

# TIC

## TANTALUM-NIOBIUM

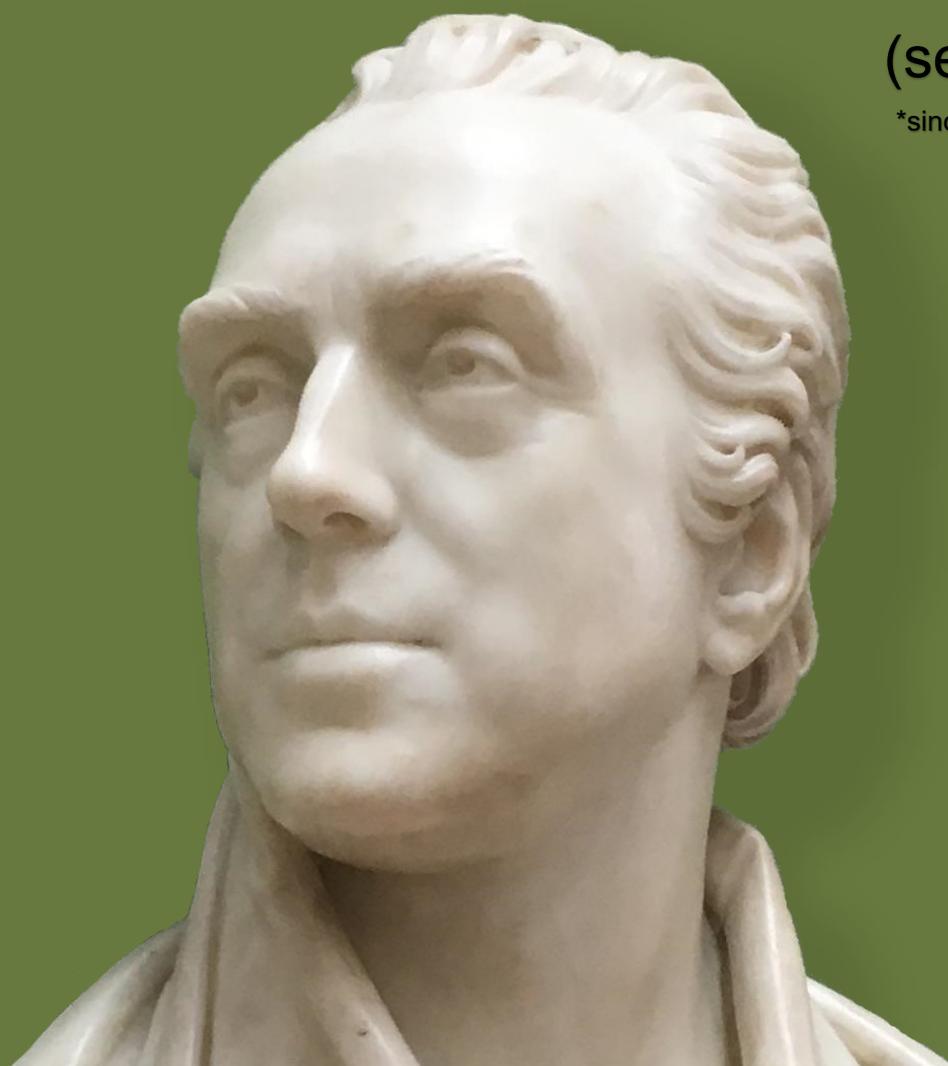
### INTERNATIONAL STUDY CENTER

#### Bulletin N° 178: July 2019

# Charles Hatchett and the origin of columbium\*

(see page 9)

\*since renamed niobium



## Contents

To join the Bulletin mailing list email [info@tanb.org](mailto:info@tanb.org)

President's Letter	2	60th General Assembly: Technical Abstracts	16
Director's Letter	3	Hong Kong: 60th General Assembly host city	20
Maglev trains: very fast niobium	4	An open letter on synthetic concentrates	21
The Ekeberg Prize: Shortlist 2019	7	Tantalum-niobium intellectual property update	22
Charles Hatchett and the origin of columbium	9	Diary of forthcoming events	23
Is pure tantalum (Ta) radioactive?	12	Member company and T.I.C. updates	23
The Tarantula Project	14	The Executive Committee 2018-2019	23

