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## TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

## Bulletin No.190



The Ekeberg Prize 2023: Entries



Flow and stock estimation of tantalum for sustainable supply chain

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#### **President's Welcome**





With the sweltering summer heat already here in the northern hemisphere, I am looking forward to a more moderate climate when we meet at T.I.C. GA64, in Rio de Janeiro, September 10 - 13, 2023.

The response to the Early Bird registration opportunity was the best we have seen in a long time, and this is very exciting. Additionally, many of our friends from China have also registered early. This is the first time we have been able to meet with them, at a GA, since the beginning of Covid and I look forward to greeting them once again.

As I write this letter the T.I.C. staff are in the midst of finalizing plans for GA64. We are looking to make this GA an incredibly special, Brazilian flavoured experience. I am really looking forward to this GA as I was not present at the two earlier GAs held in Rio.

We have received excellent submissions for the Ekeberg Tantalum Prize. The submissions will soon go out to the panel of experts for review and selection of the winner. The quality of submissions is increasing every year as the Ekeberg prize becomes more recognizable in the metals-based community. Our TPO Ian Margerison has been doing extensive outreach in this area, with the entries supporting this effort. The abstract entries of the five finalists are printed in this bulletin.

The technical program for GA64 is also coming along quite well. Something we decided to do this year was to invite mining and minerals engineering students, from the various regional universities, to attend the technical sessions, and learn about the tantalum/niobium industry as well as learn how global industry organisation's function. We are also reaching out to various mining related organisation's such as Brazil Women in Mining and The Brazilian Mining Association (IBRAM), among others. We look forward to their participation.

We have had an interesting year relating to supply chain activity, and while we will not be having any supply chain presentations this year, we look forward to and welcome participation by the various supply chain related organizations.

I would be remiss in not mentioning the departure of Mrs. Emma Wickens, who was our Secretary General for the last 16 years. For those who know Emma, you understand well that her commitment and dedication was key to the T.I.C. functioning smoothly. We wish her only the best in her new endeavours.

With that I also want to welcome our new Secretary General Mrs. Heather Margerison. Heather has been helping Emma over the past few years, onsite at the GAs. Many of you have already met Heather at the previous two GAs. Please welcome and congratulate Heather when you check-in in Rio

In closing, I look forward to hearing from you as we continue to move through this year and closer to GA64, and of course meeting you in Rio.

Sincere regards and travel safe.

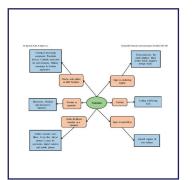
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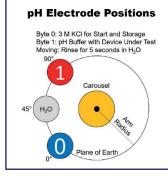
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#### 主席致辞

亲爱的T. I. C. 成员和朋友们



北半球已经进入炎热的夏季,我期待着2023年9月10日至13日在里约热内卢召开的T. I. C. GA64会议时气候更加温和。 早鸟 "注册机会的反响是我们长期以来看到的最好的,这非常令人兴奋。此外,许多来自中国的朋友也提前注册。这是自Covid成立 以来,我们第一次在大会上与他们见面,我期待着再次与他们见面。

在我写这封信的时候, T. I. C. 的员工们正在最后确定GA64的计划。我们希望把这次大会办成一次非常特别的巴西风情大会。我非常期待这次大会, 因为我没有参加前两次在里约举行的大会。

我们已经收到了艾克伯格钽奖的优秀作品。这些作品将很快交由专家小组审查并选出获奖者。随着艾克伯格奖在金属界的知名度越来越高,参选作品的质量也在逐年提高。我们的TPO Ian Margerison在这一领域进行了广泛的宣传,参赛作品也支持了这一努力。五位入围者的论文摘要刊登在本公告中。

GA64的技术计划也进展顺利。我们今年决定邀请各地区大学的采矿和矿物工程专业的学生参加技术会议,了解钽/铌行业,并学习全球行业组织的运作方式。我们还将与巴西矿业妇女组织和巴西矿业协会(IBRAM)等矿业相关组织进行接触。我们期待他们的参与。我们在供应链活动方面经历了有趣的一年,虽然今年我们不会有任何供应链方面的演讲,但我们期待并欢迎各种供应链相关组织的参与。

我不能不提到Emma Wickens女士的离任,她在过去的16年里一直担任我们的秘书长。认识Emma的人都知道,她的承诺和奉献精神是T.I.C.顺利运作的关键。我们衷心祝愿她在新的工作中一切顺利。

在此,我还要欢迎我们的新任秘书长Heather Margerison女士。在过去的几年里,Heather一直在大会现场帮助Emma。你们中的许多人已经在前两届大会上见过Heather了。请在里约报到时欢迎并祝贺Heather。

最后,我期待着在今年的GA64上听到您的消息,当然也期待着在里约见到您。

诚挚问候, 一路平安。

Dr Daniel F. Persico President, T.I.C.

#### Lettre du Président



Chers membres et amis de la C.I.T.,

Alors que la chaleur étouffante de l'été est déjà présente dans l'hémisphère nord, j'attends avec impatience un climat plus modéré lorsque nous nous réunirons à l'AG64 de la T.I.C., à Rio de Janeiro, du 10 au 13 septembre 2023.

La réponse à la possibilité d'inscription anticipée a été la meilleure que nous ayons connue depuis longtemps, ce qui est très encourageant. En outre, beaucoup de nos amis chinois se sont également inscrits en avance. C'est la première fois que nous avons pu les rencontrer, lors d'une AG, depuis le début de la Covid et je me réjouis de les saluer à nouveau.

Au moment où j'écris cette lettre, l'équipe T.I.C. est en train de finaliser les plans de l'AG64. Nous cherchons à faire de cette AG une expérience incroyablement spéciale, à la saveur brésilienne. J'attends avec impatience cette AG, car je n'étais pas présent aux deux précédentes AG tenues à Rio.

Nous avons reçu d'excellentes candidatures pour le prix Ekeberg du tantale. Elles seront bientôt transmises au panel d'experts qui les examinera et sélectionnera le lauréat. La qualité des candidatures augmente chaque année et le prix Ekeberg est de plus en plus reconnu par la communauté des métallurgistes. Notre OPC, lan Margerison, a mené de nombreuses actions de sensibilisation dans ce domaine, et les candidatures soutiennent cet effort. Les résumés des cinq finalistes sont publiés dans ce bulletin.

Le programme technique de l'AG64 est également en bonne voie. Cette année, nous avons décidé d'inviter des étudiants en ingénierie minière et minérale des différentes universités régionales à assister aux sessions techniques et à découvrir l'industrie du tantale et du niobium ainsi que le fonctionnement des organisations industrielles mondiales. Nous nous adressons également à diverses organisations liées à l'exploitation minière, telles que Brazil Women in Mining et l'Association brésilienne de l'exploitation minière (IBRAM), entre autres. Nous attendons avec impatience leur participation.

Nous avons connu une année intéressante en ce qui concerne les activités liées à la chaîne d'approvisionnement et, bien que nous n'ayons pas de présentations sur la chaîne d'approvisionnement cette année, nous attendons avec impatience la participation des diverses organisations liées à la chaîne d'approvisionnement et nous nous en réjouissons.

Je m'en voudrais de ne pas mentionner le départ de Mme Emma Wickens, qui a été notre secrétaire générale pendant les 16 dernières années. Ceux qui connaissent Emma savent que son engagement et son dévouement ont été essentiels au bon fonctionnement du T.I.C. Nous lui souhaitons le meilleur dans ses nouvelles activités.

Je tiens également à souhaiter la bienvenue à notre nouvelle secrétaire générale, Mme Heather Margerison. Heather a aidé Emma ces dernières années, sur place, lors des AG. Beaucoup d'entre vous l'ont déjà rencontrée lors des deux dernières AG. Je vous invite à lui souhaiter la bienvenue et à la féliciter lors de votre enregistrement à Rio.

Pour conclure, je me réjouis d'avoir de vos nouvelles tout au long de cette année et à l'approche de l'AG64, et bien sûr de vous rencontrer à Rio.

Sincères salutations et bon voyage.

Dr Daniel F. Persico President, T.I.C.

#### 社長のあいさつ

親愛なるT.I.C.メンバーと友人の皆様、



2023年9月10日~13日にリオデジャネイロで開催されるT.I.C.GA64でお会いできるのを楽しみにしています。

早期登録の反響は、ここ数年で最高のものでした。さらに、中国からの多くの友人たちも早期登録を行った。彼らとはコビド始まって以来の再会であり、また挨拶できることを楽しみにしている。

この手紙を書いている今、T.I.C.のスタッフはGA64のプランを詰めている最中だ。私たちはこのGAを、ブラジルの香り漂う特別なものにしたいと考えている。 私はリオで開催された以前の2回のGAには出席していないので、このGAを本当に楽しみにしている。

エーケベルグ・タンタル賞には素晴らしい応募があった。応募作品は間もなく専門家パネルに送られ、審査と受賞者の選考が行われる。エーケベルグ賞が金属ベースのコミュニティでより認知されるようになるにつれて、応募作品の質は年々高まっています。私たちのTPOであるイアン・マージェリソンは、この分野で広範な働きかけを行っており、応募作品はこの努力を支えている。最終選考に残った5件のアブストラクト・エントリーはこの会報に掲載されている。GA64の技術プログラムもかなり順調に進んでいる。今年は、様々な地域の大学から鉱業・鉱物工学の学生を技術セッションに招待し、タンタル・ニオブ産業について学ぶとともに、世界的な業界組織がどのように機能しているかを学んでもらうことにしました。また、Brazil Women in MiningやThe Brazilian Mining Association (IBRAM)など、様々な鉱業関連団体にも働きかけています。彼女たちの参加を楽しみにしている。

今年はサプライチェーンに関する興味深い年でしたので、サプライチェーンに関するプレゼンテーションは行いませんが、様々なサプライチェーン関連団体の参加を楽しみにしていますし、歓迎します。

この16年間、事務局長を務めてくださったエマ・ウィッケンズ女史の退任について触れないのは、私の不徳の致すところであろう。エマをご存知の方は、彼女の献身的な取り組みがT.I.C.を円滑に機能させる鍵であったことをよくご存知でしょう。私たちは、彼女の新たな活躍を祈っています。

それとともに、ヘザー・マージェリソン新事務局長を歓迎したいと思います。ヘザーはここ数年、選手権の現場でエマを助けてきました。ヘザーとは過去2回の総会ですでにお会いした方も多いでしょう。リオでのチェックインの際には、ヘザーを歓迎し、祝福してください。

そしてもちろん、リオでお会いできることを楽しみにしています。

よろしくお願いします。

Dr Daniel F. Persico President, T.I.C.

