Topical Symposium on Sustainable Surface Engineering
Room Palm 5-6 - Session TS5-WeA

Circular Strategies for Surface Engineering

Moderators: Marcus Hans, RWTH Aachen University, Germany, **Nina Schalk**, Montanuniversität Leoben, Austria

2:00pm **TS5-WeA-1 Coated Cemented Carbides – Tooling a Sustainable Future***, **Uwe Schleinkofer (uwe.schleinkofer@ceratizit.com)**, C. Czettl,* CERATIZIT Austria GmbH, Austria **INVITED**

The demand for high performance manufacturing process in industries like aerospace, automotive and general engineering led to very productive and rapidly developing chip removal processes. Thuss coated cemented carbide cutting tools were developed during the last decades significantly to reduce costs and increase productivity. In addition to these needs, the sustainability aspects of such tools in terms of manufacturing and application got more and more in focus. One of the biggest contributors here is the raw material, mainly the element Tungsten for the Tungsten Carbide used in the cemented carbide. Examples of recycling technologies and closed loop scenarios to get back the worn-out tools will be summarized to show the state of the art. The influence of tailored microstructures and properties of coatings play a decisive role for the durability and performance of the tool. Furthermore, the metal cutting applications will be discussed to discuss the main factors influencing the sustainability in the chip removal process. The energy consumption of the machine is related to that of cooling pumps and additional aggregates. Examples are shown how innovative machining strategies can contribute to a more sustainable future.

2:40pm **TS5-WeA-3 Designing Selective Stripping Processes for Al-Cr-N Hard Coatings on WC-Co Cemented Carbides***, A. Kretschmer, V. Jaszfi, V. Dalbauer,* TU Wien, Institute of Materials Science and Technology, Austria*; V. Schott, S. Benedikt, A. Eriksson,* Oerlikon Balzers, Liechtenstein*; A. Limbeck,* TU Wien, Austria*; **Paul Heinz Mayrhofer (paul.mayrhofer@tuwien.ac.at)**,* TU Wien, Institute of Materials Science and Technology, Austria

Hard coatings like (Al,Cr)N are commonly used to protect cemented carbide cuttings tools from wear and corrosion. While such coatings increase the tool-lifetime, they also hinder the recycling effort of damaged tools. We report a new recycling strategy for coated cemented carbide tools by applying an interlayer between an arc evaporated $Al_{0.7}Cr_{0.3}N$ coating and the WC-Co substrate. By selectively dissolving this interlayer in a concentrated basic solution, the coating spalls off the substrate, which is left intact. Four bases have been tested as saturated solutions: LiOH, NaOH, KOH, and CsOH, of which NaOH showed the highest reactivity. It was therefore used for subsequent investigations. Three different methods have been tested: (1) a metallic Al-doped interlayer region between substrate and coating can be removed in 3 h at 140 °C. Depositing an (2) $Al_{0.7}Cr_{0.3}$ or (3) $Al_{0.9}Cr_{0.1}N$ interlayer leads to a significantly faster removal compared to the first method. Hereby a substrate could be fully de-coated in 4 h at only 110 °C. The reaction time was also decreased by pre-treating the samples in concentrated HCl, HNO_3, or H_2SO_4 solutions at 90 °C for 10 min before subjecting the samples to the NaOH bath. Such treated substrates were fully de-coated in 3 h at only 90 °C. While HNO_3 oxidized the substrates significantly, HCl and H_2SO_4 caused only negligible substrate damage.

3:00pm **TS5-WeA-4 Perspectives on Sustainability of Coated Metal Cutting Tools***, **Lars Johnson (lars.johnson@sandvik.com)**,* Sandvik Coromant R&D Materials and Processes, Sweden **INVITED**

