

# Building bridges

How niobium is connecting the world (page 18)



(Photo: Shutterstock)

**The Ekeberg Prize:  
a retrospective and  
the 2021 shortlist**

(pages 7 and 11)



**62nd General  
Assembly: Technical  
Programme Abstracts**

(page 28)





# TANIOBIS

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# President's Welcome

Dear Members and friends,

As we approach the end of July, we are starting to see more light at the end of the tunnel with regards to Covid-19. And while there remains a broad spectrum in the level of vaccination, depending on the country, we at least understand that the vaccines, while not 100% effective (no vaccines are), are having the intended effect in those countries where there is a significant portion of the population already vaccinated. Please get vaccinated as soon as you are able.

This level of improvement has given the Executive Committee the confidence to hold an in-person 62nd General Assembly (GA62), in London, on November 14th to 16th 2021. While holding a meeting in Geneva is certainly possible, the ability to tour CERN remains unknown and therefore we have postponed our event in Geneva to 2022. We have also pushed GA62 back as far as feasibly possible to allow enough time for more people to be vaccinated and attend in person. The ability to meet in person, face-to-face, will serve as an indicator that things are moving towards some type of normal.

In the northern hemisphere we are now in the full swing of summer holidays, and the ability, in certain countries, to move around without masks will be a welcome change. It is my hope that those of you who are able to take advantage of this change will still do so in a safe and healthy manner.

Wishing you and yours all the best.

I look forward to seeing you in London in November.

Regards,

Daniel F. Persico, Ph.D.,

President

## Contents

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### Featured articles:



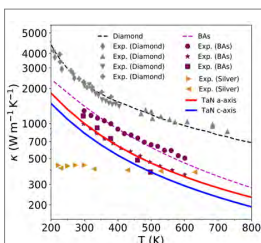
The Anders Gustaf Ekeberg Tantalum Prize: a retrospective

Page 7



Steel producers respond to demand for high performance bridge steels with niobium

Page 18



The Ekeberg Prize 2021: shortlisted abstracts

Page 11



62nd General Assembly: Technical Programme Abstracts

Page 28

### Regular articles:

- |    |                                    |    |                |
|----|------------------------------------|----|----------------|
| 33 | Tantalum and niobium patent update | 35 | Editor's Notes |
| 34 | Member updates and diary of events | 35 | Disclaimer     |



# T.I.C.'s 62nd General Assembly

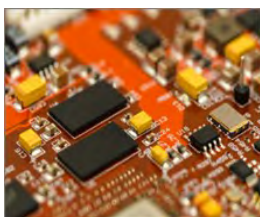
(conference and AGM) will take place in

## London, UK

November 14th - 16th 2021

Non-members are welcome to attend this event. The T.I.C. General Assembly attracts industry leaders from around the world. Full details will be made available online at [www.tanb.org](http://www.tanb.org).

Our 2021 conference will explore issues such as:



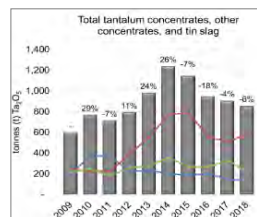
Capacitors



Superalloys



Superconductors



Statistics



And much more

Full details will be made available online at [www.tanb.org](http://www.tanb.org), in members' monthly updates and in future editions of the Bulletin magazine.

Presentations are given in English. All questions about the General Assembly, including about sponsorship opportunities, should be sent to Emma Wickens at [info@tanb.org](mailto:info@tanb.org).



The 62nd General Assembly will include the award ceremony for the 2021 Anders Gustaf Ekeberg Tantalum Prize (Ekeberg Prize), the annual international award for excellence in tantalum research and innovation.

The shortlist can be found on pages 11-17 or at <https://www.tanb.org/view/prize>.



# 主席致辞



亲爱的会员和朋友们：

随着7月底的到来，我们开始看到关于新冠肺炎疫情的更多曙光。虽然各国的疫苗接种水平仍有很大差异，但我们至少明白，疫苗虽然不是100%有效（没有疫苗是100%有效的），但在那些很大部分人口已经接种的国家，正在发挥预期效果。请在有能力的情況下尽快接种疫苗。

这种程度的改善使执行委员会有信心在2021年11月14日至16日于伦敦举行的第62届大会（GA62）时，大家可以亲临现场参加。虽然在日内瓦举行会议肯定是可能的，但参观欧洲核子研究中心的可能性仍是未知数，因此我们将在日内瓦的活动推迟到2022年。我们还将第62届大会的时间尽可能往后推，以便有足够的时间让更多人接种疫苗并亲自前来参加。能够亲临会场面对面的交流，将会是一个指标，表明事情正朝着某种正常的方向发展。

在北半球，我们现在正处于如火如荼的暑假中，在某些国家，能够不戴口罩到处走动将是一个很好的变化。我希望这些能够利用这个变化的人仍然保持安全和健康的方式接触。

祝你和你的家人一切顺利！

我期待着11月在伦敦与你们见面。

谨此致意

致以诚挚的问候，

丹尼尔·佩尔西科博士（Daniel Persico），主席

# Lettre du Président



Chers membres et amis,

Alors que nous approchons de la fin du mois de juillet, nous commençons à voir la lumière au bout du tunnel en ce qui concerne la Covid-19. Et bien que le niveau de vaccination reste très variable selon les pays, nous savons au moins que les vaccins, même s'ils ne sont pas efficaces à 100 % (aucun vaccin ne l'est), ont l'effet escompté dans les pays où une partie importante de la population est déjà vaccinée. Je vous recommande de vous faire vacciner dès que vous le pouvez.

Ce niveau d'amélioration a donné au Comité Exécutif la confiance nécessaire pour organiser une 62e Assemblée Générale (GA62) en personne, à Londres, du 14 au 16 novembre 2021. Bien que la tenue d'une réunion à Genève soit certainement possible, la possibilité de visiter le CERN reste inconnue et nous avons donc reporté notre événement à Genève à 2022. Nous avons également repoussé l'événement GA62 aussi loin que possible afin de laisser suffisamment de temps à un plus grand nombre de personnes pour se faire vacciner et participer en personne. La possibilité de se rencontrer en personne, face à face, servira d'indicateur que les choses évoluent vers un certain type de normalité.

Dans l'hémisphère nord, les vacances d'été battent leur plein et la possibilité, dans certains pays, de se déplacer sans masque sera un changement bienvenu. J'espère que ceux d'entre vous qui pourront profiter de ce changement le feront de manière sûre et saine.

Je vous souhaite, à vous et aux vôtres, le meilleur.

Je me réjouis de vous voir à Londres en novembre.

Salutations,

Daniel F. Persico, Ph.D., Président

# 社長のあいさつ



メンバーおよび友人の皆様へ。

7月も終わりに近づき、Covid-19に関しては、トンネルの終わりに光が見え始めています。国によってワクチンの接種レベルにはまだ大きな差がありますが、100%の効果があるわけではありませんが（ワクチンはありません）、すでに人口のかなりの部分がワクチンを接種している国では、意図した効果が得られていることが少なくとも理解できます。できる限り早くワクチンを接種してください。

このようなレベルの向上により、執行委員会は、2021年11月14日から16日にかけて、ロンドンで対面式の第62回総会（GA62）を開催する自信を得ました。ジュネーブでの開催は確かに可能ですが、CERNを見学できるかどうかは未知数であるため、ジュネーブでの開催を2022年に延期しました。また、より多くの人々がワクチンを接種し、直接参加できるよう、GA62を可能な限り延期しました。直接会って話ができるということは、物事がある種の正常な状態に向かっていることを示す指標となります。

北半球では本格的な夏休みに入りましたが、国によってはマスクをせずに移動できるようになるのは歓迎すべきことです。この変化を利用できる方々が、安全で健康的な方法で行動されることを願っています。

皆様のご健勝を心よりお祈り申し上げます。

11月にロンドンでお会いできることを楽しみにしています。

ありがとうございました。

ダニエル・F・パーシコ、PhD、社長

# Boas-vindas do Presidente



Prezados Membros e amigos,

Ao nos aproximarmos do final de julho, estamos começando a ver mais luz no fim do túnel em relação à Covid-19. E, embora ainda haja uma ampla variabilidade no nível de vacinação, dependendo do país, pelo menos entendemos que as vacinas, embora não tenham 100% de eficácia (nenhuma vacina tem), estão produzindo o efeito desejado naqueles países onde há uma significativa parcela da população já vacinada. Por favor, vacine-se tão logo seja possível.

Este nível de melhoria deu ao Comitê Executivo a confiança necessária para promover a 62ª Assembleia Geral (GA62) de forma presencial, em Londres, de 14 a 16 de novembro de 2021. Embora fosse certamente possível realizar uma reunião em Genebra, a possibilidade de visitar o CERN continua sendo uma incógnita, e por isso adiamos nosso evento em Genebra para 2022. Também adiamos a GA62 o máximo possível, de modo a dar tempo suficiente para que mais pessoas possam se vacinar e, assim, comparecer fisicamente. A capacidade de nos encontrarmos pessoalmente, frente a frente, servirá como um indicador de que as coisas estão caminhando para algum grau de normalidade.

No hemisfério norte, estamos agora em pleno período de férias de verão, e a possibilidade de se locomover sem máscaras, em alguns países, será uma mudança bem-vinda. Espero que aqueles de vocês que possam aproveitar esta mudança o façam de maneira segura e saudável.

Desejo a vocês e aos seus tudo de melhor.

Espero vê-los em Londres, em novembro.

Atenciosamente,

Daniel F. Persico, Ph.D., Presidente

# 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 2021 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) and recycling tantalum by solvent extraction (2020, Prof. Jason Love et al).

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.

This year, the seven publications on the shortlist show the great versatility of tantalum in a number of cutting edge applications and new techniques (see abstracts on pages 11 to 17):

- Tantalum-titanium alloys for additive manufacturing applications
- Microwave preparation of polyoxoniobates and polyoxotantalates
- An examination of why it is so difficult to cut tantalum metal
- Integrating tantalum pentoxide waveguides into niobium-titanium nitride superconducting nanowires
- Using oxalic-nitric acid to dissolve and separate niobium and tantalum
- Ultrahigh thermal conductivity of  $\theta$ -phase tantalum nitride
- Creating homostructural Ta<sub>3</sub>N<sub>5</sub> nanotube/nanoparticle photoanodes for water splitting

## 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.

\* 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](http://www.charles-hatchett.com)) already superbly recognises niobium published research.

### **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).



### **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 34th 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 an European university. Dr Zedníček is a regular contributor to the Bulletin.



## How the winner of the Ekeberg Prize 2021 will be announced

The winning publication will be announced in September 2021. The lead author will be invited to give a keynote paper at the 62nd General Assembly, to be held in London, UK, in November 2021. 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 7). 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 will be available at <https://www.tanb.org/view/62nd-general-assembly>.

## Previous winners

Since the Ekeberg Prize was launched there have been three winning publications, examining recycling tantalum by solvent extraction, additive manufacturing and tantalum capacitors.

In 2020 the Ekeberg Prize was awarded to a team from Edinburgh University, UK, lead 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.



The 2020 winning team (left to right): Prof. Bryne Ngwenya, Luke Kinsman, Prof. Jason Love and Prof. Carole Morrison in a chemistry laboratory at Edinburgh University. (photo: T.I.C.)



Nicolas Soro, lead author of the 2019 Ekeberg Prize-winning paper  
(Photo: N.Soro)

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.



Dr Yuri Freeman, winner of the 2018 Ekeberg Prize (Photo: KEMET)

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".

### Anders Gustaf Ekeberg: the man behind the prize

When the T.I.C. was creating the Ekeberg Prize in 2017 the question of what to call the award was discussed and almost immediately one name stood out, that of the Swedish chemist who had discovered tantalum in 1802, Professor Anders Gustaf Ekeberg (see [Bulletin #175](#) for his full story).

Born in 1767, Ekeberg was a Swedish scientist, mathematician, and poet. He became a professor at Uppsala University in 1794 and initially made his name by developing advanced analytical techniques and by proposing Swedish names for the common chemical elements according to the principles set out by the "father of modern chemistry" Antoine-Laurent de Lavoisier. Ekeberg discovered the oxide of tantalum in 1802, isolating it from samples of two different minerals, specifically, tantalite from Kimito, Finland and yttrotantalite from Ytterby, Sweden.



Professor Anders Ekeberg.



A sample of yttrotantalite (dark) from Skuleboda, Sweden (photo: e-rocks.com)

However, it was not an easy process to identify tantalum and according to Ekeberg's friend, the chemist Jacob Berzelius, Ekeberg chose the name 'tantalum' partly out of his passion for ancient Greek literature and partly to reflect the difficulties that he had experienced in reacting the new element with common acids. Berzelius wrote that "The reason for the name tantalum (derived from the story of Tantalus) is [because]... metallic tantalum, reduced to the finest powder, is not attacked by any acid, not even by aqua regia, concentrated and boiling".