#### **Boas-vindas do Presidente**



Prezados Membros e Amigos da T.I.C.,

Com o calor sufocante do verão já aqui no hemisfério norte, estou ansioso por um clima mais moderado quando nos reunirmos na T.I.C. GA64, no Rio de Janeiro, de 10 a 13 de setembro de 2023.

A resposta à oportunidade de inscrição antecipada foi a melhor que já vimos em muito tempo, e isso é muito empolgante. Além disso, muitos de nossos amigos da China também se inscreveram antecipadamente. Esta é a primeira vez que conseguimos nos reunir com eles, em uma AG, desde o início da Covid, e estou ansioso para cumprimentá-los mais uma vez.

Enquanto escrevo esta carta, a equipe do T.I.C. está finalizando os planos para a GA64. Estamos procurando fazer desta AG uma experiência incrivelmente especial, com sabor brasileiro. Estou realmente ansioso por esta AG, pois não estive presente nas duas AGs anteriores realizadas no Rio.

Recebemos excelentes inscrições para o Prêmio Ekeberg Tantalum. Em breve, as inscrições serão enviadas ao painel de especialistas para análise e seleção do vencedor. A qualidade dos trabalhos enviados aumenta a cada ano, à medida que o prêmio Ekeberg se torna mais reconhecido na comunidade de metais. Nosso TPO lan Margerison tem feito um amplo trabalho de divulgação nessa área, e as inscrições apoiam esse esforço. Os resumos das inscrições dos cinco finalistas estão impressos neste boletim.

O programa técnico do GA64 também está indo muito bem. Algo que decidimos fazer este ano foi convidar estudantes de engenharia de mineração e minerais de várias universidades regionais para participar das sessões técnicas e aprender sobre o setor de tântalo/nióbio, bem como sobre o funcionamento das organizações globais do setor. Também estamos entrando em contato com várias organizações relacionadas à mineração, como a Brazil Women in Mining e a Associação Brasileira de Mineração (IBRAM), entre outras. Esperamos contar com sua participação.

Tivemos um ano interessante em relação à atividade da cadeia de suprimentos e, embora não tenhamos nenhuma apresentação sobre cadeia de suprimentos este ano, esperamos e agradecemos a participação de várias organizações relacionadas à cadeia de suprimentos.

Eu seria negligente se não mencionasse a partida da Sra. Emma Wickens, que foi nossa Secretária Geral nos últimos 16 anos. Quem conhece Emma sabe que seu compromisso e dedicação foram fundamentais para o bom funcionamento da T.I.C. Desejamos a ela o melhor em seus novos empreendimentos.

Com isso, também quero dar as boas-vindas à nossa nova Secretária Geral, Sra. Heather Margerison. Heather tem ajudado Emma nos últimos anos, no local das AGs. Muitos de vocês já conheceram Heather nas duas últimas AGs. Dêem as boas-vindas e parabenizem a Heather quando fizerom o chock in no Pio

Para encerrar, espero ter notícias de vocês à medida que avançamos neste ano e nos aproximamos da GA64 e, é claro, encontrá-los no Rio.

Saudações sinceras e boa viagem.

Dr Daniel F. Persico President, T.I.C.

#### **Editor's Notes**

Dear Members and Friends,

It has been a year of change so far at the T.I.C, with a new Secretary General, who I know well, Mrs Heather Margerison who has taken over from Ms Emma Wickens and we thank again for all her hard work over the past 16 years.



Your executive committee has been working hard in the background to make sure we have a successful 64th general assembly in Rio de Janeiro, Brazil, September 10th to 13th 2023. The T.I.C are most grateful to AMG as the main / platinum sponsors to this year's general assembly.

An exciting program for GA64 is being assembled, including a site visit to CBMM on the Wednesday 13th. Full details of the event can be found on our website at https://www.tanb.org/images/GA64\_general%20information.pdf

I have been travelling extensively this year as part of the outreach program, including a month in North America. With nine company site visits along with two conferences, MMTA April 25th to 26th, Charlotte, NC, USA and Rapid TCT May 2nd to 4th, Chicago, IL, USA.

The T.I.C will be increasing its outreach program along with pushing Niobium & Tantalum into innovative technologies, such as high entropy alloys and supporting members in Additive Manufacturing.

I look forward to welcoming members and friends to the Rio conference and please stop me during the social events if you would like a have a quick talk.

As always, safe travels to Rio de Janeiro.

Warmest regards

Ian Margerison

**Executive Marketing Manager & Technology Officer** 

## Sign up to attend at - www.tanb.org/view/64th-general-assembly

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The T.I.C. is an international, non-profit association founded in 1974 under Belgian law that represents around 90 members from over 30 countries involved with all aspects of the tantalum and niobium industry. The T.I.C. is managed by an Executive Committee elected from the

membership and representing all segments of the industry. Corporate membership costs EUR 2750 per year and full details of benefits are available at www.TaNb.org

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#### Diary of industry events\*

#### September 2023

T.I.C.'s 64th General Assembly and 2023 AGM, September 10th -13th 2023, Rio de Janeiro, Brazil <a href="https://www.tanb.org/view/64th-general-assembly">https://www.tanb.org/view/64th-general-assembly</a>

#### October 2023

EPMA PM2023 Congress & Exhibition, October 1st to 4th 2023, Lisbon, Portugal <a href="https://europm2023.com/">https://europm2023.com/</a>

LME Wee, October 9th to 13th, 2023 London, UK <a href="https://www.lme.com/en/Events">https://www.lme.com/en/Events</a>

RBA and RMI Annual Conference 2023 Oct. 16-19 | Santa Clara, California & Online https://www.responsiblemineralsinitiative.org/events/

CRU Ferroalloys 2023, October 15th to 17th, Orlando, FI, USA <a href="https://events.crugroup.com/ferroalloys/home">https://events.crugroup.com/ferroalloys/home</a>

#### November 2023

Formnext Expo 2023, Frankfurt Messe, Germany <a href="https://formnext.mesago.com/frankfurt/en/planning-preparation/exhibitor-information.html">https://formnext.mesago.com/frankfurt/en/planning-preparation/exhibitor-information.html</a>

TRANSCC 47 November 6th to 10th 2023, Vienna, Austria <a href="https://www.iaea.org/events?page=25">https://www.iaea.org/events?page=25</a>

#### 2024

Investing in Africa Mining Indaba, February 5th to 8th 2024, Cape Town, South Africa <a href="https://miningindaba.com/home">https://miningindaba.com/home</a>

MMTA's International Minor Metals Conference 2024 will be held on 17th-19th April 2024 at the Pan Pacific Hotel, Singapore.

https://mmta.co.uk/event/mmta-international-minor-metals-conference-2024/

Rapid + TCT 2024, April 23rd to 25th 2024, Anaheim Convention Center, Anaheim, CA, USA <a href="https://www.rapid3devent.com/">https://www.rapid3devent.com/</a>

PowderMet 2024 16th-19th June. David L Lawrence Convention Center & the Weston, Pittsburgh, USA

https://www.mpif.org/Events/PowderMet2024/InitialHomePage.asp

#### Member company updates

Since the last edition of this newsletter the following changes have been made to delegate contact details:

- Halcyon Inc. has nominated a new delegate, Mr Dharam Kotecha who can be contacted at dharam@halcyonmetals.com
- MERSEN Deutschland Linsengericht GmbH delegate Mr Thierry Nodari has moved position in his company and the new delegate have yet to be assigned.
- Materion Newton Inc. has nominated a delegate, Mr Robert Marchiando who can be contacted at robert.marchiando@materion.com
- Mitsui Mining & Smelting Co. Ltd has nominated a new delegate Mr Kosuke Kawana who can be contacted at k kawana@mitsui-kinzoku.com
- Orano Nuclear Packages and Services has relocated to, 23 place de Wicklow, F-78180 Montigny-Le-Bretonneux.





# The Anders Gustaf Ekeberg Tantalum Prize: a retrospective

Recognising excellence in tantalum research and innovation

The Anders Gustaf Ekeberg Tantalum Prize ('Ekeberg Prize') is awarded annually by the T.I.C. for excellence in tantalum research and innovation and the new shortlist for the 2023 award shows that the level of interest in element #73 remains as high as ever\*.

The Ekeberg Prize was established by the T.I.C. in 2017 to increase awareness of the many unique properties of tantalum products and the applications in which they excel. To date the Ekeberg Prize has been awarded for outstanding work on the subjects of tantalum capacitors (2018, Dr Yuri Freeman), additive manufacturing (2019, Nicolas Soro et al), recycling tantalum by solvent extraction (2020, Prof. Jason Love et al) cutting of tantalum (2021, Dr Jason M. Davis et al) and tantalum as easy as Pi (2022, Prof. Eric John Schelter).

Technology-driven innovations will ensure the long-term future of the tantalum market and with so many potential new or embryonic applications in development there is every reason for optimism.

#### The judging panel for the Ekeberg Prize

The Ekeberg Prize is judged by an independent Panel of Experts who are selected from around the world to provide an impartial assessment on the technical merit of the shortlisted papers. Members of the current T.I.C. Executive Committee and staff cannot sit on the Panel. This year, we are honoured to have on the Panel the following experts:

#### Dr Axel Hoppe (Chair)

Commerce Resources / consultant, Canada / Germany

Dr Axel Hoppe holds a doctorate in chemistry and has worked in the tantalum industry for many years. He has published several papers on the subject and holds various tantalum patents. For over 30 years Dr Hoppe worked at H.C. Starck, then a subsidiary of Bayer (and now TANIOBIS). His last position at Starck was Head of Technical Services and Engineering Group. Dr Hoppe was a member of the T.I.C.'s Executive Committee from 1997 to 2007 and served two terms as President (2001-2 & 2006-7). Currently he is Chairman of the Board of Commerce Resources, a Canadian junior mining company, and works as a consultant for rare and refractory metals.



#### **Professor Elizabeth Dickey**

Carnegie Mellon University, United States of America



Dr Elizabeth Dickey is the Teddy & Wilton Hawkins Distinguished Professor and Department Head of Materials Science & Engineering at Carnegie Mellon University. Her research aims to develop processing-structure-property relationships for materials in which the macroscopic physical properties are governed by point defects, grain boundaries or internal interfaces. She is regarded as a leader in the application of electron microscopy and spectroscopy techniques to understand the role of material defects on electrical and chemical transport in dielectric materials. She has over 150 peer-reviewed journal publications in these areas. She is a fellow of the American Ceramic Society, the Microscopy Society of America, and the American Association for the Advancement of Science (AAAS).

<sup>\*</sup> Although T.I.C. represents and supports both tantalum and niobium equally, the Ekeberg Prize focuses on tantalum, because CBMM's Charles Hatchett Award (www.charles-hatchett.com) already superbly recognises niobium published research.