# President's Letter

Dear Fellow Members,

As I write this I am in Hong Kong, having just completed the final Executive Committee conference call before our 60th General Assembly (GA60). Hong Kong is an ideal location to build on the many first-time attendees from the successful GA59 conference last year. All visitors will find the city of Hong Kong to have easy and welcoming visa requirements, if a visa is even necessary. Any free time from the T.I.C. events, and business meetings, will offer conference goers access to the world's highest density of exclusive shops and restaurants surrounding the conference hotel. It is truly a breathtaking location, and October offers the perfect cooler, dryer weather for maximum enjoyment of the Hong Kong outdoors.



The T.I.C. Executive Committee meeting in Edinburgh, UK, in April 2019. (photo: T.I.C.)

During my stay, there have been news reports about the very large protests occurring in Hong Kong, to register opposition to the prospect of new expanded extradition legislation. The disruption has been limited geographically and, from my own experience, it has had limited impact on the workings of the city itself. Hong Kong remains efficient and safe. While I think it unlikely there will be any protests in October, under any situation, I see no reason to think any foreseeable political occurrence will affect the success of our GA 60 event.

While I predict Hong Kong will be refreshingly uneventful for the remainder of this year, the same cannot be said for the recent tantalum and

niobium markets. Asian markets seem to have been particularly unpredictable in the last many months. I am hopeful that our GA 60 will provide the forum for many of our members to discuss what are the drivers of any recent changes in the market, and for newcomers to obtain answers to the many questions that have been raised about the causes and effects of market turbulence.

I have had so much fun distributing the foreign language versions of the Bulletin. The French version, which was professionally translated (with lots of review by Emma), was very well received in central Africa, and demonstrates the T.I.C. commitment to providing our stakeholders with resources suitable to their preferred language. The Chinese version has also been well received by members and prospective attendees alike.

I hope to see you all in Hong Kong for what I hope is another record-breaking conference. Thank you to the subteams and staff for all the hard work!

Sincerely yours,

John Crawley

President



Giving out the French Bulletin Review in the DRC to (clockwise from right) His Excellency Governor Kabila, le Conseiller spécial du Chef de L'Etat en matière de stratégie, the Technical Advisory Panel for Minerals and Mining, and Directeur de Cabinet Adjoint. (photos: J. Crawley)

Dear T.I.C. Members,

Welcome to our latest newsletter, or perhaps I should say “Bienvenue” or “欢迎” in light of our recent publications in French and Chinese. It is always a challenge to balance the need to promote tantalum and niobium as widely as possible, but remain in budget, and this year, for the first time ever, we have created a review of highlights from our quarterly Bulletin newsletters from 2018-2019 in both [Chinese](#) and [French](#). Welcome also to Ally Lam (right), who is working with us to reach out to the Chinese tantalum-niobium community ahead of GA 60 in Hong Kong.

This initiative was set in motion by our President, John Crawley, in order to improve our ability to reach the global tantalum-niobium industry and help guide issues that impact our businesses and activities. While the quarterly Bulletins will continue to be published in English, the positive feedback we have received so far suggests that annual Bulletin Reviews in more than one language would be a valuable addition to our output.



Ally Lam, working with the T.I.C. in China



In the last Bulletin ([#177](#)) we explored some of the minerals containing tantalum and niobium and since then we have received considerable feedback on this subject. Many thanks to everyone who has shared their photos of minerals with us. Our favourites are posted online at <https://www.tanb.org/news-view/new-mineral-photos-added->.

The most surprising feedback we received came from the Natural History Museum in London, UK. They told us that their impressive mineral collection included the original rock which was analysed by Charles Hatchett in 1801, in which he discovered niobium (or ‘columbium’, as he called it). This was an opportunity not to be missed and recently we visited the museum, to see Hatchett’s rock for ourselves, and in the process discovered several other connections between the life of Charles Hatchett and present day London (see page 9).