While Ekeberg was undoubtedly pleased to have identified tantalum, he placed a very high importance on utility, and one can imagine he was somewhat disappointed to have discovered an element which had no apparent purpose. If only he could have known about the many exceptionally useful applications which have developed for tantalum in the last 200 years he would undoubtedly have been very pleased indeed! **TIC**

### **The legend of Tantalus**

In Greek mythology Tantalus was the king of Phrygia in present-day Turkey, and also a demi-god. He offended the gods and in a desperate attempt to apologise he killed his own son as a sacrifice, cooked him and served him to the gods at a banquet.

However, before the meal had ended his crime was discovered and the gods were disgusted. As punishment Tantalus was condemned to suffer eternal hunger and thirst.

Tantalus was forced to stand eternally beneath a fruit tree with low branches in water up to his neck, but the water receded whenever he attempted to drink it and wind blew the fruit out of reach whenever he reached up to pick them.



The torments of Tantalus (detail) by Bernard Picart (1673-1733)

# The Ekeberg Prize 2021: 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 62nd General Assembly, scheduled to be held in London, UK, on November 14th - 16th 2021. Full details of the Ekeberg Prize winning publication and how to attend the 62nd General Assembly will be published on [www.tanb.org](http://www.tanb.org) in due course.

The following publications are shortlisted for the Ekeberg Prize 2021:

### Microwave synthesis of alkali-free hexaniobate, decaniobate, and hexatantalate polyoxometalate ions

Authors: Mark A. Rambaran, Magda Pascual-Borràs and C. André Ohlin

Organisations: Department of Chemistry, Umeå University, Umeå, Sweden

Full article at: European Journal of Inorganic Chemistry, Volume 2019, Issue 35, pages 3913-3918

<https://chemistry-europe.onlinelibrary.wiley.com/doi/abs/10.1002/ejic.201900750>

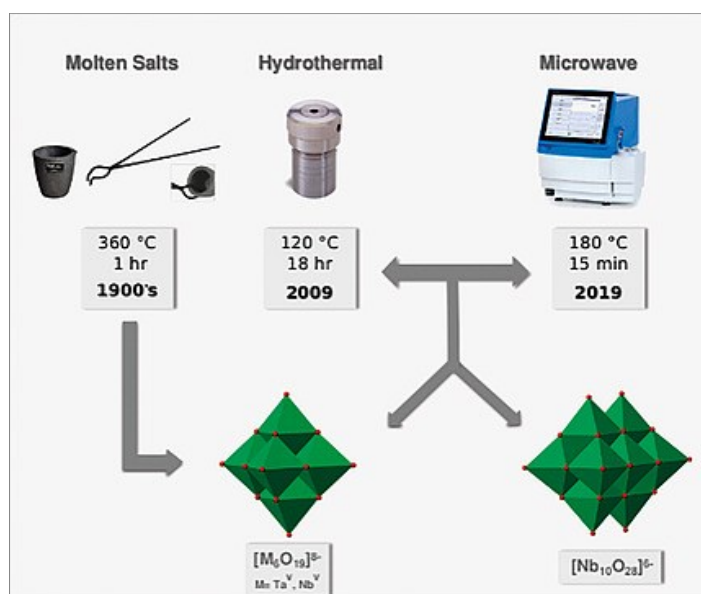
Microwave preparation of polyoxoniobates and -tantalates afford a more rapid alternative to conventional hydrothermal methods of synthesis, in addition to allowing for the use of anhydrous niobium pentoxide in lieu of niobic acid, albeit with diminished yields. Limitations associated with the pH at which different oxides can be activated and how this affects the accessibility of different products are also discussed.

| Method       | Metal Oxide   | Reaction time | Product <sup>[a]</sup> | Yield [%] <sup>[b]</sup> |
|--------------|---|---------------|------------------------|--------------------------|
| Hydrothermal | Nb <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O <sup>[c]</sup> | 18 hours      | Nb <sub>6</sub>        | 51                       |
|              | Nb <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O                | 18 hours      | Nb <sub>10</sub>       | 53                       |
|              | Ta <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O <sup>[d]</sup> | 18 hours      | Ta <sub>6</sub>        | 73                       |
|              | Nb <sub>2</sub> O <sub>5</sub> <sup>[e]</sup>                   | 18 hours      | Nb <sub>6</sub>        | 41                       |
| Microwave    | Nb <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O                | 15 minutes    | Nb <sub>6</sub>        | 80                       |
|              | Nb <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O                | 15 minutes    | Nb <sub>10</sub>       | 80                       |
|              | Ta <sub>2</sub> O <sub>5</sub> ·H <sub>2</sub> O                | 15 minutes    | Ta <sub>6</sub>        | 86                       |
|              | Nb <sub>2</sub> O <sub>5</sub>                                  | 1 hour        | Nb <sub>6</sub>        | 39                       |

[a] See Experimental Section for stoichiometries and other details. [b] Expressed with respect to the metal.

[c] Niobic acid. [d] Tantalum acid. [e] Anhydrous niobium pentoxide.

Table 1. Comparison between hydrothermal and microwave irradiation syntheses of Nb<sub>6</sub>, Nb<sub>10</sub> and Ta<sub>6</sub> at 180 °C





## Osteogenic potential of additively manufactured TiTa alloys

Authors: Erin G. Brodie<sup>1,2\*</sup>, Kye J. Robinson<sup>3</sup>, Elizabeth Sigston<sup>4,5</sup>, Andrey Molotnikov<sup>1,2,6</sup>, Jessica E. Frith<sup>1\*</sup>

Organisations: 1. Department of Materials Science and Engineering, Monash University, Clayton, VIC, 3800, Australia  
2. Monash Centre for Additive Manufacturing (MCAM), 11 Normanby Road, Nottinghill, VIC, 3168, Australia  
3. Department of Inorganic and Analytical Chemistry, University of Geneva, CH-1211 Geneva, Switzerland  
4. Department of Surgery, School of Clinical Sciences at Monash Health, Monash University, Clayton, VIC, 3800, Australia  
5. Department of Otolaryngology, Head and Neck Surgery, Monash Health, Clayton, VIC, 3168, Australia

Full article at: ACS Appl. Bio Mater. 2021, 4, 1003–1014  
<https://pubs.acs.org/doi/10.1021/acsabm.0c01450>

**Abstract:** The only alloy currently utilized for additive manufacture of bone implants, Ti-6Al-4V, has a high elastic modulus and bioinert surface, potentially inducing stress shielding and hindering osseointegration. Low-modulus materials with bioactive surfaces could significantly reduce implant failure rates by improving the interaction between implants and the surrounding bone. In this study, laser powder bed fusion Ti25Ta and Ti65Ta alloys, highlighted previously for their low moduli, were assessed for their surface osteogenic potential, using human bone marrow mesenchymal stromal cells (hBMSCs). Polished metallic substrates were utilized to avoid the effects of surface topography on cell fate and highlight the chemical effect of the Ta content. Electron-dispersive X-ray and X-ray photoelectron spectroscopy revealed surface Ta enrichment on the polished TiTa substrates. XPS measured Ta oxide contents of 8.0 and 16.5 at. % for the Ti25Ta and Ti65Ta alloys, respectively. *In vitro* testing revealed increased alkaline phosphatase activity and mineralization of hBMSCs on the TiTa alloys compared to the Ti-6Al-4V control and only minor differences in biological behaviour between the Ti25Ta and Ti65Ta alloys. It was concluded that the Ti25Ta composition, with a lower Ta content but equivalent biological response, was the most promising composition for additively manufactured bone implants.

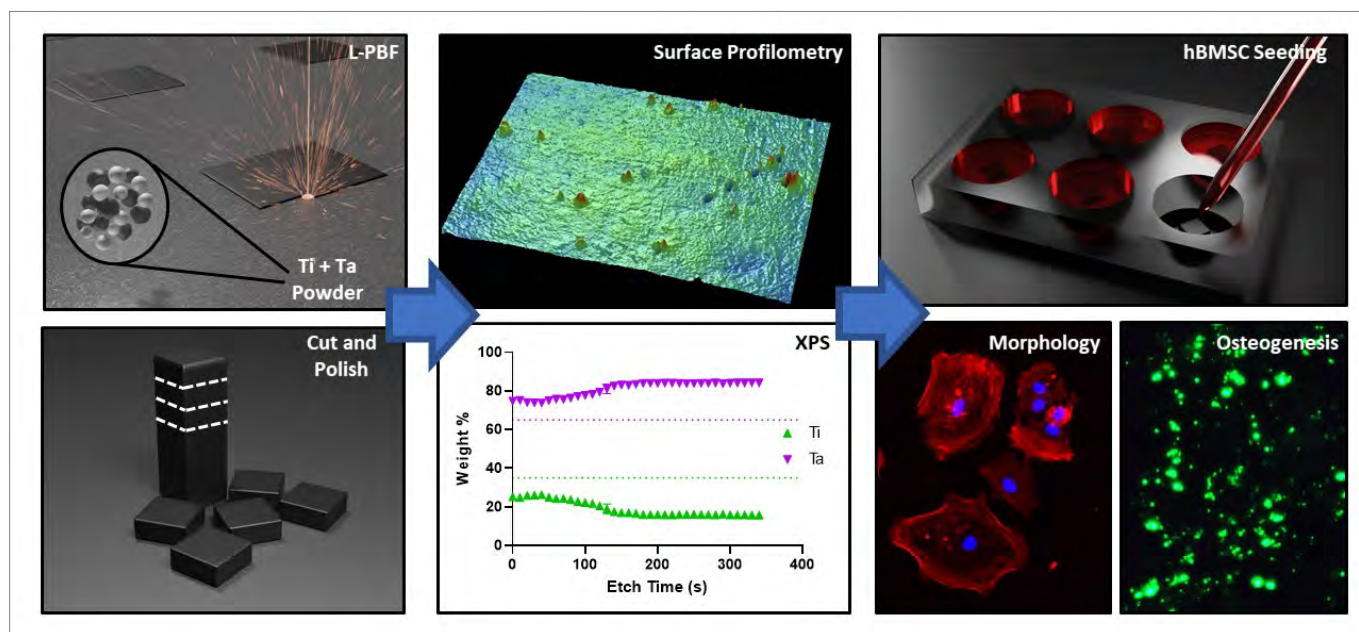


Figure 1. Experimental schematic showing L-PBF of the TiTa alloys, followed by substrate preparation and material and biological characterization

**Conclusion:** In this study, new low-modulus alloys Ti25Ta and Ti65Ta were manufactured using L-PBF. *In vitro* testing using hBMSCs was performed to determine whether the TiTa alloys displayed an improved osteogenic response compared with the industry standard material, Ti-6Al-4V. All metallic substrates were polished to remove effects of topography on cell fate. The TiTa alloys displayed enhanced ALP activity and mineralization, when compared with Ti-6Al-4V, indicating that the improved osteogenic capacity of Ta was retained in the L-PBF TiTa alloys. There was no significant difference in biological behaviour noted between Ti25Ta and Ti65Ta alloys, attributed to a nonlinear representation of Ta in the surface oxide when compared with the nominal composition. Both the L-PBF Ti25Ta and Ti65Ta alloys are suitable low-modulus alternatives to Ti-6Al-4V to enhance bone-implant interactions for stress-loaded bone implants; however, the lighter and cheaper Ti25Ta alloy is the most favourable.