#### **Magnus Ericsson**

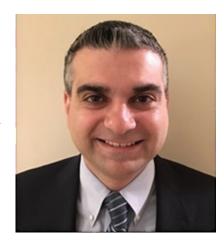
Luleå University of Technology, Sweden

Magnus Ericsson is adjunct professor of Mineral Economics at Luleå University of Technology in the mining heart of Sweden. He is a founding partner in the independent advisors RMG Consulting. He has for decades been closely involved in developing a global mining database. He has established a reputation for developing among the best overviews of the world's mining industry. He has been involved in tantalum mining in Namibia and in an advisory capacity regarding social and community matters for a niobium project in Malawi. He is the deputy chair of the foundation establishing a museum at the site on Resarö outside Stockholm where tantalum was first isolated. He is a co-founder and Editor-in-Chief of the scientific journal Mineral Economics / Raw Materials Report, now in its 35th year.

#### **Dr Nedal Nassar**

U.S. Geological Survey (USGS), United States of America

Dr Nassar is the Chief of the Materials Flow Analysis Section at the National Minerals Information Center, USGS. Dr Nassar and his team quantify the global stocks and flows of non-fuel mineral commodities at each stage of their life cycle, analyse trends and examine concerns regarding foreign mineral dependencies, develop supply and demand scenarios, and assess the mineral commodity supply risk to the U.S. economy and national security. He is a member of the U.S. National Science and Technology Council (Executive Office of the President) Critical Minerals Subcommittee. He received his Ph.D. from Yale University where he worked on the development and application of a methodology for identifying critical minerals. In 2019 he was awarded the Presidential Early Career Award for Scientists and Engineers and he also holds an MBA from Cornell University and two master's degrees from Yale University. Previously, he worked as a consultant and as a process development engineer.





#### Professor Toru H. Okabe

The Institute of Industrial Science, The University of Tokyo.

Dr Okabe's doctorate examined the processing of reactive metals, such as titanium and niobium, and his subsequent career has included postdoctoral research with Professor Donald Sadoway at Massachusetts Institute of Technology (MIT), USA. Dr Okabe specialises in materials science, environmental science, resource circulation engineering and rare metal process engineering. In addition to the research on the innovative production technology, he has worked on new recycling and environmental technology of rare metals, such as niobium, tantalum, scandium, tungsten, rhenium, and precious metals. Dr Okabe is Director General of the Institute of Industrial Science at The University of Tokyo. In 2021 he received an honorary degree from the Norwegian University of Science and Technology for his groundbreaking work on "urban mining".

#### Tomáš Zedníček Ph.D.

President of the European Passive Components Institute (EPCI).

Dr Zedníček's doctorate examined tantalum capacitors and was awarded in 2000 from the Technical University of Brno in the Czech Republic. Prior to establishing EPCI in 2014, he worked for over 21 years at a major tantalum capacitor manufacturer, including 15 years as the worldwide technical marketing manager. He has authored over 60 technical papers and a US/international patent on tantalum and niobium capacitors. He regularly presented at the CARTS passive component conference and other leading events. Since 2017 he has organized the PCNS bi-annual passive components symposium hosted by a European University. Dr Zedníček is a regular contributor to the Bulletin.



#### How the winner of the Ekeberg Prize 2023 will be announced

The winning publication will be announced in August 2023. The lead author will be invited to give a paper at the 64th General Assembly, to be held in Rio de Janeiro, Brazil, in September 2023. During the General Assembly there will be an award ceremony at which the lead author will be recognized by the tantalum industry and receive his/her Ekeberg Prize medal, made by the Kazakhstan Mint from pure tantalum metal (pictured on page 8). The T.I.C.'s General Assembly is open to both members and non-members; full details about the event, including speakers and how to book tickets are available at www.tanb.org/view/64th-general-assembly.

#### **Previous winners**

Since the Ekeberg Prize was launched there have been five winning publications, understanding differences in metal–imido bonding towards improving Ta/Nb separations, examining cutting of tantalum, recycling tantalum by solvent extraction, additive manufacturing, and tantalum capacitors.

The 2022 winning publication the 2022 Anders Gustaf Ekeberg Tantalum Prize ('Ekeberg Prize') was awarded to a US team led by Professor Eric J. Schelter, for its paper "Tantalum, easy as Pi: understanding differences in metal–imido bonding towards improving Ta/Nb separations" published in the Chemical Science, Royal Society of Chemistry. (Reprinted in the T.I.C. Bulletin number 189, published in October 2022 and available at www.TaNb.org).

In 2021 the Anders Gustaf Ekeberg Tantalum Prize ('Ekeberg Prize') was awarded to a US-Japanese team led by Dr Jason M. Davis of the Center for Materials Processing and Tribology at Purdue University, IN, USA, for its paper "Cutting of tantalum: Why it is so difficult and what can be done about it" published in the journal International Journal of Machine Tools and Manufacture and also available in Bulletin issue 187, October 2021.

In 2020 the Ekeberg Prize was awarded to a team from Edinburgh University, UK, led by Prof. Jason Love, for "Tantalum recycling by solvent extraction: chloride is better than fluoride" published in Metals. The paper examined the difficulties of recycling tantalum and discussed their work showing how Ta(V) halides, such as TaCl<sub>5</sub> and TaF<sub>5</sub>, can potentially be accessed from tantalum metal upon acid halide leaching, and can then be recovered by solvent extraction using a simple primary amide reagent. They concluded that extraction of the fluorides was poor (up to 45%), excellent extraction under chloride conditions is found (>99%) and presents an alternative route to Ta recycling.

In 2019 the winning publication was by a team from The University of Queensland, Australia, for "Evaluation of the mechanical compatibility of additively manufactured porous Ti–25Ta alloy for load-bearing implant applications". The authors were Nicolas Soro, Hooyar Attar, Martin Veidt and Matthew Dargusch from the University of Queensland, Australia, and Erin Brodie and Andrey Molotnikov from Monash University, Australia.

The paper examined how additive manufacturing using Ti–25Ta alloy has enabled the optimisation of the mechanical properties of metallic biomaterials. The mechanical properties were found to be suitable for bone replacement applications, showing significantly reduced elastic moduli and superior mechanical compatibility compared to the conventionally used biomedical Ti–6Al–4V alloy, making the Ti–25Ta alloy a promising candidate for a new generation of load-bearing implants.

In 2018, the inaugural Ekeberg Prize was won by Dr Yuri Freeman of KEMET Electronics, for his book "Tantalum and Niobium-Based Capacitors".

Dr Freeman has devoted most of his career to the development of Ta-based capacitors and made significant contributions, technological breakthroughs, and performance improvements in these devices.

Dr Freeman is the Director of Advanced Research in the Tantalum (Ta) business unit and a member of the Advanced Technology Group at KEMET Electronics. He has published more than 30 papers and received 26 patents in the field of physics and technology of Ta and Nb-based capacitors.

The judges' decision to choose the book by Dr Yuri Freeman reflected the general lack of basic books about tantalum and tantalum capacitors in education, as well as it being "a very good scientific overview, providing basic insight into the manufacturing process of Ta-based electrolytic capacitors".

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#### Revolutionising the present and shaping the future

#### The Ekeberg Prize 2023: shortlisted abstracts

#### Recognising excellence in tantalum research and innovation

The Anders Gustaf Ekeberg Tantalum Prize ('Ekeberg Prize') is awarded annually by the T.I.C. for excellence in tantalum research and innovation. The winner will be announced in September and the lead author will receive the award during the T.I.C.'s 64th General Assembly, scheduled to be held in Rio de Janeiro, Brazil, on September 10th to 13th 2023. Full details of the Ekeberg Prize winning publication and how to attend the 64th General Assembly are published on www.tanb.org

The following publications are shortlisted for the Ekeberg Prize 2023:

### Inkjet printed Ta2O5 on a flexible substrate for capacitive pH sensing at high ionic strength

Authors: Christopher Beale a,b, Antonio Altana c, Stefanie Hamacher a,b, Alexey Yakushenko d, Dirk Mayer a, Bernhard Wolfrum a,e, Andreas Offenh ausser a,

#### Organisation:

- a Institute of Biological Information Processing, Bioelectronics (IBI-3), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany
- b RWTH Aachen University, D-52062 Aachen, Germany
- c Faculty of Science and Technology, Free University of Bozen-Bolzano, I-39100 Bolzano, Italy
- d Fraunhofer Research Institute for Microsystems and Solid State Technologies, D-80686 Munich, Germany
- e Neuroelectronics, Munich Institute of Biomedical Engineering, Department of Electrical and Computer Engineering, Technical University of Munich (TUM), D-85748 Garching, Germany

Full article at: <a href="https://www.elsevier.com/locate/snb">www.elsevier.com/locate/snb</a> for more information.

#### Abstract -

Many pH sensors on the market today have specific limitations, such as the large and fragile construction of glass electrodes, or the complicated manufacturing processes of silicon-based devices including ion-sensitive field-effect transistors (ISFETs). Furthermore, most pH sensors require a stable reference electrode, which is difficult to miniaturize. In applications where the solution properties are largely understood, the use of an impedimetric sensor without a reference electrode may be sufficient, thereby simplifying the manufacturing of such sensors. In this work, inkjet printed and flash lamp annealed Ta<sub>2</sub>O<sub>5</sub> on interdigitated electrodes, with an approximate sensor area of 4 mm × 4 mm, is investigated as a capacitive pH sensing layer in 0.5 M alkali chloride buffer solutions. By using the equivalent circuit of the insulatorelectrolyte interface, the double layer capacitance is shown to decrease with an increase in pH within the range of pH 2 to pH 9, and agrees with prior results for anodic Ta2O5. When using the device as a sensor in both 0.5 M NaCl and 0.5 M LiCl aqueous solutions, the change in capacitance at 100 Hz is approximately - 110 nF/pH. Apart from pH sensing, these results may also prove informative in other applications, such as electrolytic capacitors, electrophysiology, and battery anodes in aqueous electrolyte. Moreover, the use of flexible, gold metallized polyethylene terephthalate (PET) foils as the sensor substrate potentially allows for large-scale production via roll-to-roll manufacturing, and further permits for use of the sensor in flexible application such as goods packaging.

#### Permanent magnet alloys for gap magnets

Authors: a Andriy Palasyuk, a Nath Lamichhane, a Olena Palasyuk, a Vladimir Antropov, a Paul C. Canfield, b Ralph W. McCallum, Santa Fe, NM (US)

Organisation: a Ames, IA, USA, b Santa Fe, NM, USA

Full article at: <u>United States Patent Office</u> for more information.

#### Abstract -

Provided are Ce/Co/Cu permanent magnet alloys containing certain refractory metals, such as Ta and/or Hf, and optionally Fe which represent economically more favourable alternative to Sm-based magnets with respect to both material and processing costs and which retain and/or improve magnetic characteristics useful for GAP MAGNET applications.