Best wishes,

Roland Chavasse, Director



Visiting AMG Mineração's mine in Minas Gerais, Brazil (photo T.I.C.)



Emma Wickens at EU Chemicals Policy 2030, in Brussels, Belgium (photo T.I.C.)



David Knudson & I visit Charles Hatchett's favourite London pub (photo T.I.C.)

## Maglev trains: very fast niobium

In June the T.I.C.'s Director, Roland Chavasse, visited Nanjing, China, for a high-level meeting with members of the Chinese tantalum and niobium community, including Tantalum-Niobium Branch of China Nonferrous Metals Industry Association Executive Vice President, Jiang Bin, and Jiangxi Tungsten Holding Group Company Limited Vice General Manager, Xu Yixiang. The meeting was kindly arranged and hosted by Metalink Special Alloys Corporation Director, David Ma. To reach Nanjing the journey included a ride on the Shanghai maglev train (right).



### Introduction

Niobium is an exceptional element and nowhere is this more evident than when it is used in niobium-based superconductors, materials which when cooled to almost absolute zero ( $-273.15^{\circ}\text{C}$ ), have no resistance to the passage of electrical current. When resistance falls to zero, a current can circulate inside the material without any dissipation of energy, offering the possibility of creating exceptionally strong electro-magnets.

Since the first niobium-based superconductor was developed by Bell Telephone Laboratories in 1961 a host of exceptional technologies have already been developed incorporating them in electromagnets. These uses include life-saving magnetic resonance imaging (MRI) machines (see [Bulletin #170](#)), the ITER fusion reactor under construction in France (see [Bulletin #174](#)), and the Large Hadron Collider at CERN.



The Shanghai Maglev Train (or Shanghai Transrapid), by far the fastest way to travel between Shanghai city centre and Shanghai Pudong International Airport (Photo: T.I.C.)

### Magnetic levitation (maglev) trains

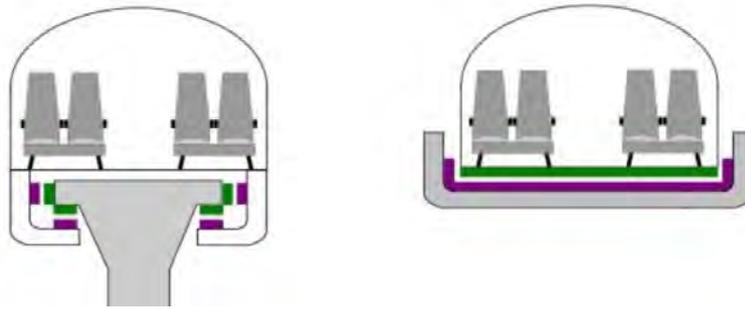
A child will tell you that two magnets will attract or repel each other, depending on the direction of their polarity. In a maglev train the concept is relatively simple (although extremely difficult and expensive in practice): the track holds one magnet, the train carries the other magnet, and by controlling their polarity the train operator can make the train hover a few centimetres above the track, thereby avoiding the need for wheels and their associated friction, weight and noise. However, although the concept has been extensively tested and is reliable, the costs of construction and operation are almost prohibitively expensive.

### Maglev technology

There are two main technologies which can suspend a maglev train. Both systems offer safe, quiet, efficient travel at very high speed, with low maintenance requirements and high capacity; but they are technically very different<sup>2</sup>.

- Electromagnetic Suspension (EMS) is based on attractive magnetic forces. The vehicle is levitated about 10 mm to 20 mm above the guideway using conventional electromagnets (not containing niobium). The Korean Incheon Airport Maglev and Chinese Shanghai Maglev Train both use EMS technology<sup>2</sup>.

