfectionism*. Researchers from academia should transfer their findings faster to industry in order to accelerate the commercialization of sustainable solutions, despite remaining challenges and open fundamental questions.

  (2) Industry needs to be more open for out-of-the-box thinking and creative innovations.
- Publications: Learning from both positive and negative research findings is required, making the publication of negative datasets and results essential, while the corresponding framework has to be still developed.
- Conferences: Sustainability-related topics should be highlighted prominently in conference programs as an important platform for fostering interdisciplinary exchange and stimulating research efforts toward more responsible and sustainable solutions.

Finally, all of these challenges share a common requirement: an urgent shift in mindset and increased awareness across the entire surface engineering community. Future research and development activities in surface engineering must not only consider processing and materials science, but rather incorporate sustainability-related aspects.

However, rethinking surface engineering cannot be completed from one day to the other, but is a continuous process. Therefore, we will continue with activities on responsible surface engineering in the future; i.e. the next IUVSTA workshop *Sustainable and resilient processes for the production of materials, fuels and coatings required for the energy transition*, supported by the *Sustainability Division*, is planned for fall 2027. If you are interested in receiving announcements for this planned IUVSTA workshop or upcoming webinars on responsible surface engineering, which we are going to organize, please contact the corresponding author of this article.

Table 1
Overview of sustainability-related topics at conferences with strong focus on surface engineering for the years 2024, 2025 and 2026.

Year	Conference	Focus on sustainability	Source
2024	EMRS spring	Topic "Decarbonized energy and sustainability"	[43]
	EMRS fall	Topic "Energy materials"	[44]
	ICMCTF	Theme "Surface engineering for sustainable development"	–
	PSE	Main topic "Plasma surface engineering enabling sustainability"	[45]
2025	EMRS spring	Topic "Materials for sustainable energy"	[46]
	EMRS fall	Topic "Materials for energy, sustainability and extreme conditions"	[47]
	ICMCTF	Theme "Surface engineering for sustainable development"	[48]
2026	EMRS spring	Topic "Materials for sustainable energy and sensing"	[49]
	EMRS fall	Topic "Energy and environmental applications"	[50]
	ICMCTF	Theme "Surface engineering: Shaping future materials"	[51]
	PSE	Main topic "Surface engineering for clean energy solutions"	[52]

CRediT authorship contribution statement

Marcus Hans: Writing – original draft, Visualization, Investigation, Funding acquisition, Data curation, Conceptualization. **Grzegorz Greczynski:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Claus Rebholz:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Sven Ulrich:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Claudia Fleischmann:** Writing – review & editing, Investigation, Conceptualization. **Henrik Pedersen:** Writing – review & editing, Investigation, Conceptualization. **Jan-Eric Sundgren:** Writing – review & editing, Investigation, Conceptualization. **Christian Mitterer:** Writing – original draft, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Given their role as editors, Marcus Hans and Claus Rebholz had no involvement in the peer review of this article and had no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to another journal editor. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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