### Hydrometallurgical recovery of manganese and nickel and isolation of tantalum from obsolete tantalum capacitor

Authors: Munmun Agrawal, Kamalesh K. Singh, Randhir Singh

Organisation: Indian Institute of Technology (Banaras Hindu University), Varanasi 221005, India

Full article at: <a href="https://www.elsevier.com/locate/jece">www.elsevier.com/locate/jece</a> for more information.

#### Abstract -

Tantalum capacitor demand is rapidly growing, primarily from the electronic and superalloy industries. Indeed, the global tantalum market is anticipated to boost at a compound annual growth rate of around 6% over the next decade. With increasing technological advancements, electronics' obsolescence rate has also increased. The obsolete capacitors from these electronics are a rich secondary resource for recycling strategically and economically significant metals. In this article, we have developed an environment-friendly hydrometallurgical route for recovery of manganese and nickel from the tantalum capacitors. Firstly, silica-free tantalum capacitor procured after pre-processing was leached using hydrochloric acid (1–3 M) for preferred dissolution of manganese and nickel, to facilitate a tantalum-rich residue. Manganese was then selectively separated from leach liquor using solvent extraction with D2EHPA and CYANEX272, with the extraction efficiency of each reagent compared. Quantitative dissolution of both manganese (99.9%) and nickel (98.9%), with no tantalum dissolution, was witnessed under the optimized leaching condition of 3 M HCl, 50 g/l pulp density, 60 °C, and 120 min. Kinetic data for manganese and nickel in the temperature range of 30-60 °C demonstrated the leaching reaction at the surface to be the rate controlling step. D2EHPA and CYANEX272 each showed excellent selectivity for manganese under the optimized conditions. However, CYANEX272 proved to be a better extractant in light of higher extraction efficiency in single-stage extraction (~75%), than D2EHPA (~40%), with less organic consumption. Above 99% manganese was selectively extracted with predicted 2-stages extraction by McCabe-Thiele plot using CYANEX272 under the optimized condition.

## An investigation on hydrofluoric (HF) acid-free extraction for niobium oxide (Nb2O5) and tantalum oxide (Ta2O5) from columbite/tantalite concentrates using alkali reductive roasting

Authors: Steven Ghambi a,d, Sergio Sanchez-Segado b,d, Vitalis Chipakwe c,d, Animesh Jha d

Organisation: <sup>a</sup> University of Malawi-The Polytechnic, Department of Mining Engineering, P/Bag 303 Chichiri, Blantyre 3, Malawi, <sup>b</sup> Department of Chemical and Environmental Engineering, Technical University of Cartagena, Cartagena 30202, Spain, <sup>c</sup> Minerals and Metallurgical Engineering, Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Luleå, Sweden <sup>d</sup> School of Chemical and Process Engineering, University of Leeds, Leeds LS2 9JT, United Kingdom

Full article at: www.elsevier.com/locate/mineng for more information.

#### Abstract -

Tantalum, niobium, and their oxides are important precursor materials, essential for high-temperature alloys and electronic devices. The primary hydrometallurgical extraction technique to extract tantalum and niobium from minerals involves hydrofluoric acid (HF) digestion of the concentrates, followed by solvent extraction as an oxide separation and purification step. Solvent extraction, on the other hand, releases organic solvents which are lost irreversibly via natural evaporation during the process. This research demonstrates a novel chemical process for the extraction and refining of columbite and tantalite concentrates (29% Ta2O5 and 16% Nb2O5). In this process, the concentrates are reduced using carbon and alkali in the temperature range of 800–950 °C, which helps in reducing and magnetically separating the iron oxides present in the concentrates as metallic iron. The remaining residue is rich in alkali complex (e.g., sodium tantalates and niobates) formed during the roasting process which was reclaimed as a purified mixture of oxides of Nb2O5 and Ta2O5, by using oxalic acid leaching, followed by sodium bisulphate roasting.

## Sign up to attend at - www.tanb.org/view/64th-general-assembly



The T.I.C. is part of a consortium studying innovative new ways to recover niobium (Nb), tantalum (Ta) and tungsten (W) from mine by-products and processing waste streams, materials which are currently uneconomical.

If you are interested in learning more about this project visit https://h2020-tarantula.eu/ or to register your interest contact the T.I.C. at info@tanb.org.



The TARANTULA project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No 821159.

### Tailoring a speciality alloy for Additive Manufacturing: From powder production to parameter optimisation

Authors: a Dr Markus Weinmann, <sup>b</sup> Dr Shaumik Lenka, <sup>a</sup> Dr David Crudden, <sup>a</sup> Dr Andre Nemeth, <sup>a</sup> Dr Melanie Stenzel

Organisation: a Taniobis GmbH, b Alloyed Ltd

Full article at: <a href="https://www.pm-review.com">www.pm-review.com</a> for more information.

#### Abstract -

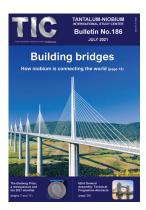
Ultra-high temperature materials, such as niobium-base alloys, have been limited to simple geometric designs due to their high working temperatures and related production costs. Now, thanks to the development of commercially available Nb-base alloy powders, it is possible to additively manufacture complex-shaped, high-performance components from this material. To do so, it is important to understand the full workflow, from powder production and characterisation, to determining the optimal process parameters for these speciality materials. In this article, Taniobis GmbH and Alloyed Ltd detail the process of preparing, characterising, and processing two such alloy powders.

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## 64th General Assembly AGM & technical conference

September 10th to 13th 2023, Rio de Janeiro, Brazil





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#### **BOOKINGS**

The final booking deadline is **Friday September 1st, 2023.** It will not be possible to attend the event without booking in advance. Tickets will not be available on the door. A booking form is sent with this notice: please use one form per delegate. Delegates from non-member organisations will only be confirmed after payment or receipt of credit card details.

#### **REGISTRATION DESK**

The T.I.C. registration desk will be open from 15:00 to 18:00 on Sunday, September 10th. Please come to the desk as early as you can to collect your papers and your badge.

Please always wear your badge during any conference event.

#### **PROGRAMME**

The 64th General Assembly of the T.I.C. is generously sponsored by our platinum sponsor Advanced Metallurgical Group N.V. (AMG) and our lanyard sponsor KEMET Electronics Corp.

**The Annual General Meeting (AGM)** of the Association will be held at 8:30 on Monday September 11th.

**Technical presentations** will be given on Monday (morning and afternoon) and Tuesday morning. Please do not schedule your side meetings during the technical sessions.

On Wednesday, Members have been offered a **tour of CBMM in Araxá**, followed by lunch.

The T.I.C. invites all delegates and accompanying persons to a **Welcome Reception** on Sunday evening, from 18:00 to 20:00.

On Monday evening, all participants are invited to a Gala Dinner in the gardens of the hotel, overlooking the pool.

#### **DELEGATES (TECHNICAL MEETING)**

**Delegates of member companies:** The AGM at 8:30 on Monday is restricted to delegates from member companies. All the delegates from a member company may attend, but only one delegate may vote. He or she will be required to sign in on arrival at the AGM so please arrive in time. If you have a vote, it is important that you attend.

**Delegates of non-member companies:** People from companies which are not T.I.C. members may attend a maximum of two annual conferences as an observer/ potential applicant. If non-members are interested in attending more conferences, they should apply for membership.

## Flow and stock estimation of tantalum for sustainable supply chain

Munmun Agrawal, Rohit Jha, Randhir Singh, Kamalesh K. Singh Indian Institute of Technology (Banaras Hindu University), Varanasi 221005, India

#### **Abstract**

Superior properties of tantalum have made it an element of choice for a wide range of highly specialized applications including electronics, automotive, and aerospace. Indeed, tantalum is a critical metal and its status is conflict mineral as the supply is limited and is largely controlled by few tantalum producing countries. Despite being the important element, a paucity of knowledge on the flow and economic importance of tantalum exists on a global scale that impedes the proper understanding of the metal. The present research, therefore, aimed to quantify the stock and flow of tantalum through its entire life cycle over the year 2010–2019, to find out the economic potential of tantalum that is being discarded. The results indicated that only 21 % of tantalum is entering into the End-of-Life stage, after completing its average residence time, which is the consequence of the relatively long lifespan of key tantalum-bearing products. Nonetheless, the amount of tantalum currently being recycled from the obsolete scrap is <20 %. This is a substantial economic loss, given the criticality of tantalum. Closing the loop of the tantalum life cycle, however, can be a great step towards economic recoveries from waste and promoting a circular economy. An increase in collection rate and increased awareness among people regarding tantalum is necessary to promote recycling to conserve resources as well as to prevent economic loss.

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#### 1. Introduction

The superiority of tantalum in terms of properties such as hardness, melting point, very strong yet ductile, "ultimate" corrosion (Fontana, 1987) and wear resistance, high capacitance/volume, biocompatibility, high-temperature strength, etc. have made its use indispensable in a wide array of highly specialized applications in many industries such as automobile, aerospace, defence, electronics, optics, chemical processing, and medical (Fig. 1) (Mancheri et al., 2018; Nassar, 2017; Soto-viruet et al., 2013). The capacitor market serves as the leading end-user of tantalum due to its' high volumetric efficiency that has enabled exceptional miniaturization of electronic gadgets—a prime demand of today's growing high-tech society (Agrawal et al., 2021; Schulz et al., 2017). The capacitors are used in many high-end applications such as smartphones, desktop computers, laptops, servers, hard disk drive (HDD), implantable cardioverter-defibrillator (ICDs), etc., and account for 34 % of annual tantalum demand (Agrawal et al., 2022; TIC, 2018).

In our modern economy, tantalum has evolved as a "technology-critical element" owing to the rapid digitalization of the world (Filella, 2017). A material's criticality is appraised based on the outcome of the supply shortage of the material and the associated supply risks (Zimmermann and Gößling-reisemann, 2013). In general, a material is termed as 'critical' when there is a high risk of a supply shortage as well as a massive impact of material's supply on the economy of the world in comparison to most of the other raw materials (Zimmermann and Gößling-reisemann, 2013). Since 2017, the supply risk for tantalum has increased. Moreover, tantalum's economic value is growing in capacitors, electro-optical systems, and gas turbine engines (TIC, 2021). Contrary to major metals, including Cu, Fe, and Ni the yearly production of tantalum is limited (1850 tons in 2019) (U.S. Geological Survey, 2020). Furthermore, tantalum has been classified under the category of "conflict mineral", together with Sn, W, and Au, since a major portion of tantalum production is concentrated in the Democratic Republic of Congo (DRC) and other African regions where mining has financed rebel movements (Mancheri et al., 2018).