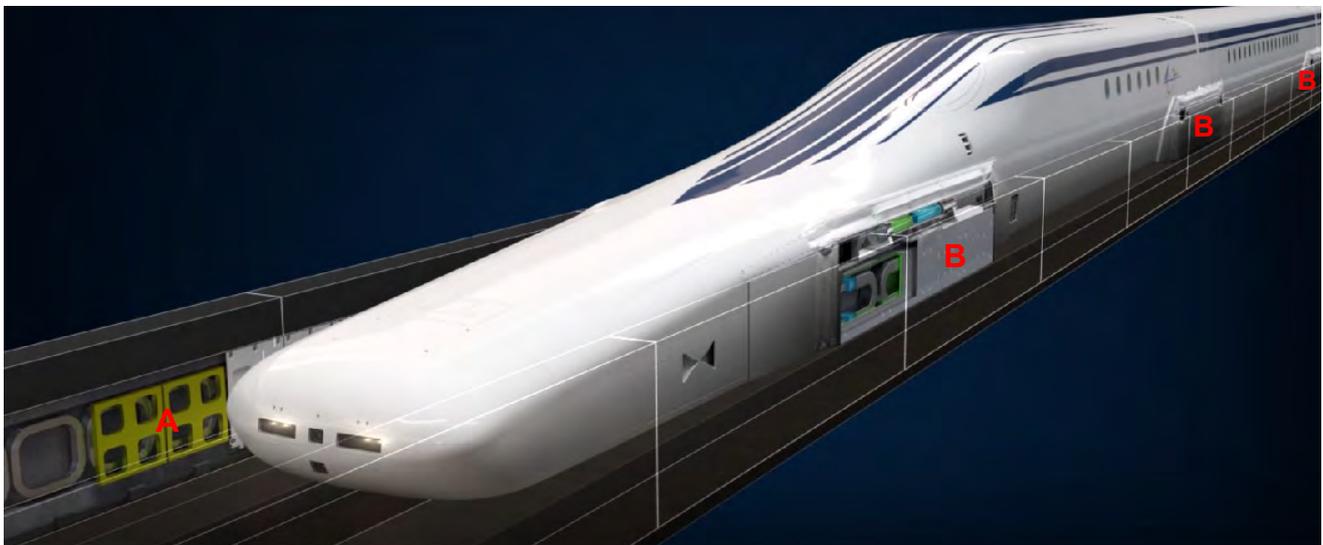
- Electrodynamic Suspension (EDS) works with repulsive magnetic forces. Here the vehicle is levitated about 10 mm to 100 mm above the track using permanent magnets (PM-EDS) or superconducting electromagnets (SC-EDS). The Central Japan Railway Company uses SC-EDS employing niobium-titanium superconducting magnets.



EMS (left) and EDS (right) maglev technology showing the two sets of magnets on each vehicle and track (Image: Thorat et al<sup>3</sup>)

The technological challenges and cost of developing maglevs are considerable. Dozens of related patents have been filed since the early 1900s and only a handful of commercially viable systems have ever been built. The first, AirLink, was in the UK from Birmingham airport to the city from 1984-95. While it was popular and cheap to run, it was also unreliable and expensive to maintain. In the 1980s Germany built Berlin's M-Bahn, a driverless train on a mile of track with just three stations. While it proved the technology the line was closed with the German reunification in 1990. However, the German manufacturer, TransRapid, continued to develop maglevs and in 2001 it was commissioned to build the Shanghai Maglev Train<sup>1</sup> (pictured left).

The technological challenges and costs of developing maglev technology are so high that today only three high-speed lines are operational; one each in Japan, China and Korea. Of these, the line in China currently holds the title of the world's fastest electric train and the longest maglev line, making the 30 km journey from the airport to Shanghai's business district in just eight minutes.