## Cutting of tantalum: why it is so difficult and what can be done about it

Authors: Jason M. Davis<sup>ab</sup>, Mojib Saei<sup>a</sup>, Debapriya Pinaki Mohanty<sup>a</sup>, Anirudh Udupa<sup>a</sup>, Tatsuya Sugihara<sup>c</sup>, Srinivasan Chandrasekar<sup>a</sup>

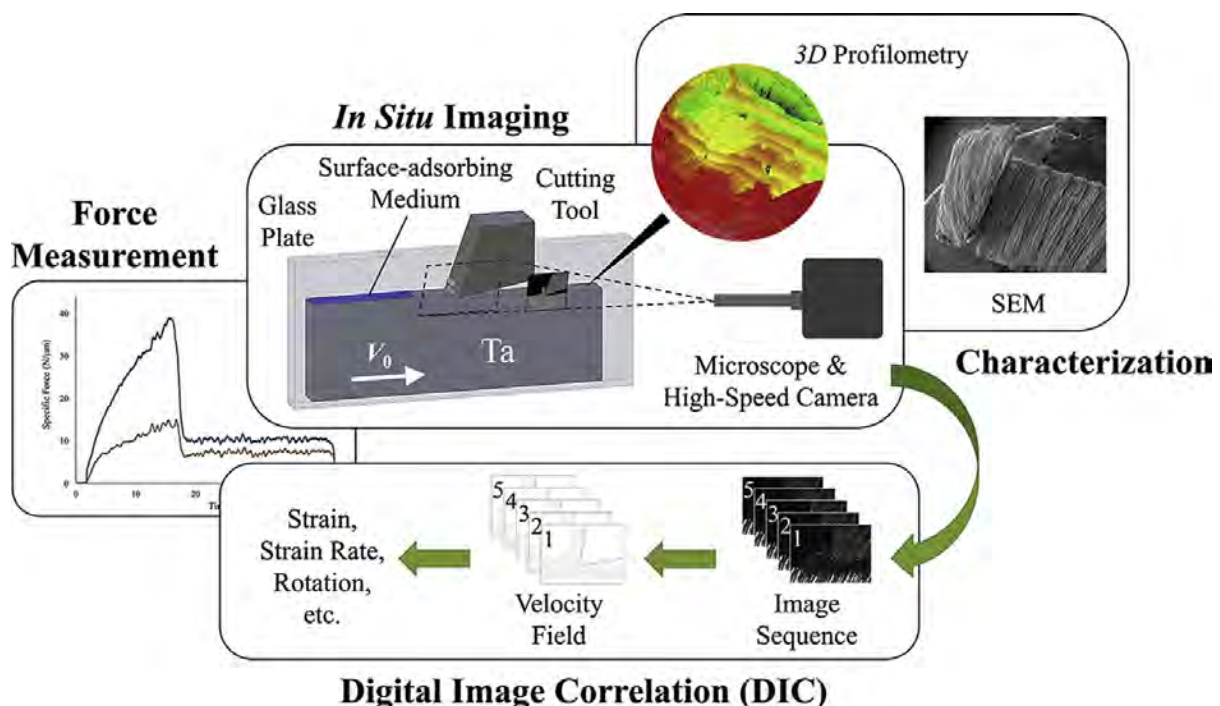
Organisations: A. Center for Materials Processing and Tribology, Purdue University, West Lafayette, IN, 47907-2023, USA  
B. Special Warfare and Expeditionary Systems Department, Naval Surface Warfare Center, Crane Division, Crane, IN, 47552, USA  
C. Department of Mechanical Engineering, Osaka University, Suita, Osaka, 565-0871, Japan

Full article at: International Journal of Machine Tools and Manufacture, Volume 157, October 2020, 103607;  
<https://doi.org/10.1016/j.ijmachtools.2020.103607>

**Abstract:** Tantalum has long drawn the ire of machinists, being particularly difficult to cut. Often referred to as being ‘gummy’, cutting of tantalum is characterized by very thick chips, large cutting forces, and a poor surface finish on the machined surface. These unfavourable attributes of the cutting have usually been attributed to bcc tantalum’s high strain-hardening capacity, relative softness, and low thermal conductivity; and a small shear plane angle. Here, we show using in situ high-speed imaging at low speeds, and ex situ chip morphology observations at higher commercial cutting speeds (625 mm/s), that the gummy nature of Ta in cutting, including the large forces and thick chips, is actually due to the prevalence of a highly unsteady plastic flow – sinuous flow – characterized by large-amplitude folding and extensive redundant deformation.

The sinuous flow and the associated folding are much more amplified and extreme in tantalum (chip thickness ratio, 30–50), and with different morphology, than that observed in fcc Cu and Al (chip thickness ratio, 10–20), wherein this flow mode was first uncovered. The in situ observations are reinforced by force measurements, and chip morphology and cut-surface characterization. The observations also suggest that the sinuous flow, in the same genre of unsteady mesoscale flow modes such as shear banding and segmented flow, is quite prevalent in cutting of highly strain-hardening metal alloys.

By application of a surface-adsorbing (SA) medium, e.g., permanent marker ink, to the initial workpiece surface, we show that sinuous flow can be disrupted and replaced by a more energetically favorable flow mode – segmented flow – with thin chips and >70% reduction in the cutting force. This flow disruption is mediated by a local ductile-to-brittle transition in the deformation zone, due to the action of the SA medium – a mechanochemical (MC) effect in large-strain deformation of metals. Equally importantly, the MC effect and underlying segmented flow are beneficial also for machined surface quality – producing nearly an order of magnitude improvement in the surface finish, creating a surface with minimal residual plastic strain, and reducing level of material pull-out. Thus, by use of the SA medium and triggering the MC effect, a promising new opportunity is demonstrated for improving the machinability of Ta by ameliorating its gumminess. The results could enhance the viability of Ta for applications such as gun barrel liners – applications for which it has been hitherto considered but discarded due to its poor machining characteristics.



# Superconducting nanowire single-photon detectors integrated with tantalum pentoxide waveguides

Authors: Martin A. Wolff<sup>abc</sup>, Simon Vogel<sup>abc</sup>, Lukas Splitthoff<sup>abc</sup>, Carsten Schuck<sup>abc</sup>

Organisations: A. Institute of Physics, University of Münster, Wilhelm-Klemm-Str. 10, 48149, Münster, Germany  
B. CeNTech – Center for Nanotechnology, Heisenbergstr. 11, 48149, Münster, Germany  
C. SoN – Center for Soft Nanoscience, Busso-Peus-Straße 10, 48149, Münster, Germany

Full article at: Scientific Reports volume 10, Article number: 17170 (2020)  
<https://www.nature.com/articles/s41598-020-74426-w>

**Abstract:** Photonic integrated circuits hold great potential for realizing quantum technology. Efficient single-photon detectors are an essential constituent of any such quantum photonic implementation. In this regard waveguide-integrated superconducting nanowire single-photon detectors are an ideal match for achieving advanced photon counting capabilities in photonic integrated circuits. However, currently considered material systems do not readily satisfy the demands of next generation nanophotonic quantum technology platforms with integrated single-photon detectors, in terms of refractive-index contrast, band gap, optical nonlinearity, thermo-optic stability and fast single-photon counting with high signal-to-noise ratio.

Here we show that such comprehensive functionality can be realized by integrating niobium titanium nitride superconducting nanowire single-photon detectors with tantalum pentoxide waveguides. We demonstrate state-of-the-art detector performance in this novel material system, including devices showing 75% on-chip detection efficiency at tens of dark counts per second, detector decay times below 1 ns and sub-30 ps timing accuracy for telecommunication wavelengths photons at 1550 nm. Notably, we realize saturation of the internal detection efficiency over a previously unattained bias current range for waveguide-integrated niobium titanium nitride superconducting nanowire single-photon detectors. Our work enables the full set of high-performance single-photon detection capabilities on the emerging tantalum pentoxide-on-insulator platform for future applications in integrated quantum photonics.

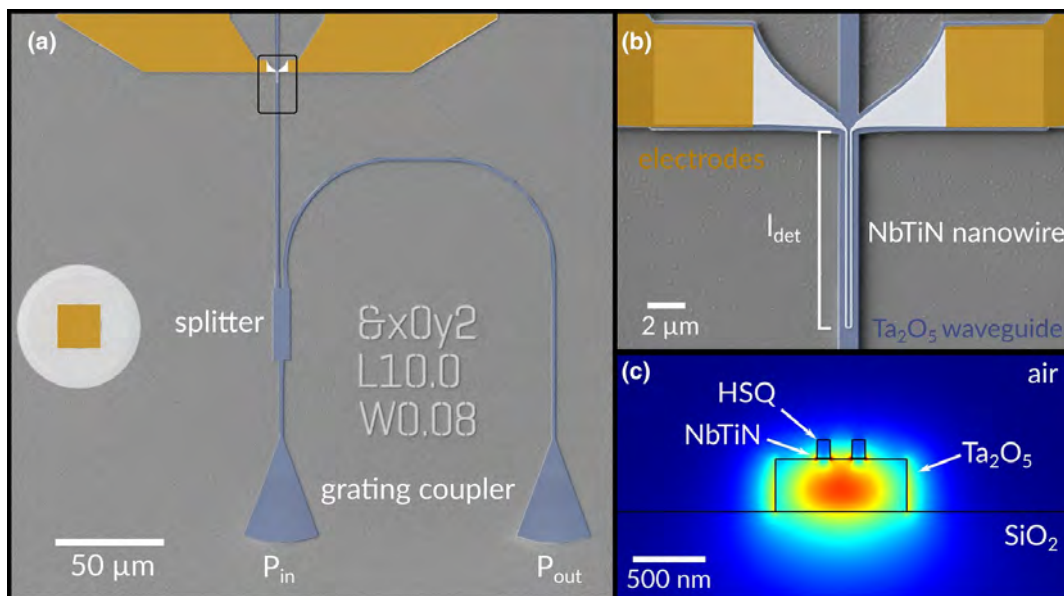


Figure 1: (a) Nanophotonic circuit for characterization of the SNSPD. Two grating couplers are used for the alignment and calibration of the chip inside the cryostat, with input power port  $P_{in}$  and output power port  $P_{out}$ . A multi-mode interference device serves as an optical power splitter of the incoming light. (b) Scanning electron micrograph (false color) of a fabricated Ta<sub>2</sub>O<sub>5</sub> SNSPD device. The length of the nanowire,  $l_{nw}$ , is equal to approximately twice the detector length,  $l_{det}$ . (c) Illustration of a supported TE<sub>00</sub> mode inside the tantalum pentoxide waveguide on an insulating silicon dioxide on silicon substrate with the niobium titanium nitride nanowire and hydrogen silsesquioxane resist on-top (simulated using the finite element method). The gap between the NbTiN nanowires is 150 nm.

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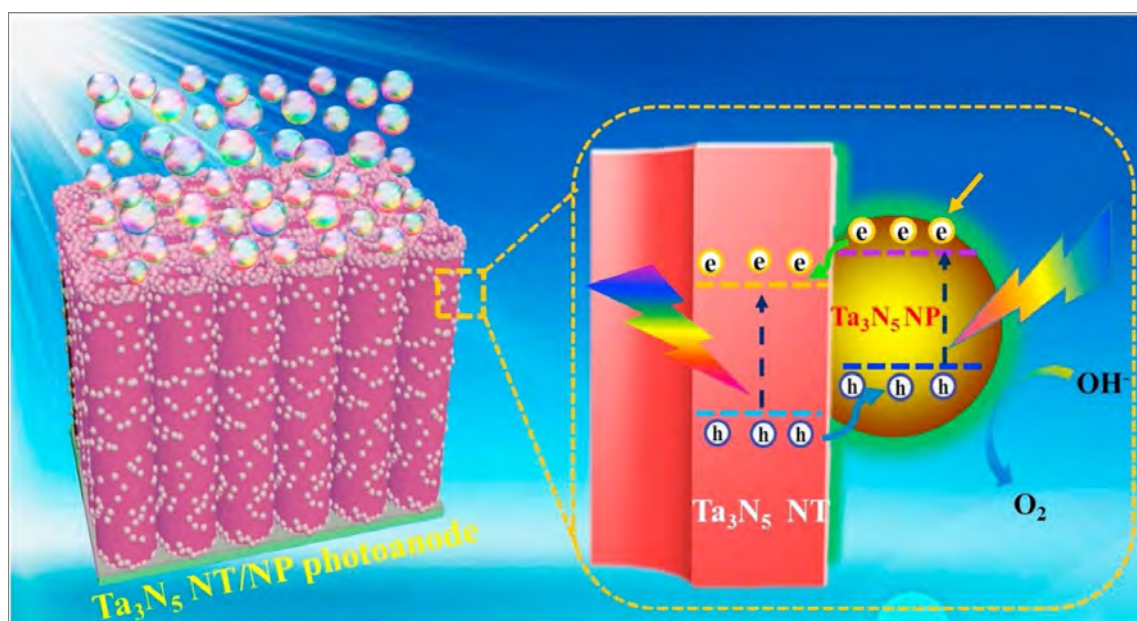
# Homostructural Ta<sub>3</sub>N<sub>5</sub> nanotube/nanoparticle photoanodes for highly efficient solar-driven water splitting

Authors: Xian Zhang<sup>a,b</sup>, Huilin Guo<sup>a</sup>, Guojun Dong<sup>b</sup>, Yajun Zhang<sup>b</sup>, Gongxuan Lu<sup>b</sup> and Yingpu Bi<sup>b,c</sup>

Organisations: A. Key Laboratory of Synthetic and Natural Functional Molecule Chemistry (Ministry of Education), College of Chemistry and Materials Science, Northwest University, Xi'an, 710127, PR China  
B. State Key Laboratory for Oxo Synthesis & Selective Oxidation, Lanzhou Institute of Chemical Physics, CAS, Lanzhou, 730000, PR China  
C. Dalian National Laboratory for Clean Energy, CAS, Dalian, 116023, PR China

Full article at: Applied Catalysis B: Environmental, Volume 277  
<https://www.sciencedirect.com/science/article/abs/pii/S0926337320306329>

**Abstract:** Herein, we demonstrated a one-step ammonia treatment for fabricating homostructural Ta<sub>3</sub>N<sub>5</sub> nanotube/nanoparticle photoanodes with a top-open structure. Compared with the relatively low activities of traditional Ta<sub>3</sub>N<sub>5</sub> nanotube photoanode, this homo-photoanode exhibited a remarkably enhanced photocurrent density (1.58 mA cm<sup>-2</sup> at 1.23 V vs. reversible hydrogen electrode (RHE)). Moreover, after the decoration of Co(OH)<sub>x</sub> cocatalyst, the photocurrent density could be further increased up to 8.73 mA cm<sup>-2</sup> at 1.23 V<sub>RHE</sub>, accompanying with the significantly improved water oxidation stability as well as an evident negative shift of onset-potential (200 mV). More detailed studies reveal that the significantly promoted PEC activities should be attributed to the matched bandgaps between Ta<sub>3</sub>N<sub>5</sub> nanotube and nanoparticle as well as the ordered top-open nanoarchitecture, which could accelerate charge separation and provide more active sites for water oxidation. Thereby, the construction of homostructural semiconductor photoanodes should be highly promising for promoting the development of PEC water splitting for practical applications.