The unstable supply and cyclic shortage of tantalum, owing to the scarcity of resources, is causing significant price fluctuation and supply strain. This has intensified the need for the substitution of tantalum capacitor. The substitution was witnessed with other capacitors (aluminum capacitor, multi-layer ceramic capacitor) (Nakatani, 2010; Zednicek et al., 2002). However, so far, no substitution was possible without a loss in the performance, such as lesser stability, increased size of the capacitor, reduced capacitance, and reduced ripple capability (Peiro et al., 2013; Schulz et al., 2017). The growing concern regarding the risks and complexities involved within the supply chain is again coupled with low recycling rates (RR).

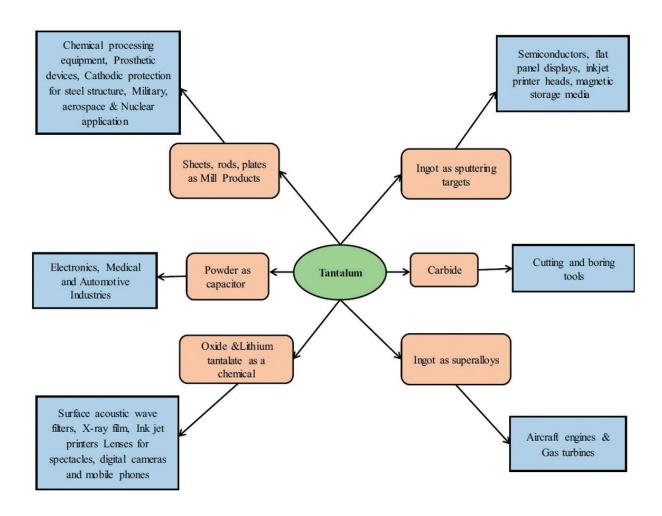


Fig. 1. Major end-use applications of Tantalum (Mancheri et al., 2018; Nassar, 2017; Soto-viruet et al., 2013).

To address the issues of potential supply shortage, supply risk in the future, price, dissipative losses, sustainability, economic concerns, and future demand, a better understanding of the flow of tantalum through the whole supply chain, i.e., from mining to manufacturing, processing, consumption, reuse, recycling, and the discard is essential (Bloodworth, 2014). This stimulated the need to develop a comprehensive material flow analysis (MFA) of tantalum. In contrast to metals such as gold (Au), palladium (Pd), Copper (Cu), Indium (In), Neodymium (Nd), dysprosium (Dy), cobalt (Co), tungsten (W), and other rare earth elements (REE) where plenty of studies have been performed to present a comprehensive material flow analysis (Bonnin et al., 2013; Chancerel, 2010; Chancerel et al., 2009; Chancerel and Rotter, 2009; Du and Graedel, 2011a, 2011b; Habib et al., 2014; Harper, 2008; Harper et al., 2012; Leal-ayala et al., 2015; Shedd, 1998; Spatari et al., 2005; Thiebaud et al., 2018), there seems a significant lag in the area about tantalum. This is mainly attributed to the lack of knowledge regarding the flow (Zimmermann and Gößling-reisemann, 2013), opacity in the element supply chain, and availability of limited data (Filella, 2017). However, a few attempts have been made to develop an understanding of tantalum flow. Peiro et al., 2013 developed the MFA of Ta and other scarce metals, emphasizing their complex inter-relationships (Peiro et al., 2013). Cunningham, 1998 developed recycling flow of tantalum in U.S. for 1998 (Cunningham, 1998). Yen et al., 2016 have given substance flow analysis (SFA) of tantalum in Taiwan for 2013. The research focused solely on the amount and direction of flow of tantalum in the form of capacitors, powder, and waste products within the national borders (Yen et al., 2016). Achebe, 2016 developed a global substance flow analysis of tantalum in 2014. The study focused mainly on the processing stage of the tantalum life cycle i.e., from material sourcing to production and manufacturing (Achebe, 2016). Deetman et al., 2017 derived the European tantalum flows for 2007. The study did not consider End-of-Life (EoL) Ta stock. Moreover, because of data constraints, the SFA modelled for the year 2007, which might not reflect the status in current scenarios (Deetman et al., 2017). Nassar, 2017 presented dynamic global stocks and flow of tantalum for the year 1970–2015 (Nassar, 2017). However, none of the studies provided a quantitative estimation on waste generation and associated economic loss with the amount of metal going into discards.

The goal of the present work is therefore to develop a quantitative model on global tantalum flows to build a comprehensive knowledge on stock and flow of the metal through its entire life cycle with special emphasis given on waste flows. In addition, an economic evaluation of discarded Ta-containing e-waste was done. Based on the results of the study, potential solution in the future is discussed for planning on supply security strategies, resource conservation, and economic gain.

#### 2. Material Flow Analysis (MFA)

Material flow analysis is a method of mapping out quantitative data of flows and stocks of materials (goods or substances) within a system defined in space and time through the process chain (Brunner and Rechberger, 2004). A model comprises processes (where material's transformation/transport/storage takes place) and flows (mass flow rate which link the processes). The terms frequently used in the manuscript i.e., tantalum flow, material flow of tantalum, flow of tantalum all refers to the same concept. The amount of material stored within a process is termed as stock. Anything outside the system boundaries is termed input/output flows (Cencic and Rechberger, 2008). It has now become a globally accepted decision-support tool from a resource, environmental, and waste management point of view and to assess future sustainability (Brunner and Rechberger, 2004; Habib et al., 2014; Leal-ayala et al., 2015). It is based upon the methodological principle of conservation of matter (Ayres and Ayres, 2002; Islam and Huda, 2019). The MFA leads to a better comprehensive knowledge of a reference system that ultimately results in better ecological and economic accounting of the system (Agamuthu et al., 2015; Bonnin et al., 2013). Although there may be a critical data gap on stock and flow of material (Gusukuma and Kahhat, 2018) yet, surveys, interviews, and field studies can be performed to develop the required flow and stock as given by Kahhat and Williams, 2012 (Kahhat and Williams, 2012).

In general, the MFA comprises of four steps: (1) goal and system definition (2) process chain analysis in which different processes involved in the process chain are defined for which input/output has to be quantified (3) accounting and balancing to calculate flows and stocks of material and (4) modelling and result evaluation (Ayres and Ayres, 2002; Brunner and Rechberger, 2004). Two different approaches are followed to measure stocks of material; bottom-up approach & top-down approach. The top-down approach gathers information on materials flow and derives in-use stock by subtracting inflow and outflow data. In contrast that, the bottom-up approach derives the in-use stock by collecting the information on stock variables (Gerst and Graedel, 2008). MFA can be either static which gives a picture for a particular year or dynamic to show the changes in a system over a longer time interval (Müller et al., 2014).

#### 3. Methodology

The steps involved in material flow analysis of tantalum are presented with the help of a flowchart in Fig. 2. This chapter is organized in the following manner. Section 3.1 describes the system boundaries considered in the present research to derive the MFA. Section 3.2 presents the data collection and assumptions made during this analysis.

Section 3.3 represents the flows and stock estimation whereas Section 3.4 shows the economic assessment of waste flows.

#### 3.1. System boundaries

MFA gives the systematic assessment of material's mass flow within a system boundary defined in space and time. The space boundary chosen in the present study is the globe, whereas the time boundary is confined within a decade from 2010 to 2019 to provide the most relevant information on tantalum flow over the recent past. The choice of such a large spatial and temporal boundary imposes a major limitation insofar as the accessibility of data for every flow of the material is concerned.

#### 3.2. Data collection and assumptions

As mentioned earlier, data availability and assumptions are the principle limitation of performing MFA, which is even more challenging with regard to tantalum, however, an extensive data collection was performed through various scientific journals, reports, and websites to derive the global anthropogenic material flow of tantalum through its life cycle stages. The specific countries involved in different stages of MFA i.e., Ore producing, fabricating/refining and capacitor manufacturing are listed in Table S1.

Along the entire life cycle, tantalum passes through five main stages viz. production, processing, manufacturing, consumption, and EoL. In the production unit, tantalum is produced from the raw materials either by primary (natural ore) or secondary means (EoL products recycling). Then it is sent to processing unit where intermediate products (tantalum powder, ingots, sheets, rods, etc.) are manufactured. Thereafter it enters into the manufacturing unit for the fabrication of finished good. Finally, it is consumed by the users and then either discarded on enters into the recycling unit. Statistics related to the production were obtained from a bulletin published by the Tantalum-Niobium international study center (TIC, 2016, 2020, 2021). Using the data published by the U.S. Geological Survey (U.S. Geological Survey, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021), Fig. 3 presents the graph on global countrywise mine

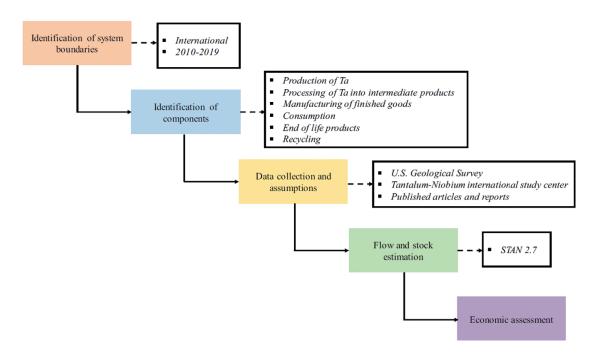
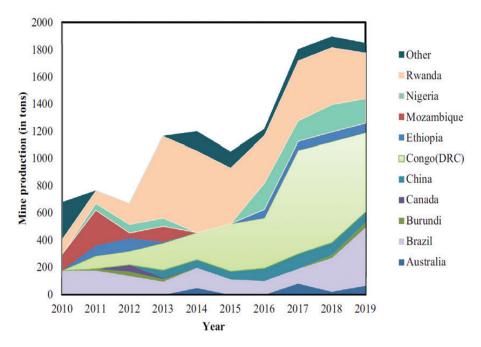


Fig. 2. Material flow analysis framework for tantalum.



**Fig. 3**. Country wise annual tantalum production during 2010–2019 (U.S. Geological Survey, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020).

production of tantalum for the year 2010–2019. Earlier input flows data, needed to determine waste flows of products expiring during 2010–2019 from production before 2010, was obtained from TIC bulletins (Bulletin104, 2000; TIC, 2006, 2010).

The data on the allocation of tantalum into various product streams were taken from the Roskill information service (TIC, 2018). Due to the unavailability of data, the relative distribution of tantalum into each category is assumed to be more or less similar as shown in Fig. 4. However, a sensitivity analysis was done with maximum, mean, and minimum percentage of each product categories to draw its effect on total waste flow for the year 2010–2019.

After completion of the average lifetime, the product enters into the EoL stage. Average lifetime data given in Table 1 for each product category, needed to calculate the total EoL waste, was obtained from various sources in the literature (Nassar, 2017; Nomura and Momose, 2008; Oguchi et al., 2006, 2008; Smith, 1994; Streicher-porte et al., 2007). After reaching the EoL stage, the product is either recycled for resource recovery or ends up as waste. Data regarding the amount of tantalum being lost along the different life cycle stages were taken from Gille and Meier (2012).