Effects of climate change due to the emissions of greenhouse gases (GHG) from human activity is increasingly apparent, as predicted by climate science. Therefore, there is urgency in reducing the emission of GHG globally to meet the Paris Agreement goals of limiting the level of global warming. For the manufacturing industry, the last couple of years have been focused on the setting of targets in agreement with these goals, using frameworks as the Science Based Targets Initiative [1]. For example, Sandvik group has set targets of reduction of scope 1 and 2 GHG emissions to 50 % by 2030, 90 % by 2040, and net zero for scopes 1, 2, and 3 by 2050. To meet these ambitious yet necessary targets, improvements must be made across the full value chain; from suppliers and production, to customers' use of and the recycling of our products. Coated metal cutting tools are an interesting example to consider for the coating field, as the coating of tools have greatly enhanced their performance and service lifetime over the last half-century. Here, perspectives of the improvement in energy efficiency and reduction of GHG emissions will be discussed. Starting from the deposition process itself, where recent reports on low-temperature deposition indicates that significant reductions in energy usage are possible [2]. Yet, as further improvements are needed, implications of how the coating equipment field needs to develop will also be considered. Another perspective is the impact of performance of the total GHG emissions over the lifetime of the tool at the user, where its performance and stability determine the total contribution to the emission when manufacturing a component. Finally, the need for reuse and recycling of used tools is also considered, which also greatly affects their sustainability. In closing the need for holistic approaches will be emphasized, to avoid sub-optimizations, as it is our collective need and our collective improvements that will determine to what level we can mitigate climate change.

1. https://sciencebasedtargets.org/

2. Li, Xiao, *Toward Energy-efficient Physical Vapor Deposition: Routes for Replacing Substrate Heating during Magnetron Sputtering by Employing Metal Ion Irradiation*, Linköping University 2023, https://doi.org/10.3384/9789180752428

3:40pm **TS5-WeA-6 Towards Responsible Surface Engineering***, **Marcus Hans (hans@mch.rwth-aachen.de)**, J. Schneider,* RWTH Aachen University, Germany*; A. Matthews,* University of Manchester, UK*; C. Mitterer,* Montanuniversität Leoben, Austria

Surface engineering comprises technologies, which enable improved structural and functional surface properties. Plasma-assisted physical vapour deposition (PVD) covers a set of advanced plasma-assisted surface engineering technologies, increasingly employed to address global challenges, such as reduction of CO_2 emissions. Despite the smaller volume and mass of thin films and coatings compared to bulk materials as well as the relatively low synthesis temperatures of PVD compared to other surface engineering technologies, PVD processes are often resource-intensive. In this review we critically evaluate two important questions in this context:

1. How sustainable are PVD processes and materials?
2. Which pathways are needed for responsible surface engineering?

The consideration of energy and mass balances demonstrates that state-of-the-art PVD processes and materials are not necessarily sustainable. Responsible surface engineering comprises pathways to enhance the sustainability of processes as well as materials and involves a change in mindset of materials scientists and process engineers.

4:00pm **TS5-WeA-7 Reprocessing High Performance Cutting Tools – Performance Plus with Dedicated Coating Solutions***, **Dominik Blösch (d.bloesch@platit.com)**, C. Krieg,* PLATIT AG, Switzerland*; J. Kluson,* PLATIT a.s., Czechia*; H. Bolvardi, A. Lümkemann,* PLATIT AG, Switzerland*; B. Torp,* PLATIT Inc., Switzerland **INVITED**

In the last decades, the research and development within surface engineering has focused mainly on the enhancement of surface properties by the design of multifunctional coatings and surfaces, while the sustainability of such processes and products was typically neglected. The approach of a circular economy for surface engineering requires innovative rethinking along the lines of reducing, reusing, repairing, and recycling. In this contribution we would like to introduce circular economy strategies for surface engineering as follows:

1. Sustainability with in-house PVD production: By integrating the coating process into the tool production plant, shipping between job coating centers and production places becomes superfluous, effectively reducing CO_2 production through optimized logistics. Furthermore, one major benefit of an vertically integrated coating center is having the PVD process including all aspects of the process chain on site. This permits functional coatings to be developed for specific applications, bringing us to the next point...
2. Extend usage by "Dedicated development": Using flexible in-house PVD technology including pre- and post-treatment de-coating and washing, the life of the coated part is maximized. Each step in the process chain is optimized individually. The lifetime of the coated parts for each specific application can thereby be extended rather than applying the typical job-coating business strategy where "one size fits all". The full potential of even the best PVD coatings cannot be exploited when making compromises in terms of coating type, coating thickness and plasma treatment.

3. Resource conservation by reprocessing to restore original production quality: Worn tools are refurbished several times by resharpening just prior to reaching end-of-life, effectively preventing scrap. One challenge of reprocessing (de-coating, resharpening, cutting edge preparation, washing, coating, post-polishing) is removal of the worn and often partially oxidized PVD coating without damaging the base material below. Leveraging know-how for each individual process step, we achieve the original manufacturing quality in tools to enable multiple service lives.

Using this threefold approach of vertical integration, dedicated development, and reprocessing, substantial improvement to the sustainability of PVD-coatings is achieved without necessitating any compromise on quality.

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