Graphical abstract: Homostructural Ta<sub>3</sub>N<sub>5</sub> nanotube/nanoparticle photoanodes with a top-open structure exhibited the significantly enhanced photoelectrochemical activities for solar-driven water splitting.

## Highlights:

- Homostructural Ta<sub>3</sub>N<sub>5</sub> nanotube/nanoparticle photoanodes exhibited excellent water splitting activities.
- The photocurrent density of 8.73 mA cm<sup>-2</sup> at 1.23VRHE has been achieved on this photoanode.
- The enhanced PEC activities should be attributed to the matched bandgaps and top-open nanoarchitecture.
- This work provides a novel insight toward the construction of Ta<sub>3</sub>N<sub>5</sub> photoanodes for efficient water oxidation.

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# Ultrahigh thermal conductivity of $\theta$ -phase tantalum nitride

Authors: Ashis Kundu<sup>1,2</sup>, Xiaolong Yang<sup>1,2</sup>, Jinlong Ma<sup>1,4</sup>, Tianli Feng<sup>5</sup>, Jesús Carrete<sup>3</sup>, Xiulin Ruan<sup>6</sup>, Georg K. H. Madsen<sup>3</sup>, Wu Li<sup>1</sup>

Organisations: 1. Institute for Advanced Study, Shenzhen University, Shenzhen 518060, China  
2. College of Physics and Optoelectronic Engineering, Shenzhen University, Shenzhen 518060, China  
3. Institute of Materials Chemistry, TU Wien, 1060 Vienna, Austria  
4. School of Energy and Power Engineering, Huazhong University of Science and Technology, Wuhan 430074, China  
5. Department of Mechanical Engineering, University of Utah, Salt Lake City, Utah 84112, USA  
6. School of Mechanical Engineering and the Birck Nanotechnology Center, Purdue University, West Lafayette, Indiana 47907-2088, USA

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<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.126.115901>

**Abstract:** Extracting long-lasting performance from electronic devices and improving their reliability through effective heat management requires good thermal conductors. Taking both three- and four-phonon scattering as well as electron-phonon and isotope scattering into account, we predict that semimetallic  $\theta$ -phase tantalum nitride ( $\theta$ -TaN) has an ultrahigh thermal conductivity ( $\kappa$ ), of 995 and 820 W m<sup>-1</sup> K<sup>-1</sup> at room temperature along the a and c axes, respectively. Phonons are found to be the main heat carriers, and the high  $\kappa$  hinges on a particular combination of factors: weak electron-phonon scattering, low isotopic mass disorder, and a large frequency gap between acoustic and optical phonon modes that, together with acoustic bunching, impedes three-phonon processes. On the other hand, four-phonon scattering is found to be significant. This study provides new insight into heat conduction in semimetallic solids and extends the search for high- $\kappa$  materials into the realms of semimetals and noncubic crystal structures.

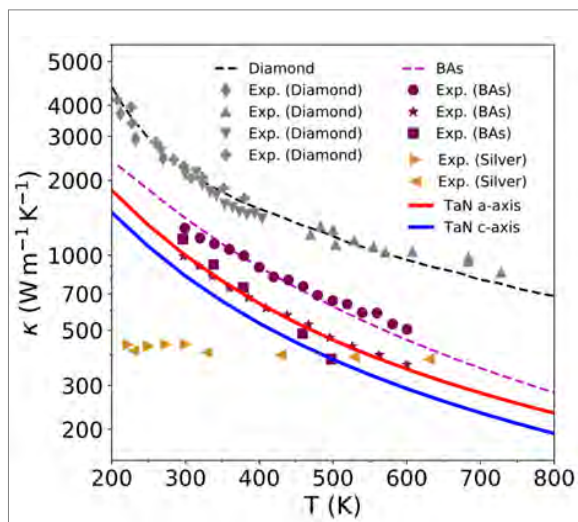


Figure 1: Calculated total thermal conductivity ( $\kappa = \kappa_{el} + \kappa_{ph}$ ) as a function of temperature for TaN along the a and c axes in comparison with available results of  $\kappa$  for diamond and BAs. Theoretical results for diamond and BAs are taken from Refs. [14, 27].

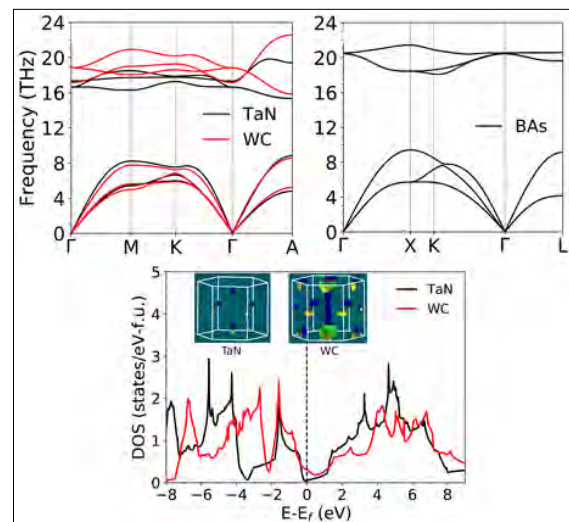


Figure 2: Calculated phonon dispersion along high-symmetry directions for (a) TaN and WC and (b) BAs. (c) Calculated electronic DOS for TaN and WC.  $E_f$  denotes the Fermi energy. The insets show the bulk Fermi surfaces for both compounds.

**Conclusions:** In summary, we predict an ultrahigh  $\kappa$  in semimetallic TaN using a first-principles approach based on the Boltzmann transport equation and exhaustively considering all plausible relevant contributions to heat carrier scattering. The room-temperature thermal conductivity values obtained for this compound are close to the 1000 W m<sup>-1</sup> K<sup>-1</sup> mark, 995 and 820 W m<sup>-1</sup> K<sup>-1</sup> along the a and c axes, respectively. The high value of  $\kappa$  in TaN is only possible thanks to a unique combination of phononic, electronic, and even nuclear properties. On top of the presence of a large acoustic-optical gap and a significant degree of bunching of the acoustic branches, the singular isotopic distribution of Ta leads to very weak mass-disorder scattering and the low electronic density of states at the Fermi level to depressed phonon-electron interactions. In light of those requirements, our exploration of 4d and 5d transition metal carbides and nitrides shows that TaN is the only compound in this family likely to have an ultrahigh  $\kappa$ . Therefore, TaN can be considered as a record-breaking material with a thermal conductivity several times higher than silver and comparable to diamond. In addition to the potential for thermal management, applications that require both high thermal and high electrical conductivities such as leadframes and diffusion barriers in integrated circuits could represent compelling cases for TaN.

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## Niobium and tantalum processing in oxalic-nitric media: $\text{Nb}_2\text{O}_5 \cdot n\text{H}_2\text{O}$ and $\text{Ta}_2\text{O}_5 \cdot n\text{H}_2\text{O}$ precipitation with oxalates and nitrates recycling

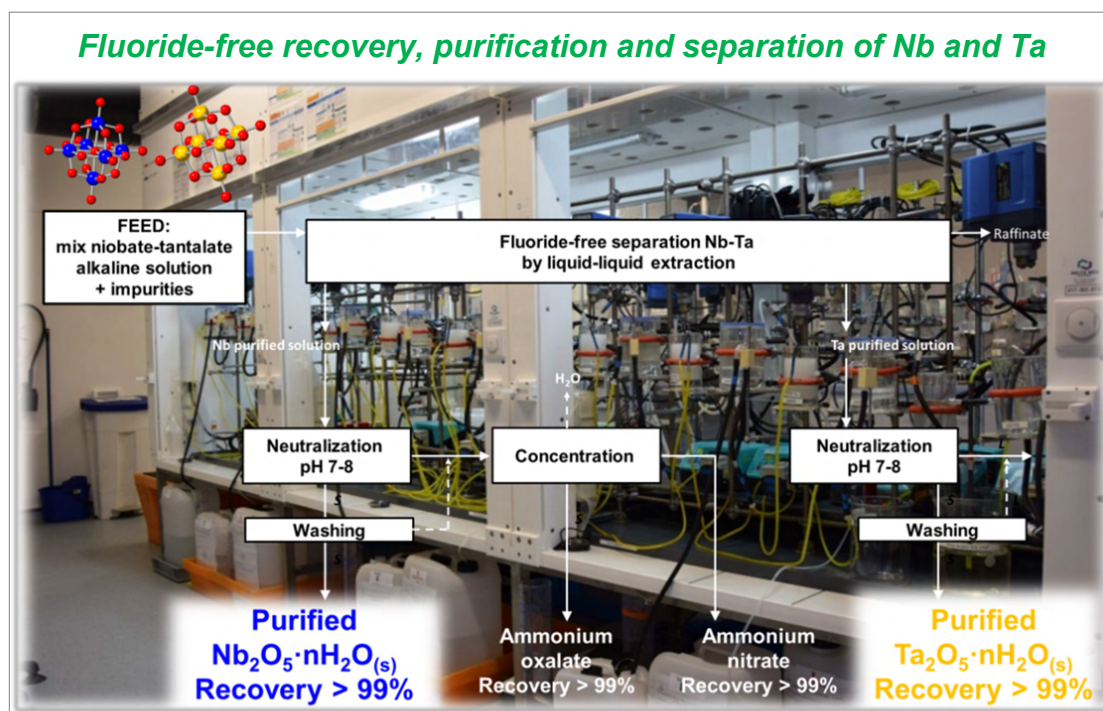
Authors: Gauthier J.-P. Deblonde<sup>abc</sup>, David Bengio<sup>b</sup>, Denis Beltrami<sup>b</sup>, Sarah Bélair<sup>b</sup>, Gérard Cote<sup>a</sup>, Alexandre Chagnes<sup>d</sup>

Organisations: A. PSL Research University, Chimie ParisTech – CNRS, Institut de Recherche de Chimie Paris, 11 rue Pierre et Marie Curie, 75005 Paris, France  
B. ERAMET IDEAS, 1 avenue Albert Einstein, 78193 Trappes, France  
C. Lawrence Berkeley National Laboratory, Chemical Sciences Division, Berkeley, CA 94720, USA  
D. Université de Lorraine, CNRS, GeoRessources, 54000 Nancy, France

Full article at: Separation and Purification Technology, Volume 226, 1 November 2019, Pages 209-217;  
<https://www.sciencedirect.com/science/article/abs/pii/S1383586619320817?via%3Dihub>

**Abstract:** Oxalate-based aqueous media represent one of the rare options for solubilizing weighable amounts of niobium (Nb) and tantalum (Ta) without using toxic fluoride-based mixtures. Recent progress in the hydrometallurgy of Nb and Ta also highlighted the potential of oxalate-nitrate media for the separation of Nb and Ta. Nonetheless, the resulting purified aqueous solutions, containing Nb or Ta in  $\text{HNO}_3\text{-H}_2\text{C}_2\text{O}_4$  mixtures, need to be further processed in order to yield Nb and Ta solid products that can be commercialized. Furthermore, oxalic acid is relatively expensive in the frame of the hydrometallurgy of Nb and its recycling can significantly increase the process economy. In this study, the precipitation behaviour of Nb, Ta, and their usual minor impurities (Ti and Fe), from oxalic-nitric acid solutions has been investigated for the first time. Neutralization of Nb- $\text{HNO}_3\text{-H}_2\text{C}_2\text{O}_4$  mixtures to pH 7–8 by concentrated NaOH or  $\text{NH}_4\text{OH}$  was found to be effective in decomposing the oxalate complexes ( $[\text{NbO}(\text{C}_2\text{O}_4)_3]^{3-}$  and  $[\text{NbO}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$ ) and precipitating Nb in the form of amorphous  $\text{Nb}_2\text{O}_5 \cdot n\text{H}_2\text{O}$  (s) while leaving the oxalate and nitrate ions in the filtrates.