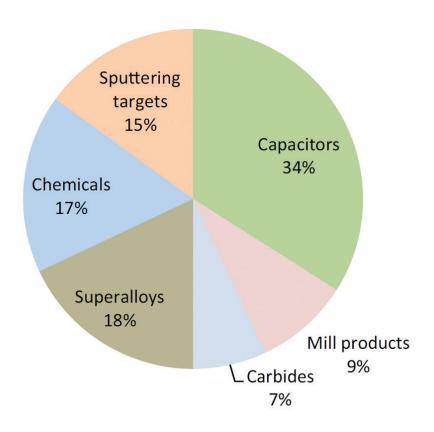


Fig. 4. Consumption of Tantalum in different product categories (TIC, 2018).

#### 3.3. Flows and stock estimation

After collecting data, the next exercise that needs to be performed is product balancing (mass balance calculations based on principle of conservation of mass) to facilitate flows and stock estimation. Free software developed by the Vienna University of Technology (TU Wien), STAN 2.7 (Wien, 2006) was employed to perform the MFA (screen capture for the same is included in the supplementary file Fig. S1) it enables the graphical modelling and analysing flow and stocks of a complex system by using predefined components, where the mass conservation is maintained throughout the flow. The STAN allows the analyst to integrate uncertainties of input data in the form of standard deviation. Besides that, the software also aids in data reconciliation, error propagation, and gross error detection (Agamuthu et al., 2015). The analysis results are visualized in the form of a Sankey diagram. The diagram shows energy or mass flow with the help of arrows where the widths of the arrows correspond to the relative magnitude of flows. Every process within the supply chain acts as a reservoir, where matter flows, processed, used, and then transferred (most probably after transformation) into another stage of the life cycle within the system boundary (Spatari et al., 2005).

The basic equation employed by the software to develop the mathematical model based on the law of mass conversation is Eq. (1):

$$dStock = \sum F_{in} - F_{inout}$$

where Fin and Fout are input and output stock respectively and dStock is the accumulation of stock in a process. Under the steady-state condition where the net accumulation of stock is zero, the equation can be modified as Eq. (2):

$$\sum F_{in} \cdot = \cdot \sum F_{out}$$

After the completion of useful life, the product enters into the EoL category. The flow leaving the consumer unit and appearing in the EoL stage was determined using a residence time model (a model used to calculate the discard flow based on the average lifetime of product). The model accounts for the waste stream by utilizing the annual input data of Ta for each end-use category together with the mean residence time of the product. The formula used to determine the total EoL flow of Ta is Eq. (3):

**Table 1**Average lifespan of various tantalum-based products.

Product category	Product components	Average product life (year)	Reference
	Cellular phones	4.3	(Oguchi et al., 2006)
	Computers & business machines	7.1	(Nomura and Momose, 2008)
Capacitor	Consumer electronics	6.8	(Oguchi et al., 2008)
	Automobiles	15.9	(Nassar, 2017)
	Infrastructure, industrial, and specialty	15.3	(Nomura and Momose, 2008)
Mill products		20	(Rowe, 1997)
	Cutting tools	1	(Smith, 1994)
	Wear parts	1	(Smith, 1994)
	Mining and drilling tools	30	(Smith, 1994)
Sputtering targets		7.2	(Nassar, 2017)
Superalloys		11	(Nassar, 2017)
Chemicals		8	(Nassar, 2017)

$$F_{i,j} = \sum_{i=1}^{6} \sum_{j=2010}^{2019} F_{i,j-RT}$$
(3)

where,  $F_{i,j}$  = EoL flow of Ta for product i in year j. i = product category counter. j = year counter. RT = residence time of the product.  $F_{i,j}$ -RT = amount of Ta entering the product category i in year j-RT.

#### 3.4. economic assessment of the waste flows

After calculating the total EoL stock and determining the recycling flow, next we assessed the economic value of the discarded material. The economic value of the recyclable material was computed by using the following Eq. (4):

Total economic value of waste = Total Ta content of the waste

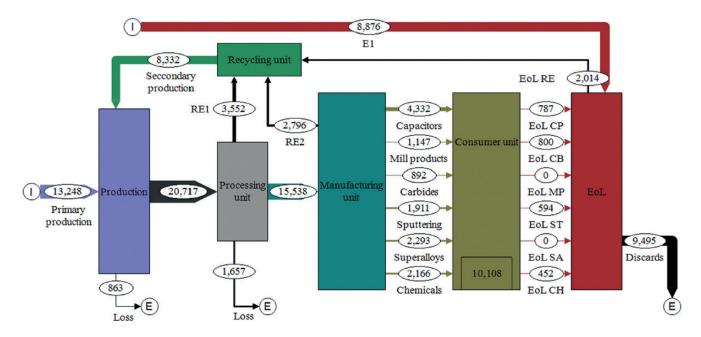
Since the largest proportion of total tantalum (34 %) is consumed in the electronics sector in the form of capacitors, we considered only capacitor waste from the resource recovery point of view. Most of the literature has reported a recovery yield of tantalum from capacitor waste in the range of 90–98 % (Chen et al., 2019; Mineta and Okabe, 2005; Niu et al., 2017), a mean value of that was considered in this research for the economic assessment of waste.

#### 4. Results

This section describes the results of MFA in Section 4.1 followed by an economic assessment of discarded e-waste in Section 4.2. The result of the material flow analysis of tantalum through its life cycle stages is presented in Fig. 5. The rectangular boxes show each life cycle stages from which material (tantalum) passes. Each process is connected by arrows which show the mass flow. The width of an arrow is proportional to the amount of mass flow from one life cycle stage to another whose value is shown in the ellipse. The amount of material stored in a process i.e., stock is represented by a rectangular box inside a process box. Arrows with end knot 'I & E' refers to import (flow into the system) and export flows (flow out of the system), respectively.

#### 4.1. The MFA of Ta

Result shows that a total of 21,580 tons (primary and secondary) of tantalum was produced from 2010 to 2019. Out of this, 13,248 tons of tantalum was from primary mine production; whereas, 8332 tons of tantalum was secondary from tin slags and pre-consumer scrap recycling.



**Fig. 5.** Global mass flow of tantalum for 2010–2019 (CP-capacitor, CB-carbides, SA-super alloy, MP-mill product, CH-chemical, ST-sputtering target, E1-waste flows from stock (CP, CB,MP, SA, CH, ST) before 2010, RE-recycling).



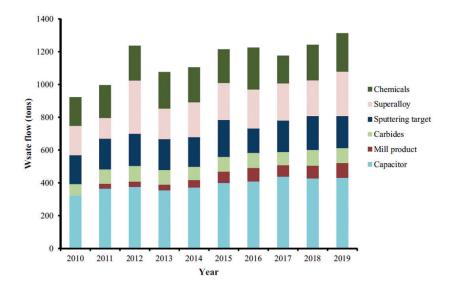
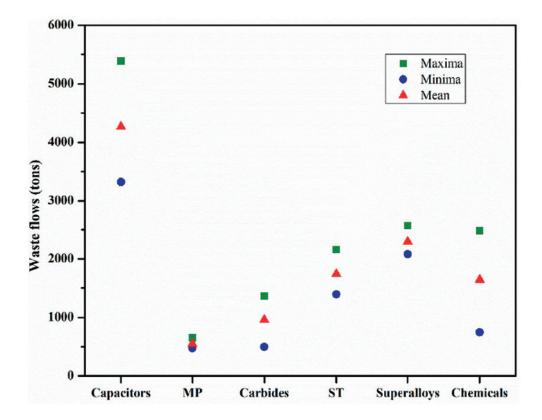


Fig. 6. Worldwide tantalum waste generation for each product categories during 2010–2019.

The pre-consumer scrap reclaimed during the processing and manufacturing stage plays a significant role in tantalum supply, accounting for 20–25 % of the annual tantalum production (Buchert et al., 2009; Burt, 2016). During the production stage about 4 % of tantalum is lost which do not return to the supply chain. After the production, tantalum enters the processing stage, where intermediate products (powder, ingots, fabricated products, etc.) are manufactured. During this stage the amount of tantalum end up as waste is around 8 %, whereas, 17 % of waste is recycled/refurbished and re-enter into the supply chain. These intermediate products are then treated in manufacturing units to produce finished goods. A considerable amount of scrap is generated during this stage. According to (Nassar, 2017), 8 %, 5 %, and 10 % of tantalum flow into the manufacturing stage is generated as scrap during capacitor, carbides, and superalloy manufacturing, respectively. A large portion of this scrap is recycled (approximately 18 %) and sent back to the production unit. The outlet of the manufacturing unit shows the proportion of tantalum going into each of the product categories. It is seen that the capacitor segment accounts for the largest share of tantalum consumption (4332 t), followed by superalloys (2293 t), chemicals (2166 t), sputtering targets (1911 t), mill products (1147 t), and carbides (892 t). Fig. 5 further shows that 10,108 t of total tantalum was held in stock whereas, 2633 t of tantalum left the consumer unit (for the modelled period), entering the EoL stage after completing their average lifetime.

Fig. 6 demonstrates year-wise data on waste flows for individual product categories. Besides this, the products expiring during the modelled year (8876 t) from the stocks before 2010 were also accounted while calculating total EoL products. Out of total EoL product, the amount of tantalum being recycled was only 2014 t (i.e. <20 % of the total EoL discards!) with the remaining (>80 %) ending up in discards. A major portion of EoL product recycling is coming from mill products and the superalloy sector. However, the capacitor segment, with a huge recycling potential, is the greatest handicap with almost no recycling. Ta waste flows are on the rise over the decades studied in this work (Fig. 6). Based on this trend and with the increasing demand of tantalum it can be expected that the future waste generation will confirm to this trend. Likewise, recycling rate of Ta is on the rise. The RR has gone up from a value of  $\sim$ 6.5 % in 1995 to  $\sim$ 17.5 % in 2012 (Gille and Meier, 2012). In all likelihood, the RR of Ta will be accelerating in the years to come, given the pressure on the primary resources and a growing awareness about urban mining. The present trends in waste generation and the RR suggests that in a decade or so it is possible to achieve a declining net waste generation.

Due to unavailability of data for each year it was assumed that relative distribution of tantalum into each product category is more or less same, which is not the case in real. Therefore, to get an estimate on effect of data variation on waste generation, sensitivity analysis was done for individual product category. From the data reported by Roskill for the year 2008, 2012, 2016, and projected data for 2026 (Table S2), minimum, mean, and maximum value was selected for each product category (Stratton, 2013; TIC, 2018). The result of sensitivity analysis is presented in Fig. 7. In all three cases, the amount of tantalum ending up as waste is evident where capacitor segment accounting for largest waste generation in all three scenarios.