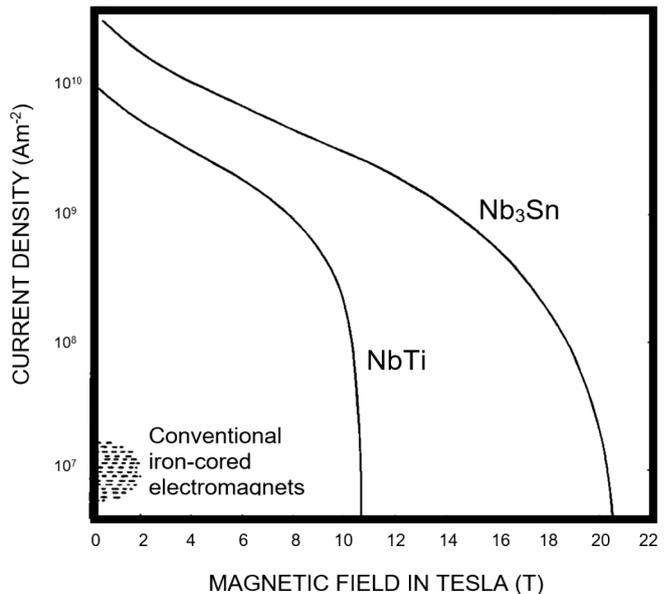
A partly cut-away image of Japan's record-breaking maglev train showing propulsion coils on the track ("A") and superconducting coils on the side of the train ("B") (Image: Central Japan Railway Company<sup>5</sup>)

The highest speed reached with a maglev train is (at the present time) 603 km/h and it was possible to achieve it using passive SC-EDS technology adopted by the Japanese high speed L0 train series owned by the Central Japan Railway Company (pictured above). The train uses the superconductivity phenomenon to obtain zero electrical resistance and thus a very powerful magnetic force<sup>4</sup>. The magnets on board the vehicles achieve a superconducting state by cooling a niobium-titanium alloy with liquid helium to a temperature of -269°C. As a result the train floats 100 mm above the track. The propulsion, levitation and guidance systems are all installed in the sides of the guideway. Japan chose SC-EDS because the maglev system had to allow for the frequency of small earthquakes in Japan which can displace the track by up to 20 mm<sup>6</sup>.

## Superconducting niobium alloys

Superconductivity was first identified in 1911, but for many years remained a laboratory curiosity while metallurgical and manufacturing technology struggled to catch up. For maglevs superconductivity is an immense benefit in terms of reducing power requirements: once the power is introduced into the system at the beginning of the ride, it stays, without loss, for the whole ride, cutting down hugely on the power requirement per passenger-mile travelled.

The first niobium-based superconductor developed was niobium-tin ( $\text{Nb}_3\text{Sn}$ ) by Bell Telephone Laboratories in 1961 and this prompted many others to be developed. Although initially disregarded, in time niobium-titanium ( $\text{NbTi}$ ) alloys emerged to become the most widely used, making it possible to fabricate magnets that generate magnetic fields of up to 10.5 T (Tesla) with unprecedented efficiency and economy.  $\text{NbTi}$  is relatively inexpensive, has excellent mechanical properties and produces reliable, stable and extremely uniform magnetic fields, making it the commercial 'work horse' of superconducting magnets. For information on how  $\text{NbTi}$  alloy is produced and used to manufacture superconducting magnets please see [Bulletin #170](#).



The critical current densities at 4.2 K of  $\text{NbTi}$  and  $\text{Nb}_3\text{Sn}$ . Also shown for comparison is the usual operating region of conventional iron-yoke magnets with water-cooled copper windings. (chart: Martin N. Wilson. CERN, 1996)<sup>7</sup>

## Looking ahead

Japan, Korea and China all have ambitious plans to develop maglev technology further and create networks in the future. In Korea the unmanned Incheon Airport Maglev shuttle which opened in 2012 will have two further network expansions. It currently travels to and from South Korea's Incheon airport at the comparatively sedate 110km/h, pausing at seven stations along the way.

The furthest advanced project is the Chūō Shinkansen, a 286 km line linking Tokyo with Nagoya in Japan. Construction is already well under way and the line is due to be completed in 2027. About 90% of the 286 kilometre line to Nagoya will be built underground or through tunnels. The trains on this line will employ  $\text{NbTi}$  alloy cooled to  $-269^\circ\text{C}$ <sup>6</sup>. Maglevs on this route will transport passengers at 505 km/h and should the project be successful it will be extended to Osaka.