The same phenomena take place with the Ta- $\text{HNO}_3\text{-H}_2\text{C}_2\text{O}_4$  solutions with precipitation of  $\text{Ta}_2\text{O}_5 \cdot n\text{H}_2\text{O}$ (s). Taking advantage of the solubility difference between nitrate and oxalate salts, the subsequent concentration of the nitrate-oxalate filtrates by evaporation yields to the quantitative and selective recovery of the oxalates as crystalline  $\text{Na}_2\text{C}_2\text{O}_4(\text{s})$  or  $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}(\text{s})$  (purity > 95%) and a concentrated solution of sodium or ammonium nitrate. The developed method exhibits high precipitation yields (>99.9%) for Nb and Ta and high recovery yields (>99%) for the nitrates and oxalates. The process was optimized at the laboratory scale and then validated on industrial Nb (~10 g/L) and Ta (~400 ppm) solutions with successful production of purified  $\text{Nb}_2\text{O}_5 \cdot n\text{H}_2\text{O}$ (s) (purity of 99.5 wt%) and a  $\text{Ta}_2\text{O}_5 \cdot n\text{H}_2\text{O}$ (s) concentrate (>20 wt% Ta), followed by the recovery and separation of the oxalates and nitrates. Taken together, the proposed precipitation method and the fluoride-free liquid-liquid Nb-Ta separation recently reported pave the way for more sustainable hydrometallurgical processes for Nb and Ta.



Graphical abstract: A new hydrometallurgical process, that does not require any fluoride-based reagent, allows the separation and purification of Ta and Nb. The developed strategy paves the way for more sustainable hydrometallurgical processes for niobium and tantalum.



# Steel producers respond to demand for high performance bridge steels with niobium

*Paper written by Steven G. Jansto Ph.D., Principal Partner at Research and Development Resources and a CBMM Technical Consultant working on behalf of CBMM North America, Inc. Copyright © CBMM. This article was first published on [www.niobium.tech](http://www.niobium.tech).*



The Millau Viaduct in France is the tallest bridge in the world at 343m (1,125 ft). Niobium was used at the rate of 0.025% per tonne of steel to reduce its overall weight by some 60%.

(Photo: Shutterstock)





Øresund Bridge connects Denmark and Sweden and was constructed with 82,000 tonnes of high strength steel. With a 0.02% Nb addition, a 15,000 tonne reduction in weight and a cost saving of \$25 million were realized. (Photo: Shutterstock)

### Key takeaways

- The civil engineering community is looking toward steel producers to provide the next generation of bridge materials that meet robust performance standards, offer design-flexibility, provide durability and resiliency, and allow for faster, lower cost bridge construction. Steel producers are responding with alloyed, high performance steels containing Niobium (Nb).
- Nb-containing bridge steels have demonstrated a consistency in the base mechanical properties, as well as exhibiting outstanding toughness, weldability and corrosion resistance.
- Lower carbon Nb-alloy steel designs are cost-effective in mill production, enabling the entire supply chain, from designer through to the end user, to realize the benefits of Nb as an additive.
- Nb-containing weathering steels for bridge construction are proving to be economical and extremely valuable as a carbon footprint environmental asset. Eliminating the need for steel painting generates an initial 10% cost saving. Without painting, exposure to contaminated blast debris or volatile organic compounds (VOC) is eliminated. Life cycle cost savings can exceed 30% due to extended corrosion resistance and less overall maintenance.

### Abstract

Nb-containing bridge steels are being produced by steelmakers to respond to the demand for better performing, value-added bridge materials. These steels possess a combination of exceptional properties – high strength, excellent weldability, impressive toughness at low temperature, desired ductility, superb corrosion resistance and high formability.

High performance steels (HPS) that include weathering steels for bridge structures, possess an optimized balance of these primary properties, providing a cost-effective product for bridge structures at strength levels from 355MPa to 700MPa, and demonstrating excellent corrosion resistance.

The combination of a desirable strength-toughness balance, favourable weathering properties and reduced pre-heat temperatures for welding in these low carbon Nb-bridge steels generates significant cost savings. When selected for new bridge construction or the rehabilitation of existing bridges, Nb-containing low carbon bridge steels are made in the form of net shape cast beams and/or welded plate sections that ensure lighter, more corrosion-resistant superstructures. The enhancements give designers and structural engineers the opportunity to specify HPS to further improve bridge structure design and performance.

## Introduction

Materials and structural engineering bridge designers are currently focused on developing high performance bridges that feature excellent loading behaviour, effective resistance to vibration, superb fabrication and corrosion resistance qualities, as well as improved fatigue and fracture toughness. Nb-containing steels improve the consistency of the base mechanical properties, and exhibit ideal toughness, weldability and corrosion resistance. Over the past 20 years, quality improvements relating to steel cleanliness, surface quality, mechanical properties and corrosion resistance have become increasingly evident.

Niobium and copper-containing bridge steels have been used successfully, especially with weathering steel grades. Many weathering bridge steels belong to the family of 355, 420, 460 and 500MPa yield strength levels. Critical connection components occasionally approach yield strength levels reaching 700MPa and may be specified (for example, HPS 100 W with niobium and copper). Selection of a weathering steel for a specific application is based on material availability and cost, fabrication, site location, weather conditions and a cost-benefit economic analysis. When specifying Nb-containing steels, the hybrid component – combination of high strength and mild steel grades – of structural design is simplified. This design can also achieve overall bridge steel dead weight reduction by integrating S355 with higher strength grades such as 420, 460 and 500MPa.

## Niobium-containing bridge applications

A high performance bridge steel (Q370qE-HPS) comprising low carbon content ( $<0.10\text{wt}\%$ ), Nb microalloying ( $0.025\text{-}0.050\text{wt}\%$ ) and low carbon equivalent (CEV) ( $<0.38\%$ ) has been produced using the thermomechanical controlled process (TMCP) for railway bridge applications. The results show the microstructure consists of fine-grained, quasi- polygonal ferrite (QPF), less pearlite and many finely dispersed Nb-rich nano-precipitates. Consequently, an excellent combination of high strength, high toughness and low yield-to-tensile strength ratio (YR) is obtained. TMCP of a low carbon Nb-microalloyed steel can lead to a significant refinement of ferrite grain, and simultaneously, less pearlite and even degeneration of the pearlite structure. [1] These events are likely to heighten interest to achieve a better balance of the final combination of YS, TS, YR and toughness.

Successful commercialization has led to Nb-bearing beams replacing V-bearing beams with substantial toughness improvements in beams and plates produced to various specifications, including ASTM992, ASTM572, ASTM588, ASTM710, Q345e and S355. Implementing Nb technology has vastly improved toughness properties through grain refinement and strategic cooling practices during rolling. Low carbon low alloy (LCLA) chemistry for a S355 bridge steel is less than the following:  $0.10\%\text{C}$ ,  $0.025\text{-}0.035\%\text{Nb}$ ,  $0.010\%\text{S}$ ,  $0.015\%\text{P}$ ,  $1.40\%\text{Mn}$ , with residuals less than  $0.70\%$  (i.e.,  $\text{Cr} + \text{Ni} + \text{Cu} + \text{Mo}$ ). The addition of Nb refines the grain by two ASTM sizes, lowers the carbon equivalent by  $0.07\%$  and significantly improves the toughness compared to V-bearing low C steels as shown in Figures 1 (a) [2] and (b). [3] Low carbon Nb-containing bainitic steels also offer a solution to produce bridge steel plates with excellent properties. The favoured microstructure and desired balance of mechanical properties are being achieved through an optimal combination of alloying additions and appropriately designed TMCP. Bainite is obtained in bridge steels by means of retarding the ferrite formation. [4] Nb is also effective for increasing the volume fraction of bainite. [5, 6] As in lower strength bridge steels, reducing the carbon to less than  $0.10\%$  is essential for maintaining toughness and sufficient HAZ (heat affected zone) properties. However, a minimum amount of alloying is necessary to prevent extensive softening while retaining adequate toughness. [7, 8]

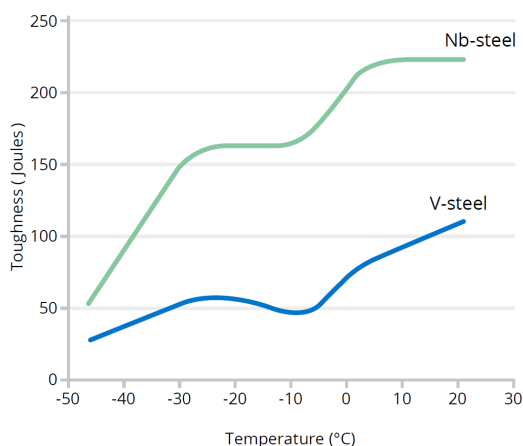


Figure 1. (a) Charpy V-notch impact strength comparison - Nb vs. V at Mill #1 [2]

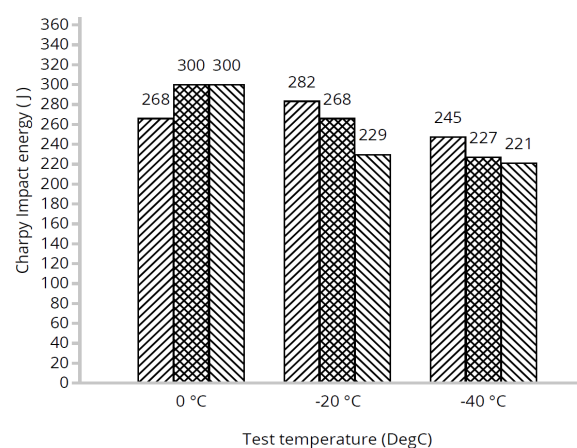


Figure 1. (b) Charpy V-notch impact strength toughness Nb steel at Mill #2 [3]



| Where elemental chemistry not listed, consider as maximum. | ASTM* A710/736 Grade A | ASTM A710 Grade B | ASTM A710/736 Grade C | MIL-S-24645** |           |
|--|------------------------|-------------------|-----------------------|---------------|-----------|
|  |                        |                   |                       | HSLA-80       | HSLA-100  |
| Carbon   | 0.07                   | 0.06              | 0.07                  | 0.06          | 0.06      |
| Manganese  | 0.40-0.70              | 0.40-0.65         | 1.3-1.65              | 0.40-0.70     | 0.75-1.05 |
| Phosphorus   | 0.025                  | 0.025             | 0.025                 | 0.020         | 0.020     |
| Sulfur   | 0.025                  | 0.025             | 0.025                 | 0.006         | 0.006     |
| Silicon  | 0.40                   | 0.15-0.40         | 0.40                  | 0.40          | 0.40      |
| Nickel   | 0.07                   | 0.06              | 0.07                  | 0.06          | 0.06      |
| Chromium   | 0.60-0.90              | –                 | –                     | 0.06-0.90     | 0.45-0.65 |
| Molybdenum   | 0.15-0.25              | –                 | 0.15-0.25             | 0.15-0.25     | 0.55-0.65 |
| Copper   | 1.00-1.30              | 1.00-1.30         | 1.00-1.30             | 1.00-1.30     | 1.45-1.75 |
| Niobium  | 0.02 min               | 0.02 min          | 0.02 min              | 0.02-0.06     | 0.02-0.06 |

Table 1. Low Carbon Copper-Niobium Bearing Bridge Steels [12]

\* ASTM specifications. \*\* Military specifications.

### ASTM A710 low-carbon age-hardenable copper-niobium bearing structural steels

NUCu 70W (Northwestern University Cu- Precipitation–Strengthened) steel, which is a copper precipitation-hardened, high performance Grade 70 weathering product, has been standardized as A710 Grade B. Research studies began at Northwestern University during the late 1990s with the support of the Federal Highway Administration, Illinois Department of Transportation and the school’s Infrastructure Technology Institute. Initially, the steel did not contain Nb. [9, 10]

Specifically, the corrosion properties of unpainted steel were compared. The newly developed NUCu steel features the lowest loss in thickness among commercial construction and weathering steels in accelerated automotive SAE J2334 salt, wet/ dry, eight-week corrosion tests performed by Bethlehem Steel Corporation. [11] Both A710 and A736 steels are available in three different classes: Class 1, as rolled; Class 2, normalized; and Class 3, quenched.

In some instances, improved toughness at low temperature is desired for certain regions of Canada and the northern United States. To meet the demand, research and development of weathering resistant copper age-hardening steels (A710 type) has ensued. Table 1 compares the composition of the three ASTM grades involving A710-type steels with HSLA-80 and HSLA-100 of the MIL-S-24645. Note the minimum 0.02%Nb level.

The carbon content is reduced well below 0.10% to a range of 0.06-0.07%C. A lean carbon and alloy composition creates an extremely low carbon equivalent for excellent weldability, toughness and formability. Figure 2 illustrates that the NUCu (ASTM A710 Grade B) steel features a far superior corrosion resistant characteristic than any other commercially available weathering bridge steel. In addition, the paint adherence and corrosion resistance are markedly improved over popular HPS 70W bridge steels as shown below. Figure 2 illustrate corrosion and salt spray comparison results.