**Fig. 7.** Effect of change of relative distribution of tantalum into each product category on waste generation during 2010–2019 (MP- mill product, ST- sputtering target).

From the above results, it can be concluded that tantalum is forming an open-loop life cycle with substantial material loss of high economic value which is described in the subsequent section. Losses occurring in various life-stages, including the 8876 t of waste flow beginning 2010 (Fig. 5), are, in most part, recoverable if it's not processed further, i.e., it's still is stored by the end user at the EoL. The exact status of the global waste tantalum inventory is hard to fathom unless these inventories are visited to recover metal values methodically.

#### 4.2. Economic assessment of potentially recyclable waste

The total economic value of waste generation from tantalum-containing e-waste (capacitor waste) was calculated using Eq. (4). The capacitor segment, although accounts for the largest proportion of total tantalum consumption (34 %), yet their contribution to EoL recycling was nil, which is why we have chosen capacitor waste for recycling point of view. To present the most feasible scenario, we considered that only 20 % of Ta from the electronic waste could be successfully collected and recycled. The annual report on mineral commodity summaries given by the U.S. Geological Survey for the year 2021 showed that the tantalum market price was 161 USD per kilogram of Ta2O5 in 2019. The total content of tantalum entering into the waste flow in the year 2010–2019 from the capacitor segment alone was calculated to be approximately 3190 tons which is equivalent to 3896 tons of Ta2O5. Based on this, the calculation was performed as follows:

Total economic value of waste = 
$$3896 \times 1000 \times 0.20 \times 0.95 \times 161$$
  
  $\approx 120 \text{ million USD}$ 

Thus, tantalum from e-waste alone and assuming only a 20 %recycling rate, with a total value of 120 million USD, was discarded over 2010–2019. Since the recycling rate and recovery yield we assumed here is not fixed in practical, that is why we have done sensitivity analysis to analyse the effect of variation of those factors on total economic value. The range for recycling ration was set to 5–50 % whereas, the range for recovery yield was varied from 85 to 99 %. In the most pessimistic (RR = 5 % and recovery yield = 85 %) and the optimistic scenarios (RR = 50 % and recovery yield = 99 %) studied, the economic value of the recycling in the capacitor segment ranged from 27 to 310 million USD.

Considering the scarcity of resources and risk involved in the supply of tantalum, this serves as a grave concern and at the same time, a great opportunity in the future to harness secondary means of production of a critical material like tantalum for a sustainable supply. Furthermore, the amount of tantalum lost in other product categories accounting for 64 % of Ta usage, and in other part of the supply chain, need to be considered to reach our final goal of maximum resource utilization with minimal dissipative loss along the life cycle stages.

#### 5. Discussion

Based on the results obtained in the Section 4, Section 5.1 identifies the key factors accounting for the low RR of tantalum and finally (Section 5.2) presents some potential measures that can be adopted to improve the RR.

#### 5.1. Key causes of low RR

From the result of the MFA and the economic assessment of Ta-containing e-waste, it is clear that tantalum recycling has a huge economic potential. For any closed-loop life cycle, the amount of waste being generated along the supply chain is minimized as the material flow along the cycle is maximized. Promoting the close loop life cycle ultimately aims to save the natural resource while keeping the environmental burden minimal. The reality is not that perfect for the tantalum life cycle. Currently, a considerable part of tantalum supply relies upon natural resources, i.e., conventional mining and artisanal or small-scale mining. Besides this, a significant amount of tantalum is lost along the life cycle. Plenty of pre-consumer scrap arising from the manufacturing of electronic components, superalloys, and Ta carbides are presently being recycled owing to their high purity, reduced complexity, and ease in collection and processing of waste (Mancheri et al., 2018). Despite that, EoL stage recycling of tantalum is very less. The chemical characteristic of tantalum facilitates its oxidation during base metal recovery. Hence tantalum gets dissipated into the slag phase and ultimately ends up in landfilling or other construction work and evades recycling. Another cause for the low EoL recycling rate is the tiny concentration of tantalum (<0.01 % in waste printed circuit boards (WPCBs)) with respect to other metals such as Cu (16 %), Ni (2 %), Ag (0.05 %), Au (0.03 %) (Ari, 2016) in consumer finished products which makes the tantalum recycling process economically unattractive.

Recycling aims to restrain the natural resources' consumption and bring down the environmental burden. Recycling is the strategy for closing the loop of the materials life cycle and satisfying the demand employing urban mining from EoL products. Fig. 8 shows the schematic diagram of existing open-loop life cycle and proposed close-loop life cycle of tantalum. The solid arrows in the figure represent existing open loop life cycle, whereas, the dashed arrows represent the proposed route for closing the loop or maximizing the flow of tantalum along its life cycle stages. The dashed line from processing and consumption unit is to make the flow of waste occurring in the reference stage to the recycling unit. Similarly, the dashed arrow from processing to production stage corresponds to the material which is lost during the processing and can be re-used without any recycling treatment. Closing the loop and avoiding the loss of material in different life cycle stages will be a vital part considering the high economic value of tantalum. High recycling efficiency will greatly minimize dependency on primary resources (dominated by a few countries), which is of great importance from resource conservation standpoint.

#### 5.2. Potential solution to improve RR

1. Recycling rate of any metal is the function of collection rates. Majority of EoL product does not reach to the recycling chain. The collection of EoL products containing tantalum is quite low. For instance, only 10 % of total EoL mobile phones are currently being collected (Wansi et al., 2018). Results of the previous studies showed that a larger proportion of total EoL stock was stored by the user, mainly households and small and medium business sectors (Agamuthu et al., 2015; Gusukuma and Kahhat, 2018). Collection of these obsolete products has a higher activity due to its impact on downstream processes, i.e., recycling and environmental disposal. Several different approaches can be adopted to improve collection rate. Producers hold responsibility for financing e-waste collection and recycling. An effective take-back scheme should be implemented by extending supplier as well as consumer responsibility to promote collection of EoL waste stream from household and businesses to the supply unit. Moreover the usual habit of the consumers is to store the electronic gadgets in households even

after it has become obsolete (Gurauskiene, 2011). For that, the consumers should develop awareness and consciousness about electronic waste recycling and actively participate in the environmental protection. From 2018, EU directive on Global E-waste Monitor revised the legislation by setting a target for the collection of 85 % of total e-waste generation (Forti et al., 2020). The implementation of these directives, however, should be strictly followed to build a critical mass flow of material towards the recycling.

- 2. From the recycler's point of view, a different approach could be adopted for the recycling of tantalum based products. Taking the example of tantalum in electronic waste (because maximum proportion of Ta is utilized in electronic sector), physical separation of tantalum capacitor from the WPCBs before treating it as a whole for the recovery of other base metals and precious metals could be an alternate economical way to recover the metal. By doing this loss of tantalum into the slag phase, while recovering the base metals, will be greatly minimized.
- 3. Besides this low collection rate, tantalum is often lost in other material flows. This loss is mainly due to tiny concentration of tantalum in comparison to other base and precious metals and lack of awareness and actionable information within the recovery framework regarding importance of critical high-tech metals present in e-waste (He et al., 2021) especially Ta. The government should recognize strategic importance of Ta present in e-waste. Furthermore, the government should make appropriate policies to spread awareness among people regarding the economic importance of critical metals and their dissipative losses. Also, the government should invest fund in research and development area so that the researcher may come up with a better cost-effective recycling strategies.

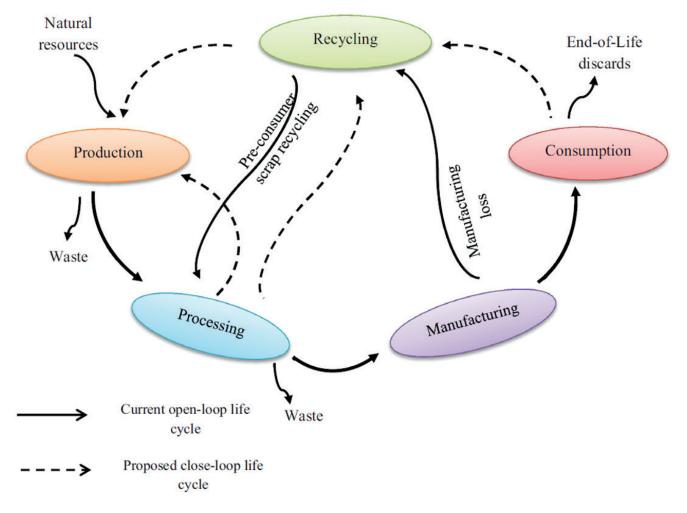


Fig. 8. Current open-loop and proposed close-loop life-cycle of tantalum.

Regarding the existing circular economy approaches, there are various legally binding policies and legislation are enacted in different regions of the world. However, enforcement of those policies is the key issue. Various legislations are made to improve the collection rate such as e-waste collection in shops and municipalities by private operators, municipal drop-off, collection points, private pick-up, collection from

repair and service centers in Belarus, various laws by Asian countries to drive formal recycling, etc. A large proportion of e-waste generated in Central Asia ends up in landfills or illegal dumping sites (Forti et al., 2020). In Europe, the major portion of e-waste generated is regulated by the WEEE Directive (2012/19/EU) (Union, 2020) which set target for collection, recycling, reuse, and recovery. Besides this, various policies such as extended producer's responsibility, take-back scheme, setting of collection points and pick-up centers are functioning in different parts of the world (Forti et al., 2020). Strict implementation of those policy throughout the world may help in achieve this circular economy goal. A detailed table (Table S3) to summarize the amount of e-waste generated and recycled country-wise, and the concern/issues of associated country/region with low RR is presented along with some recommendations to improve this RR. As the number of countries are large, only those responsible for generation of >100 tons of e-waste are included in the table. Each country in a particular region is divided into two part based on the status of national e-waste legislation/policy or regulation.

#### 6. Conclusions

The present study mapped the global anthropogenic mass flow of tantalum for the last decade (2010–2019) through its five main life cycle stages from production to disposal and evaluated the economic value of discarded Ta-containing e-waste. The calculation based on the average lifetime of the product showed that out of the total Ta entering the EoL stage, only 17.5 % was actually recycled with no recycling from capacitor waste. A large proportion of total tantalum entering into the EoL stage is being dissipated. In addition to that, the chemical nature of tantalum leads to its oxidation during the processing of other base metal and evade recycling route by formation of slag. The total economic value of waste by recycling just 20 % of capacitor turned out to be 120 million USD.