CRRC's new prototype maglev in May 2019  
(photo: CRRC)

In May 2019 the Chinese state-owned China Railway Rolling Stock Corporation (CRRC) unveiled a new prototype maglev train that it said is planned to transport passengers at speeds of up to 600 km/h. The project will now enter a period of testing, before full production is expected to begin in 2021. Maglev trains may never become commonplace due to their high costs and significant technological challenges in their development, and yet there is significant interest, giving this niche use for niobium a very interesting future. **TIC**

## Notes:

1. <https://www.theguardian.com/technology/2018/may/29/maglev-magnetic-levitation-domestic-travel>
2. [https://www.researchgate.net/publication/330493773\\_Hyperloop\\_as\\_an\\_evolution\\_of\\_maglev](https://www.researchgate.net/publication/330493773_Hyperloop_as_an_evolution_of_maglev)
3. Thorat et al, "Theory of Superconductivity and Use of Superconductors in Magnetic Levitation System", IJESC, Volume 8(3), 2018 <http://ijesc.org/upload/b0122b9212aa19e93e3b1377ff6577ae.Theory%20of%20Superconductivity%20and%20Use%20of%20Superconductors%20in%20Magnetic%20Levitation%20System.pdf>
4. Mohanty, S, "MAGNETIC LEVITATION TRAINS" Journal of Mechanical Engineering and Technology (IJMET), Volume 9, Issue 5, May 2018, [http://www.iaeme.com/MasterAdmin/UploadFolder/IJMET\\_09\\_05\\_002/IJMET\\_09\\_05\\_002.pdf](http://www.iaeme.com/MasterAdmin/UploadFolder/IJMET_09_05_002/IJMET_09_05_002.pdf)
5. Central Japan Railway Company, <https://scmaglev.jr-central-global.com/>
6. New Scientist, "Japan's 'hover' train takes the fast track", 02/09/1989
7. Martin N. Wilson, CERN, "Superconducting materials for magnets", 1996, <https://cds.cern.ch/record/308014/files/p47.pdf>

# The Anders Gustaf Ekeberg Tantalum Prize: Shortlist 2019

The Anders Gustaf Ekeberg Tantalum Prize ('Prize') is awarded to the lead author(s) of the published treatise, paper or patent that is judged to have made the greatest contribution to advance the knowledge and understanding of the element tantalum (Ta).

To be eligible for consideration the publication must be in English and be made between October 2017 and June 2019. For further details about the Prize, please visit [www.tanb.org/view/prize](http://www.tanb.org/view/prize).

The winner will be chosen by the independent panel of experts and the Prize medal, made from pure tantalum metal, will be awarded at the 60th General Assembly in Hong Kong in October 2019.

Please note that the summarised abstracts are designed to give a flavour of the research and are for information only. Such short summaries can't do justice to the original publications. **TIC**



## Multi-valued and fuzzy logic realization using TaOx memristive devices

Authors(s): Debjyoti Bhattacharjee<sup>1</sup>, Wonjoo Kim<sup>2</sup>, Anupam Chattopadhyay<sup>1,3</sup>, Rainer Waser<sup>2,4</sup> & Vikas Rana<sup>2</sup>

Organisation(s):

1. School of Computer Science and Engineering, Nanyang Technological University, Singapore.
2. Peter Grünberg Institut 7, Forschungszentrum Jülich GmbH, 52425, Jülich, Germany.
3. School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore.
4. Institut für Werkstoffe der Elektrotechnik II, RWTH Aachen University, 52074, Aachen, Germany.

Full article at: <https://www.nature.com/articles/s41598-017-18329-3>

Summarised abstract: Among emerging non-volatile storage technologies, redox-based resistive switching Random Access Memory (ReRAM) is a prominent one. The realization of Boolean logic functionalities using ReRAM adds an extra edge to this technology. Recently, 7-state ReRAM devices were used to realize ternary arithmetic circuits, which opens up the computing space beyond traditional binary values. This paper reports on the realization of multi-valued and fuzzy logic operators with a representative application using ReRAM devices.

## Microstructure and tensile properties of a Ti-28Ta alloy studied by transmission electron microscopy and digital image correlation

Authors(s): Gang Chen<sup>a,b,c</sup>, Jingou Yin<sup>b</sup>, Shaoyang Zhao<sup>b</sup>, Huiping Tang<sup>b</sup>, Xuanhui Qu<sup>a</sup>.