Figure 2. Painted Steel Corrosion Comparison [11]

Table 2 shows the values of the ASTM G101 corrosion index for several bridge steels. [13, 14] These are non-weatherable steel grades A36 and A572-50; weatherable and non-weatherable A588 steels used in bridge construction the past few decades; weatherable, high performance A709 50W and 70W used the past 15 years; and A710 Grade B steel developed at Northwestern University and used for bridge construction in Illinois. A588 weatherable steels derive their weatherability characteristic primarily from Cu (0-.20-0.50%) and Cr (0.30-0.60%); A709 HPS70W steel from Cu (0.25-0.40%) and Cr (0.45-0.70%); and A710 Grade B from Cu (1.20- 1.40%). A710 Grade B possesses the highest G101 index among all weathering steels used today. Table 2 compares commercially produced bridge steels currently available for building bridges in North America. [13, 14]

| Steel Grade  | G101 New Index |
|--------------|----------------|
| A36          | 2.85           |
| A572-50      | 3.24           |
| CORTEN B     | 4.90           |
| A588 Grade C | 4.95           |
| A588 Grade B | 5.43           |
| A709 50W     | 4.95-6.51      |
| CORTEN A     | 5.88           |
| A709 HPS 70W | 6.62           |
| A710B        | 7.33           |

Table 2. ASTM G101 Index for Commercially Produced Bridge Steels

The original ASTM Standard G101 corrosion index, based on the work of Legault and Leckie [15], was used to predict if a steel is weatherable. They utilized a portion of an extensive database published by Larrabee and Coburn. [16] The ASTM Standard G101 was established to estimate corrosion resistance of low-alloy weathering steels derived from chemical composition data and actual atmospheric exposure tests. Many high strength, low alloy steels are currently used in the development stage with chemical composition ranges extending beyond those covered by the ASTM Standard G101. These steels may contain more nickel and copper or elements not included in the Standard G101. Being able to estimate the weatherability of these steels is of primary interest today. As a result, new equations have been added to the revised ASTM Standard G101 corrosion index. [17]

#### Corrosion Behavior in Niobium- containing Steels

Continuing research involves the characterization of CuNb precipitates and grain refinement of Nb as to their potential role in improving corrosion performance. The composition of co-precipitated NbC carbide precipitates, Fe<sub>3</sub>C iron carbide (cementite) and Cu-rich precipitates continues to be studied by atom- probe tomography (APT). [18] Cu-rich precipitates located at a grain boundary (GB) also are under study. ATP results for carbides are supplemented with computational thermodynamics predictions of composition at thermodynamic equilibrium. Two types of NbC carbide precipitates are identified based on their stoichiometric ratio and size.



Decades of structural and material neglect, lack of budget, end of design life, and the effects of weather and hazard events have produced an urgent need for bridge replacement and rehabilitation throughout the United States and abroad with new and improved higher toughness and more corrosion resistant steels. (Photo: Shutterstock)

Grain refinement is known to influence improvements affecting strength and wear resistance. Inherent processing involved in grain refinement alters both the bulk and surface of a material, leading to changes in grain boundary density, orientation and residual stress. Ultimately, these surface changes can impact electrochemical behavior and consequently, corrosion susceptibility as evidenced by the large number of studies addressing the effect of grain size on corrosion. These studies cover a broad range of materials and test environments. However, limited research has been conducted to gain a fundamental understanding of the grain refinement mechanism with Nb. Generally, the studies seek to determine how grain size affects corrosion resistance of an alloy. Existing literature is often contradictory, even within the same alloy class, and a coherent understanding of how grain size influences corrosion response is noticeably lacking. [19] Cross-application and development of additional global corrosion on weathering bridge steels are highly recommended to better understand enhanced corrosion behavior and corrosion behavior via Nb-grain refinement and NbC precipitation.



(Photo: Shutterstock)

The Hong Kong-Zhuhai-Macao bridge is the world's longest cross-sea project at 55Km (34 miles), incorporating a bridge and a 6.7Km (4 miles) seabed tunnel. The HBIS Group optimized levels of vanadium, chrome, niobium and copper to provide high strength, anti-seismic wire bars with an unprecedented anti-corrosion ability used for the immersed tunnel construction.

#### HPS 50W, 70W and 100W HPS bridge steels

Development of HPS grades was initiated through a cooperative agreement involving the Federal Highway Administration, the U.S. Navy, and American Iron and Steel Institute. The goal was to enhance weldability and toughness over previous versions of grade 70 and 100 steel. [20] Prior to HPS, steels with yield strength greater than 355MPa (A852 and A514) were extremely sensitive to welding conditions. As a result, fabricators often encountered welding problems. HPS grades essentially have eliminated such concerns due to the lower carbon approach. In addition, these grades provide enhanced fracture toughness compared to non-HPS grades and have replaced A852 grades.

HPS properties are achieved largely by dramatically lowering the percentage of carbon in the steel chemistry. Since carbon is traditionally a primary strengthening element in steel, the composition of other alloying elements becomes more precisely controlled in order to meet the required strength and compensate for the reduced carbon content. Lower carbon levels are essential to improving steel mechanical properties and weldability. Recently, incorporating Nb into numerous steel grades is displacing the traditional practice of using higher carbon (greater than 0.11%C) and higher manganese structural steels. The application of Nb-technology in bridge steels, as well as cross- application into lower strength plate, section and long products, depend on the design criterion of the end user. The customer often desires improved toughness (i.e., energy absorption for the civil engineering community), a higher level of fracture toughness, improved cyclic fatigue performance (seismic), greater homogeneous grain size and microstructure.

On the processing side, adding Nb for structural steel plate and long product applications, normalizing and heat treatment cycles can be shortened or entirely eliminated for bridge and other infrastructure applications. The impressive results are increased throughput, productivity, capacity and achieving operational cost reduction of 5-15 percent. [21]



|                         |     | C    | Mn   | P     | S                 | Si   | Cu   | Ni   | Cr   | Mo   | V    | Nb   | Al    | N     |
|-------------------------|-----|------|------|-------|-------------------|------|------|------|------|------|------|------|-------|-------|
| Old 70W                 | Min | –    | 0.80 | –     | –                 | 0.25 | 0.20 | –    | 0.40 | –    | 0.02 | –    | –     | –     |
|                         | Max | 0.19 | 1.35 | 0.035 | 0.040             | 0.65 | 0.40 | 0.50 | 0.70 | –    | 0.10 | *    | –     | –     |
| HPS70W<br>and<br>HPS50W | Min | –    | 1.10 | –     | –                 | 0.30 | 0.25 | 0.25 | 0.45 | 0.02 | 0.04 | –    | 0.010 | –     |
|                         | Max | 0.11 | 1.35 | 0.020 | .006 <sup>A</sup> | 0.50 | 0.40 | 0.40 | 0.70 | 0.08 | 0.08 | *    | 0.040 | 0.015 |
| HPS100W                 | Min | –    | 0.95 | –     | –                 | 0.15 | 0.90 | 0.65 | 0.40 | 0.40 | 0.04 | 0.01 | 0.020 | –     |
|                         | Max | 0.08 | 1.50 | 0.015 | .006 <sup>A</sup> | 0.35 | 1.20 | 0.90 | 0.65 | 0.65 | 0.08 | 0.03 | 0.050 | 0.015 |

Table 3. Chemical Compositions of Weathering HPS Grades [22]

<sup>A</sup> The steel shall be calcium treated for sulfide shape control.

\* Nb added by discretion of steel producer at 0.01-0.02%Nb in HPS 50W and 70W for grain refinement.

For reference, the finer grain size produced with the Nb addition in plate or section steel may allow the mill to adjust its chemistry to a leaner alloy system with reduced Mn levels. In 2018, CBMM North America, Inc. published a white paper that outlines the production process for lowering Mn levels in infrastructure steels. [21] Cross-application for bridge steels is progressing. Experience is proving that HPS steels, due to their higher strength, can deliver more cost-effective bridge projects. The scope of this benefit generally equates to the size and span length of the bridge. The longer the bridge, the greater the cost saving. Since the price of HPS steel is higher than conventional steel, the designer should carefully consider all the project details to ensure that the benefits outweigh an additional product cost.

HPS 50W is an as-rolled steel produced to the same chemical composition requirements as grade HPS 70W. As with higher strength HPS grades, HPS 50W features enhanced weldability and toughness compared to grades 50, 50W and 50S. The primary advantage of HPS 50W is a high toughness that exceeds current American Association of State Highway & Transportation Officials specifications for grades 50 and 50W. Enhanced toughness may be beneficial for certain fracture critical members with low redundancy, such as tension ties in tied arch bridges. Table 3 compares old and new compositions for 70W and the carbon reduction.

As previously discussed, the trend toward production of a leaner alloy system has led to the adoption of a MicroNiobium addition (less than 0.02%) specifically to obtain grain refinement of at least two ASTM grain sizes. The system meets ASTM A20 specifications since Nb is considered a residual element in the 0.01% to 0.02% range and adheres to all HPS and ASTM A709 chemical requirements.

#### Future opportunities for weathering bridge steels

An opportunity exists for the global steel industry to further develop value-added HPS bridge materials that will meet future construction and performance needs across the marketplace. Because of increased raw material, alloy and steelmaking costs, the civil engineering community demands bridge steels that translate into faster, lower cost bridge replacement in the United States and Europe, as well as new bridge construction in Brazil, China, Russia and India. Another opportunity is to develop even lower carbon-lean alloy bridge steels. Many current HPS products of 490MPa and 700MPa are rich alloy compositions that drive up costs for the end user. Research activity in some areas of the world is focused on developing a series of Nb-bearing LCLA bridge steels that further improve HPS 50W, HPS 70W and HPS 100W, especially their fracture toughness, fatigue and low temperature impact properties.

From a materials engineering perspective, the following list outlines material and fabrication demands provided by the civil engineering community and end users. These objectives are intended for steel producers committed to next-generation bridge steel development. It is important to note that many of the listed opportunities represent potential for Nb-bearing steels.

- Improved corrosion resistance of weathering carbon steels
- Reduced weight of bridge assemblies for faster installation time
- Civil engineering goal: two crane lifts of bridge assembly to span a six-lane highway, thereby reducing traffic closure time
- Improved weldability to increase fabrication and field erection productivity

- Increased use of hot forming for cured bridge beams
- Improved corrosion resistance with excellent toughness
- Reduced cost of high-performance bridge steel materials
- Fire-resistant steel (rebar) for tunnel and long span bridge applications (Class II flammable truck traffic)
- Improved structural performance (i.e. deflection, expansion)



Nb-containing high performance bridge steels are providing engineers design flexibility, lowering initial costs through weight savings in transportation and fabrication, and resulting in life-cycle savings with fewer maintenance requirements and a longer service life. (Photo: Shutterstock)

### Conclusion

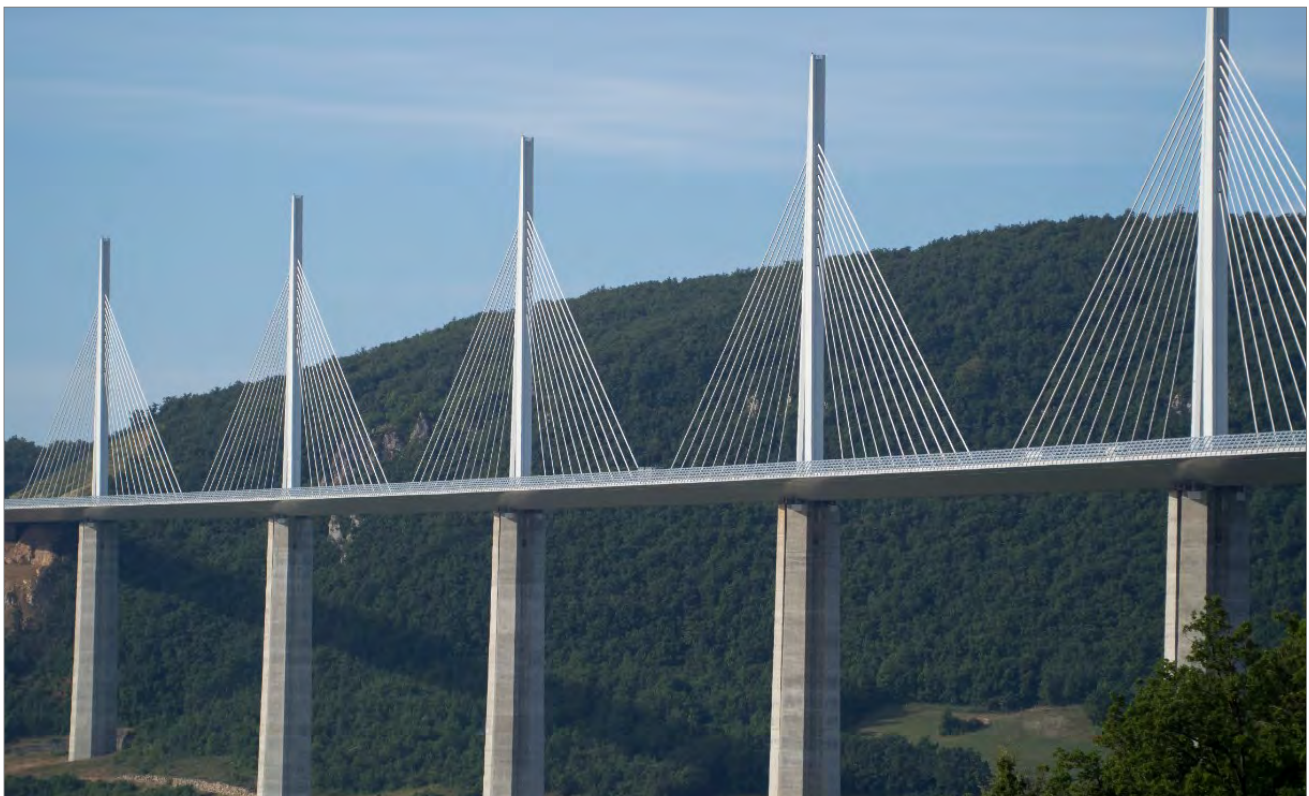
The use of weathering steels for bridge construction provides substantial cost saving, as well as environmental benefits. A cost saving exceeding 10 percent is initially realized because the painting step is eliminated. The steel is also easier to handle and install during construction. Life cycle cost savings of more than 30 percent can be realized since weathering steels require less maintenance and have proven to be more durable than common construction steels. The use of weathering steels also provides major environmental benefits as no volatile organic compounds (VOC) associated with paints are involved.