The potential solution proposed in the present study to reduce the amount of tantalum going into the waste flow and promote the circular economy is developing a close-loop life cycle for the metal. The step will significantly minimize the economic loss with reduced material dissipative losses while lowering down the dependency on natural resources for the supply. Another solution to promote the recycling of tantalum is facilitating a higher collection rate of the obsolete scrap by extending suppliers and consumers responsibility to mandate a take-back scheme. Increasing awareness among people and sensitization of the government and the companies involved towards the "criticality" of tantalum are needed in order to promote future research and development in the area of Ta recycling.

#### **Data availability**

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

#### **Declaration of competing interest**

The authors 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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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi. org/10.1016/j.spc.2022.10.002.

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#### 64th General Assembly: Technical Programme Abstracts



The following papers are expected. The announced presenter is the first author listed, unless otherwise specified. Please note that this list is subject to change.

#### **Ekeberg Prize, winning publication**

The winner will be announced in September.

#### **Brazil Mining Industry: Yesterday, Today and Tomorrow**

By Julio Cesar Nery Ferreira – IBRAM (Brazil Mining Association)

The presentation will cover a short history and evolution of mining in Brazil, including the broad set of minerals mined in Brazil, by volume/value today. The content will cover the potential for tantalum offtake from lithium mining and the importance of the various sources of niobium and the Brazilian Governments strategy regarding investment and increased royalties from mining and impact on investments. The presentation will provide a focus on critical minerals and potential impact on future mining development in Brazil, with potential issues/challenges moving forward based on global ESG strategies.

#### **Ekeberg Tantalum Innovation Prize Winner**

#### Niobium refining by electron beam cold hearth refining

By Mr Jochen Flinspach – AMG/ALD Vacuum Technologies

Considerations and results from melt trials performed at ALD Vacuum Technologies GmbH. Niobium Metal production typically starts with aluminothermic reduced Niobium with a high residual content of Aluminium. Such Material is the starting point for further refining with the Electron beam melting technology. The ALD inhouse system is set up to be able to perform all melting configuration used in the industry and perform tests on a production scale. Standard procedure for production of high purity Niobium is at least triple melting of the material to achieve low impurity contents. Cold hearth refining is well known and established in the Titanium industry especially for the remelting of scrap and some characteristics can be thought to be beneficial for refractory metal melting also. ALD performed trials on their inhouse system to investigate if a double melt process combining cold hearth refining and a further vertical dripmelt is feasible to achieve a similar refining effect than the standard triple melt.

### Prospects for greatly increased tantalum supply on the back of the electrification of transportation

By Andrew Matheson – Ximei Resources Holding Ltd

Rapidly increasing demand for lithium has spurred expansions of lithium production in hard rock as well as brine lithium deposits, not to mention a substantial upswing in exploration. Hard rock lithium mines in many instances hold the promise of tantalum as a byproduct stream, meaning that tantalum supply can in theory see large increases in tandem with lithium. The presentation explores the potential for such an increase as well as some of the challenges.

### Research on Preparation Technology of High Purity Tantalum Powder for High Purity Sputtered Tantalum Target

By Mr Chen Xueqing – Ningxia Orient Tantalum Industry Co., Ltd

This article introduces the development trend of high-purity tantalum powder for high-purity sputtering tantalum targets, mainly elaborating on the preparation methods of this kind of high-purity tantalum powder. Through the research on the deep removal technology of W, Mo, Nb in the preparation process of high-purity Potassium heptafluorotantalate, the research on the physical property control technology and anti-corrosion mechanism in the reaction process of sodium reduction of Potassium heptafluorotantalate, and the research on the subsequent impurity control technology of high-purity tantalum powder, then high-purity tantalum powder with purity (GDMS detection) of more than 99.998% has been developed, of which the total amount of three high-temperature Refractory metals such as W, Mo, Nb is less than 0.35ppm, It meets the specification requirements for high-purity sputtering tantalum targets with a purity of over 99.9998%.

#### **Brazil Women in Mining: An Overview**

By Patricia Procópio – Women in Mining - Brasil

Women are significantly underrepresented at all levels of the mining industry, from Engineering to the Board Room. The Women in Mining Brasil (WIM) organization has developed a comprehensive strategy to address these and other issues, both corporate and social, related to increasing women's inclusion in the mining industry, in Brasil. The presenter Patricia Procópio, President of WIM Brasil, was selected as one of the "100 Global Inspirational Women in Mining" and thus has a unique position and view of the issues related to the barriers and challenges facing women in their efforts to become a more relevant force in the global mining industry.

#### **Tantalum Wire for Medical Applications**

By Scott Shoppell, Jeff Slater – Fort Wayne Metals

Fort Wayne Metals has been supporting a wide range of tantalum (Ta) based applications in the medical community for over three decades. The material properties of Ta have made it an excellent choice for applications where biocompatibility, imaging, corrosion resistance, ductility, and osseointegration are critical to the success of the device. The recent acquisition of equipment and assets from Plansee SE will significantly expand our capabilities to support Ta markets and applications (e.g. capacitor industry) that go well beyond our existing medical customers. Fort Wayne Metals has also expanded its processing and development efforts in critical applications involving niobium (Nb), specifically related to superconducting, green energy, and medical markets. This presentation will highlight our company, along with a wide range of materials, capabilities, and products that add value to the Ta and Nb communities, along with the overall global metals marketplace.

#### Top 10 business risks and opportunities for mining and metals in 2003

By João Brito Ferreira - Value Chain Integration Leader for Mining & Metals/Partner Ernst & Young

Over the past 20 years, various factors have impacted and therefore initiated risk in the mining and metals sector. Global economy dependent, factors such as cost reduction, industry consolidation, capital management, resource nationalism, global skills shortages, tightening economies and inflation all contributed to increased or decreased risk, in the past, depending on where we were in the cycle.

Over the past few years, the emergence of social issues has led the list of risk factors: the environment, social issues, and governance (ESG) heading up this change. As such, the mining and metals sector is responding with more fundamental shifts in business and operating models, analyzing where optimal value can be found, and responding with changes in business models in pursuit of value attainment.

The ultimate goal, as always, is to gain a sustainable competitive advantage. In this presentation we will review the fundamental issues impacting and creating risk in the mining and metals sector today and discuss possible remedies.

#### **CBMM: Leading Niobium Supply and Innovation**

By Isadora Maria Oliveira Anício Costa; Edmundo Burgos Cruz; Rogério Marques Ribas; Mariana Perez de Oliveira; Gustavo Giovanni Ribeiro Abdo; João Batista Ferreira Neto; Rafael Agnelli Mesquita — Companhia Brasileira de Metalurgia e Mineração

Companhia Brasileira de Metalurgia e Mineração (CBMM), headquartered in Araxá, Brazil, is the global leader in production and commercialization of niobium products. With over 60 years of influence in the niobium industry, CBMM has leveraged its expertise and pioneering mindset to consistently drive advancements, ensuring market readiness to meet the escalating demands of its diverse customer base spread across more than 50 countries. The company offers an extensive portfolio of products, centrally focused on the provision of ferroniobium, an important component used in the alloying of numerous steel types. It also supplies specialized products including niobium oxides, vacuum-grade ferroniobium and nickel-niobium alloys, and niobium metal, thus catering to diverse needs such as batteries, power electronic components, castings, superalloys for the aerospace and chemical industries, amongst others. As part of its commitment to innovation, the company continues to focus on diversifying niobium applications and exploring new segments. At the forefront of the green energy transformation, CBMM is enhancing lithium-ion batteries by the addition of niobium into the cathode formulations bringing excellent ionic conductivity and stabilizing effects leading to much better charging rates and cycle life. From the anode perspective, niobium-based oxides can rapidly and reversibly intercalate large amounts of lithium for thousands of cycles, offering new strategies towards designing batteries with advantages in energy density, ultra-fast charging capabilities, wider range of temperature operations and ultimately decades of life span. The company is also exploring the potential of niobium bearing soft magnetic materials that can bring miniaturization and higher efficiency in a series of different power electronic component application, such as components used in the on board and off board charging of electric vehicles. Beyond that, CBMM continues to deepen its understanding of niobium-based superconductors, which are essential for powering healthcare and scientific equipment that requires strong, stable magnetic fields. It also holds promise for use in energy-efficient power transmission applications in renewable energy technologies, such as wind turbines and solar panels. The main target is to increase the niobium market in applications where it brings valuable and sustainable solutions to the entire supply chain and end users.

#### A Ta-Nb Composite Anode Lead Wire for Tantalum Capacitor

By Linghui DU - Shaanxi Unique Rare Metal Materials Co., Ltd.

A tantalum-niobium composite anode lead wire for tantalum capacitor and a preparation method thereof are discussed in this paper. Compared with pure tantalum anode lead wire, tantalum-niobium composite wire, a new type of anode lead wire, has not only almost the same performance but also lower cost. It includes: a core body, which is made of niobium-based alloy; and a tantalum metal layer, which clad the core body. The outer tantalum layer can form an oxide film with a high dielectric constant and high reliability on the surface of lead wire thereof by means of anodization which meets the requirement of tantalum capacitors for a high dielectric constant of the anode lead. Moreover, the cheaper niobium-based alloy core can lower the cost significantly at the same time. Tons of this new type of anode lead wire have been used in tantalum capacitors and good performance has been showed in mass production.

#### Vanadium versus Niobium: Competing or Complementary?

By Erik Sardain - Project Blue

Niobium and Vanadium bear many similarities. Steel accounts for about 90% of end usage for both metals and they have a similar role which is increasing steel's resistance and strength. By reducing the amount of steel required for a given resistance, they can be perceived as 'green metals' as lower steel consumption also translates into lower carbon emissions. As such, both vanadium and niobium fit within the steel industry's decarbonization trend. Both vanadium and niobium have benefited from the staggering development of the Chinese steel industry and from increasingly stringent standards. With the Chinese steel industry plateauing, both vanadium and niobium are looking for new applications in the energy transition sphere. Although they can be seen as competing metals, their differences are as important as their similarities. Vanadium's main exposure is to long products, while niobium's is to flat products and therefore offers a wider range of applications. Their market structure is different, implying distinct price movements. New prospects in the batteries sector are also different: vanadium aims at playing a major role in energy storage through the Vanadium Redox Batteries (VRBs) while niobium could be a key component in lithium batteries primarily for Electrical Vehicles (EVs). Therefore, the development paths of vanadium and niobium could move apart in the coming decade. But not always. Steel alloys combining vanadium and niobium could offer a stronger resistance by using less of both metals. At the end, vanadium and niobium could be more complementary than competitors.

#### T.I.C. Statistics: Past and Future

By Ian Margerison – T.I.C.

- The T.I.C. will show the issues in the past with obtaining statistics and present results that have not been seen before, with reference why these were not published.
- A solution will be outlined during the presentation how the T.I.C. would like to proceed with statistics in the future with the use of third-party information.
- Market trends will be investigated to give an insight into past tantalum and niobium market.
- The T.I.C. will not give future trends or price tends as per the charter.



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