Finally, over the life of the structure there is no need for removal or disposal of contaminated blast debris that is required in the use of non-weathering steels. The overall benefits have contributed to the growing popularity of selecting weathering steels for new highway bridge construction. A cautionary note is that such steels are not considered adequate for use in marine and other high saline environments. Research involving low carbon, copper and niobium-bearing steels is continuing to include these applications. While corrosion resistance remains a critical research subject, other key attributes being studied for weathering bridge steels are toughness, weldability and low temperature performance. Substantial progress can be traced to the success of the ASTM A710B bridge steel grade. Recent corrosion science activities are being advanced to better understand corrosion and corrosion-resistant behaviours via Nb-grain refinement and NbC precipitation in high strength low alloy steels.

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The Viaduct de Millau bridge in southern France stands as the tallest bridge in the world at 343 m (1,125 ft). Niobium was used at the rate of 0.025% per tonne of steel to reduce its overall weight by some 60 percent. (Photo: Shutterstock)

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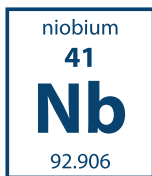


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# 62nd General Assembly: Technical Programme Abstracts

The 62nd General Assembly is scheduled to be held in London, UK, from November 14th to 16th 2021.

Please note that, while we sincerely hope this event will be able to take place, at time of publication this cannot be guaranteed due to uncertainties caused by the Covid-19 global pandemic. The Executive Committee asks for your understanding as it continues to monitor the situation closely. Please look out for further updates in due course.

Full details, including how to book tickets, sponsors and general information about the event will be circulated and made available at [www.tanb.org](http://www.tanb.org) in due course.



Photo: Shutterstock

**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.**

## **Current limitations and future opportunities in tantalum capacitors**

By Yuri Freeman and Phil Lessner

KEMET Electronics

Tantalum capacitors are the major consumers of the currently produced element tantalum. The surface mount solid electrolytic tantalum capacitors with inorganic manganese dioxide cathodes and polymer tantalum capacitors with inherently conductive polymer cathodes constitute the majority of the tantalum capacitors used in modern electronics. While the volumes of ceramic and other types of capacitors have increased exponentially in recent times, the volumes of tantalum capacitors remained stagnant with declining volumes of the solid electrolytic tantalum capacitors and slowly increasing volumes of polymer tantalum capacitors. The presentation will discuss major limitations for usage of tantalum capacitors such as ignition and burning tantalum failure mode in solid electrolytic tantalum capacitors and wear-out failure mode and anomalous charge current (ACC) in polymer tantalum capacitors and possible ways to overcome these limitations.

## **Effect of tantalum-niobium composite carbides preparation process on its physical properties**

By Bai Zhangjun, Mu Dong, Huang Yunkong, Xie Weiping, Wang Qiang. Presented by Jiang Bin.

Ningxia Orient Tantalum Industry Co., Ltd

In this paper, the influence of raw material category, sintering process and grinding process on the properties of tantalum-niobium composite carbide powder is discussed, and the physical characteristics of tantalum-niobium carbides are analysed. In the meantime, Fisher average particle size, particle size distribution, apparent density, porosity and morphology of carbides are analysed to determine comprehensive influence of various factors on the product quality. The results show that the particle size of the raw material has a great influence on the particle size of the product, showing the particle heredity rule. The porosity and apparent density of carbide products are also related to the particle size of the raw material. The smaller the particle size of the raw material, the smaller the porosity, while the apparent density tends to increase. However, the "arch bridge" formed between the agglomerated particles is destroyed due to the airflow pulverization of carbides with the same raw materials, the apparent density increases when the average particle size decreases.

## **Packaging and transportation of radioactive tantalum and niobium: finding solutions to increasingly complex problems**

By Kevin Loyens

TAM International LP

Logistics continues to be the lifeblood of the radioactive material industry - whether that be in the nuclear fuel cycle, or industries dealing with NORM material containing traces of uranium or thorium, the complex nature of transporting this material requires a strong understanding of various regulations from around the world in order to create a seamless and efficient supply chain for these vital resources. Once cargo is categorized as “IMO Class 7”, the framework for packaging and transportation significantly changes. Not only do different regulations apply in different jurisdictions, these regulations are sometimes subject to different interpretation by various stakeholders. The compliance with the various regulations impacts the packaging that is used, labelling requirements, and how transport of the cargo is organized.

The diligence required for understanding the framework for compliance, operations and insurance is significant and must be executed with precision. While the industry continues to adapt to these restrictions, it will continue to see change in the current COVID environment. Properly understanding the regulatory, operational and safety framework of transporting radioactive material will enable companies to implement an optimal strategy for efficiently managing these materials throughout their supply chain. With more than 17 years of experience, TAM International is an international company with a global network that is specialized in handling, packaging and worldwide transport of radioactive materials, and is well positioned to provide an overview of current trends, challenges, and best practices for NORM transportation.

## **Denials revisited: new momentum and ideas in addressing denial of shipment**

By Ulric Schwela

Salus Mineralis Ltd

Over the past year, significant changes have taken place in how the issue of denial of shipment is tackled. These developments promise improved awareness and longer lasting practical solutions that will promote a more reliable regulatory environment for the sustainable transport of all Class 7 materials, in compliance with relevant applicable regulations. The paper will provide a background summary of the issue and past actions, and an overview of recent initiatives that have given new momentum to addressing denial of shipment, including the:

- September 2020 IAEA General Conference resolution;
- March 2021 IAEA technical meeting and agreed actions;
- Working Group established to tackle denial of shipment;
- Code of Conduct on facilitation of transport, its potential benefits and challenges to its implementation;
- Re-establishing the National Focal Point network.

Finally the path ahead will be laid out, with significant milestones along the way.

## **Costs and value of due diligence in mineral supply chains: OECD POSITION PAPER**

By Rashad Abelson

Organisation for Economic Co-operation and Development (OECD)

Ongoing multi-stakeholder discussions have raised important questions on the perceived imbalance of how due diligence costs and benefits are distributed along the supply chain. This position paper was drafted in response to stakeholder calls that the OECD examine this topic with the objective of raising awareness, better informing discussions, identifying key research questions, and guiding stakeholders towards viable solutions.



## **Quantitative assessment of tantalum consumption in the United States from 2002 to 2020**

By Abraham Padilla and Nedal Nassar

United States Geological Survey (USGS)

Tantalum has received considerable attention in recent years largely due to its increasing use in modern electronics and the high risks associated with its supply chain. In 2020, approximately 70% of the world's supply of tantalum originated from countries in Africa, with nearly 40% thought to originate in the Democratic Republic of Congo alone. The United States (U.S.), a leading consumer of tantalum materials, has been entirely reliant on imports for its supply of primary tantalum since the 1950s. However, properly quantifying total U.S. tantalum consumption is problematic because two of the most important intermediate forms of tantalum ( $Ta_2O_5$  and  $K_2TaF_7$ ) do not have unique tariff codes and thus a significant part of tantalum material trade is not documented. Furthermore, tantalum incorporated in semi-finished and finished goods is not tracked as tantalum. As a result, estimates of consumption only capture a fraction of the total volume of tantalum consumed in any given year. In this study, we perform a material flow analysis (MFA) to quantify the total volume of tantalum consumed in the United States from 2002 through 2020.

Our results indicate that U.S. tantalum consumption may be significantly higher, and up to twice as much at times, than previously estimated. Interestingly, our estimates show that some years U.S. tantalum demand has exceeded the volume of primary tantalum produced globally according to U.S. Geological Survey estimates. This suggests that either a significant volume of global primary tantalum production is not accounted for, the volume of secondary (recycled) tantalum available is significantly underestimated, or both. Lastly, the detailed MFA results allow us to quantify the volume of tantalum in use as well as the quantity that may potentially be available for recycling in any given year, thereby providing valuable insight to both industry and policymakers for identifying possible tantalum above-ground resources available for re-use as recovery technologies, especially for electronic waste, improve.

## **Development of novel spherical multinary alloy powders containing tantalum and niobium for optimization of intrinsic material properties in AM**

By Melanie Stenzel, Bahar Fayyazi, Markus Weinmann and Christoph Schnitter

TANIOBIS GmbH

The high degree of freedom for geometric designs opened by additive processes is often seen as a main driver for improvement of components but design optimization alone is not enough to achieve the highest component performance. Intrinsic material properties also play a vital role to fit parameters to specific requirements of applications. This is especially relevant for applications in which inappropriate material properties may cause fatal failure. The present paper gives an overview of the development and optimization of refractory metal-based spherical multinary alloy powders with variable composition for applications like biomedical, aerospace or chemical process engineering. It will be shown that alloy powders based on tantalum and niobium can be applied in laser powder bed fusion (L-PBF) and alternative additive manufacturing processes, offering improved properties and mechanical characteristics compared to their conventionally manufactured counterparts. Finally the development of multinary and high entropy alloys as well as first results on their application in 3D printing including their microstructure evolution will be elaborated.

## **Niobium rod preforms for low temperature superconductors in fusion energy**

By Robert Marchiando

H.C. Starck Performance Metal Solutions

Niobium is a critical superconductor component in the development of high strength magnets required for Tokamak (magnetically confined) fusion energy. As the global scientific community drives to demonstrate its viability, sustainability, and ultimately commercialization of this new energy form, the property requirements and performance of niobium as well as tantalum will play a key role. This paper will describe the niobium rod preform and its attributes as a critical component of superconducting filaments used to manufacture superconducting wire for its application in fusion energy. The chemistry and important properties of the preform will be described in the context of producing finished niobium filaments and superconducting multifilament wire as manufactured by Kiswire Advanced Technology.

## **ICGLR Regional Certification Manual (RCM) introduces a new status for mine sites and exporters – the “Blue Status”**

By ICGLR Secretariat, presented by Gerard Nayuburundi

International Conference on the Great Lakes Region (ICGLR)

The release of the Second Edition of the Regional Certification Mechanism (RCM) Manual introduced a new concept of “Blue Status” for classifying 3TG mine sites and exporters. The Blue Status is a new, fourth status criterion under the RCM. It complements the previous three status criteria of Green (valid), Yellow (provisionally valid) and Red (not valid), which denote the outcome of the verification process. By contrast, Blue Status is the default status for all legally registered mine sites and exporters when no verification has taken place or where a verification has been requested but has not been carried out within the timeframe specified in the RCM. By this we mean when new mine sites and exporters are legally established and have not yet been verified in accordance with the RCM requirements, and when they are already in existence but State and / or ICGLR led verification processes do not have the resources available to conduct verification within the timeframes detailed in the RCM Manual.

We contend that this change is an essential ingredient to ensuring the commercial viability of formal 3TG mineral supply chains in the Great Lakes Region. The introduction of the Blue Status for 3TG mine sites and exporters is aligned with the OECD Due Diligence Guidance for Responsible Minerals from Conflict Affected and High-risk Areas as it creates an opportunity for Member State and ICGLR programs as well as businesses operating within their territories to mature in a low-capacity situation and it reaffirms the role of industry in effective due diligence. Finally, in order to avoid a situation of perpetual Blue Status, which could potentially undermine the additional checks and balances allowed for in the RCM, the revision incorporated a time limit of 3 years after which non-verified mine sites/exporters once again revert to Red Status.

## **Expanding customer and market expectations of minerals due diligence – an update on the Responsible Minerals Assurance Process (RMAP) and the Responsible Minerals Initiative (RMI)**

By Catherine Tyson and Leah Butler

Responsible Minerals Initiative (RMI)

Despite the disruptions of COVID-19 in 2020 and 2021, market expectations for due diligence for responsible mineral supply chains have continued to progress as companies deepen their understanding of due diligence and broader ESG risks along the supply chain. Regulatory demands for due diligence in mineral supply chains have continued unabated. Working together, the RMI and its stakeholders, including the T.I.C., continue to develop programs and tools that offer consolidated solutions in response to the expectations of actors along mineral supply chains and satisfy regulatory demands. In this paper and presentation, the RMI will address the current status and progress of smelter due diligence in the tantalum sector, updates to RMI's programs, new RMI program and tool offerings, the status of the RMAP and Downstream Assessment Program (DAP) recognition by the European Commission, adjusting to the EU CAHRA list and approaches to implementing enhanced due diligence activities in new areas, and opportunities for future collaboration with the tantalum industry.

## **T.I.C. 2021 annual statistics presentation**

by David Knudson and the T.I.C. Statistics Subteam

Tantalum-Niobium International Study Center (T.I.C.)

This presentation will provide a comprehensive statistical report on collected T.I.C. member data for calendar years 2011 through 2020 along with up to date publicly sourced international trade data on tantalum and niobium raw materials and products. Also covered will be the collection practices of publicly available international trade data and the methodology for its integration with T.I.C. member collected trade data. Each quarter the T.I.C. administers the collection of anonymous statistics data from its members by an independent intermediary (Miller Roskell Ltd, a chartered accountant). This data is then verified and certified by Miller Roskell Ltd and provided to the T.I.C. The data is then collated and presented in report form to our members, also on a quarterly schedule. The categories for data collected are tantalum and niobium raw materials, mining production and trading receipts, tantalum receipts by processors, and tantalum and niobium product shipments by processors.

## **A decade of ITSCI: reflecting on learning and achievements, recent COVID challenges, and how to continue to build for success**

By Roper Cleland and Mickael Daudin (co-presenting)

International Tin Association (ITA) and Pact

ITSCI is a joint-industry due diligence and traceability programme connecting mineral purchasers and smelters in over 40 countries to 3T sources in central Africa (Burundi, DRC, Rwanda and Uganda). ITSCI has built and improved due diligence systems since 2010, and our standards are 100% aligned with the OECD Due Diligence Guidance. In 2020-2021, ITSCI continued despite disruptions from COVID. ITSCI, with its implementing partner Pact, reduced operations while maintaining essential activities such as incident reporting and mitigation. ITSCI demonstrated its capacity to manage ongoing human rights, security and fraud risks on the ground, through engagement and effective mitigation as well as support to upstream actors. Today more than ever, adherence to the programme and support by the industry are instrumental to secure the wins achieved in the past 10 years, maintain highest standard for responsible business and contribute to building further resilience of local ASM communities. In the midst of recovery, ITSCI continued to build back and evolve programme needs, for instance through adapting whistleblowing and radio programming to address critical risks arising from COVID, use of local stakeholder committees and their expansion to new areas, and ongoing adjustments in field capacity and deployment based on changes in mining activities. In 2021, ITSCI also resumed the roll-out of electronic data collection in Burundi, with plans for scale up. This paper outlines some of the challenges and learning from the COVID crisis, our measures to adapt, and the ways to continue to work to success.

## **Tantalum recycling by solvent extraction: chloride is better than fluoride**

By Jason Love, Luke Kinsman, Rosa Crevecoeur, Amrita Singh-Morgan, Bryne Ngwenya and Carole Morrison

EaStCHEM School of Chemistry and the School of Geosciences, University of Edinburgh, UK

The recycling of tantalum (Ta) is becoming increasingly important due to the criticality of its supply from a 'conflict' mineral. It is used extensively in modern electronics, such as in capacitors, and so electronic waste is a potentially valuable secondary source of this metal. However, the recycling of Ta is difficult, not least because of the challenges of its leaching and subsequent separation from other metals. In this work, we show that Ta(V) halides, such as  $TaCl_5$  and  $TaF_5$ , which can potentially be accessed from Ta metal upon acid halide leaching, can be recovered by solvent extraction using a simple primary amide reagent. The need for high halide concentrations in the aqueous phase implies the formation of the hexahalide salts  $[TaX_6]^-$  ( $X = F, Cl$ ) and that an anion-swing mechanism operates. While extraction of the fluorides is poor (up to 45%), excellent extraction under chloride conditions is found (>99%) and presents an alternative route to Ta recycling.



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In addition to the presentations listed here, the following sessions are planned to take place during the conference:

- The 2021 annual general meeting (AGM) of the T.I.C. (only open to members)
- An expert panel discussion focusing on supply chain issues
- An expert panel discussion focusing on best practice in transporting Naturally Occurring Radioactive Materials (NORM)
- A presentation by the winner of the 2021 Anders Gustaf Ekeberg Tantalum Prize. They will be awarded the Ekeberg Prize medal, made from 100% tantalum, during the Gala Dinner.

Kindly note that at time of writing there remain significant uncertainties surrounding the hosting of large in-person events due to the ongoing Covid-19 pandemic and as such this program may be forced to change for reasons that are outside our control.

The T.I.C. Executive Committee shall do all it can to create and host a meaningful yet safe event. For further updates and information about how to book your ticket to attend visit [www.tanb.org](http://www.tanb.org). **TIC**



# Tantalum and niobium intellectual property update

This information is taken from the European Patent Office ([www.epo.org](http://www.epo.org)) and similar institutions. Patents listed here were chosen because of their apparent relevance to tantalum and/or niobium. Some may be more relevant than others. Note that European patent applications that are published with a search report are 'A1', while those without a search report are 'A2'. When a patent is granted, it is published as a B document. Disclaimer: This document is for general information only and no liability whatsoever is accepted. The T.I.C. makes no claim as to the accuracy or completeness of the information herein.

| Title | Applicant(s) | Publication date |
|-------|--------------|------------------|
|-------|--------------|------------------|

## TANTALUM

|   |  |            |
|---|--|------------|
| Tantalum capacitor with increased stability<br>WO2021119088 (A1)  | AVX CORP [US]  | 2021-06-17 |
| Tantalum carbonate-coated graphite member and method for producing same<br>WO2021117498 (A1)                      | SHINETSU CHEMICAL CO [JP]                              | 2021-06-17 |
| Tantalum capacitor and manufacturing method thereof<br>US2021183585 (A1)  | SAMSUNG ELECTRO MECH [KR]                              | 2021-06-17 |
| Initiator system for cationic polymerization of olefins<br>US2021171550 (A1)                                      | ARLANXEO CANADA INC [CA]; UNIV BRITISH COLUMBIA [CA]   | 2021-06-10 |
| Solar heat-collecting pipe<br>US2021172654 (A1)   | TOYOTA JIDOSHOKKI KK [JP]; JAPAN FINE CERAMICS CT [JP] | 2021-06-10 |
| A method for manufacturing tantalum powder using self-propagating high-temperature synthesis<br>KR20210059051 (A) | KOREA INST IND TECH [KR]                               | 2021-05-25 |
| Smelting equipment for the production of tantalum powder<br>KR20210060761 (A)                                     | KOREA INST IND TECH [KR]                               | 2021-05-27 |
| Tantalum-silicon alloy sputtering target material and preparation method therefor<br>WO2021103381 (A1)            | KONFOONG MATERIALS INT CO LTD [CN]                     | 2021-06-03 |
| Method for the formation of tantalum carbides on graphite substrate<br>US2021162453 (A1)                          | NAT CHUNG SHAN INST SCIENCE & TECH [TW]                | 2021-06-03 |
| Heat resistant nickel based alloy and product made from it<br>RU2748445 (C1)                                      | AKTSIONERNOE OBSHCHESTVO OBEDINENNAYA... [RU]          | 2021-05-25 |

## NIOBIUM

|  |   |            |
|--|---|------------|
| Positive electrode active material, method for producing same, and lithium secondary battery including same<br>WO2021125877 (A1)       | POSCO [KR]; RES INST IND SCIENCE & TECH [KR]                      | 2021-06-24 |
| Liquid composition for forming KNN film and method for forming KNN film using said liquid composition<br>US2021188657 (A1)             | MITSUBISHI MATERIALS CORP [JP]                                    | 2021-06-24 |
| Cold rolled steel sheet with ultra-high strength, and manufacturing method therefor<br>WO2021117989 (A1)                               | HYUNDAI STEEL CO [KR]   | 2021-06-17 |
| Congruently melting titanium-zirconium-niobium alloy<br>AU2020214788 (A1)  | RAYTHEON CO [US]  | 2021-06-17 |
| Method for pulping niobium oxide<br>PL432049 (A1)  | UNIV EKONOMICZNY WE WROCLAWIU [PL]                                | 2021-06-14 |
| Method for producing cold-rolled hot-galvanized flat products from steel with two-phase ferrite-martensite structure<br>RU2749411 (C1) | PUBLICHNOE AKTSIONERNOE OBSHCHESTVO SEVERSTAL PAO SEVERSTAL [RU]  | 2021-06-09 |
| Method for smelting high-chromium nickel alloy of EP648-VI grade<br>RU2749409 (C1)   | AKTSIONERNOE OBSHCHESTVO METALLURGICHESKIJ ZAVOD ELEKTROSTAL [RU] | 2021-06-09 |
| Electro-ceramic material component, its manufacturing method and method of converting energy<br>WO2021111035 (A1)                      | OULUN YLIOPISTO [FI]  | 2021-06-10 |
| Ceramic circuit board and method for producing same<br>US2021176859 (A1)   | DENKA COMPANY LTD [JP]  | 2021-06-10 |
| Welding wire for modified 9Cr-1Mo steel<br>WO2021107279 (A1)   | KISWEL LTD [KR]   | 2021-06-03 |

# Diary of industry events\*

- Passive Components Networking Symposium (PCNS), Milan, Italy, September 7th - 10th 2021
- MMTA International Minor Metal Conference, Charleston, South Carolina, USA, September 12th - 14th 2021
- LME London Metal Week, London, UK, October 11th - 15th 2021
- RBA & RMI Annual Conferences (venue tbc), w/c October 18th 2021
- CRU Ryan's Notes Ferroalloys, Orlando, Florida, October 24th - 26th 2021
- IAEA's 43rd TRANSSC meeting, 1st - 5th November 2021
- **T.I.C.'s 62nd General Assembly and 2021 AGM, London, UK, November 14th - 16th 2021**
- FORMNEXT, Frankfurt, Germany, November 16th - 19th 2021
- Tarantula (Month 30), (tbc) December 2021
- Investing in African Mining Indaba, Cape Town, South Africa, February 7th - 10th 2022
- IAEA's 44th TRANSSC meeting, (tbc) June 2022
- Tarantula (Month 36), (tbc) June 2022
- **T.I.C.'s 63rd General Assembly and 2022 AGM, Geneva, Switzerland, October 16th - 19th 2022**

\* correct at time of print

## Member company updates

### Changes in member contact details

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

- **Australian Strategic Materials** has changed the delegate to Mr David Woodall. He can be contacted at [dwoodall@asm-au.com](mailto:dwoodall@asm-au.com). All other details remain unchanged.
- **Minor Metals Trade Association (MMTA)** has changed the delegate to Ms Freya Kerwin. She can be contacted at [freya@mmta.co.uk](mailto:freya@mmta.co.uk). All other details remain unchanged.

## Join our mailing list to receive the Bulletin by email, free each quarter

Our mission with the Bulletin is to provide the global tantalum and niobium community with news, information and updates on our work. We hope you enjoy reading it! Recipients will also receive messages about the T.I.C. and our General Assemblies.

Email [info@tanb.org](mailto:info@tanb.org) to join our mailing list and keep up to date with the T.I.C. The full archive of Bulletins, including Bulletin Reviews, is available at [Tanb.org](http://Tanb.org).



# Editor's Notes

London, UK

Dear T.I.C. Members and stakeholders,

I hope this finds you well. My colleagues and I are greatly looking forward to welcoming you to the 62nd General Assembly (conference and annual general meeting) which will be held here in London later this year.

While there can be no doubt that the quality of video conference calls has improved enormously in recent years, it is nonetheless challenging to try and continue 'normal' business without travelling (in 2019 I spent almost 4 months away from home on T.I.C. business, but in 2020 this figure was reduced to just 4 days!). I'm sure you'll agree that it will be very good to meet face-to-face and enjoy shared meals once again.

For those of you who are planning to attend the 62nd General Assembly, I recommend that you make a reservation in your diary for Wednesday 17th November. This is the day after the conference plenary sessions close and is traditionally the day when we have a field trip to somewhere with links to our industry, such as a mine, refinery or aircraft factory.

London may lack heavy industry these days, but the city makes up for it with millennia of history and many fine restaurants; so this year we plan to hold a walking tour (with lunch) with the theme as "Charles Hatchett's London".

We will visit some of the key places and items which have survived since Hatchett's day, including the original rock sample taken from North America in which he discovered niobium\*. This event is free for General Assembly delegates to attend and, as well as showing them the interwoven histories of London and niobium, it will offer them some excellent networking opportunities too, which is the main point, of course!

Take care of yourself and those around you.

Best wishes,

Roland Chavasse




(Above) Trafalgar Square and St Martin-in-the-Fields church were well known to Charles Hatchett, the latter being where he got married.

(Right) the original rock from Connecticut, USA, in which Hatchett discovered niobium. (photos: T.I.C.)




\* See Bulletins No.183 and No.178 for more information about Charles Hatchett and the discovery of niobium (or 'columbium', as he called it).



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](mailto:info@tanb.org).



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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](http://www.TaNb.org)

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