Organisation(s):

- a. Institute for Advanced Materials and Technology, University of Science and Technology Beijing, Beijing 100083, China
- b. State Key Laboratory of Porous Metal Materials, Northwest Institute for Non-ferrous Metal Research, Xi'an, Shaanxi 710016, China
- c. State Key Laboratory of Powder Metallurgy, Central South University, Changsha, Hunan 410083, China

Full article at: <https://www.sciencedirect.com/science/article/abs/pii/S0263436818308357#>

Summarised abstract: This work presents a study of tensile behaviour for a Ti-28 at.%Ta alloy with low modulus and remarkable superelasticity. The Ti-28Ta alloy was firstly fabricated by melting the Ti/Ta powder mixture, followed by hot swaging. Microstructure and tensile behaviour were examined. The results demonstrate that Ti-28Ta alloy exhibits ductile and transgranular fracture behaviour, excellent superelasticity and remarkable ductility.

## Hydrometallurgical process for Ta recovery from epoxy-coated solid electrolyte tantalum capacitors

Authors(s): Wei-Sheng Chen<sup>1</sup>, Hsing-Jung Ho<sup>1,2</sup>, and Kuan-Yan Lin<sup>1</sup>

Organisation(s):

1. Department of Resources Engineering, National Cheng Kung University, No.1 University Road, Tainan City 701, Taiwan
2. Department of Environmental Studies for Advanced Society, Graduate School of Environmental Studies, Tohoku University, Aoba-6-6 Aramaki, Aoba-ku, Sendai 980-8577, Miyagi, Japan

Full article at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6515287/>

Summarised abstract: The tantalum content in epoxy-coated solid electrolyte tantalum capacitors (EcSETCs) is over 40 wt %. Here, we designed a recycling process that includes pre-treatment, leaching, and solvent extraction to recover tantalum. In the pre-treatment process, epoxy resin and wires were removed. Under optimal conditions, the recovery efficiency of tantalum reached over 98%, and a final product of Ta<sub>2</sub>O<sub>5</sub> with 99.9% purity was obtained after chemical precipitation and calcination.

## Exploring oxygen-affinity-controlled TaN electrodes for thermally advanced TaO<sub>x</sub> bipolar resistive switching

Authors(s): Taeyoon Kim<sup>1</sup>, Gwangho Baek<sup>2</sup>, Seungmo Yang<sup>1</sup>, Jung Yup Yang<sup>3</sup>, Kap Soo Yoon<sup>1</sup>, Soo Gil Kim<sup>4</sup>, Jae Yeon Lee<sup>4</sup>, Hyun Sik Im<sup>5</sup> & Jin Pyo Hong<sup>1,2</sup>

Organisation(s): 1. Novel Functional Materials and Devices Lab, The Research Institute of Natural Science, Department of Physics, Hanyang University, Seoul, 04763, South Korea.  
2. Division of Nanoscale Semiconductor Engineering, Hanyang University, Seoul, 04763, South Korea.  
3. Department of Physics, Kunsan National University, Geonbuk, 54150, South Korea.  
4. SK Hynix Semiconductor Inc., Icheon, 17336, South Korea.  
5. Department of Semiconductor Science, Dongguk University, Seoul, 04620, South Korea

Full article at: <https://www.nature.com/articles/s41598-018-26997-y>

Summarised abstract: Recent advances in oxide-based resistive switching devices have made these devices very promising candidates for future non-volatile memory applications. However, several key issues remain that affect resistive switching. One is the need for generic alternative electrodes with thermally robust resistive switching characteristics in as-grown and high-temperature annealed states. Here, we studied the electrical characteristics of Ta<sub>2</sub>O<sub>5-x</sub> oxide-based bipolar resistive frames for various TaN<sub>x</sub> bottoms. Our experimental findings can aid the development of advanced resistive switching devices with thermal stability up to 400°C.

---

## Evaluation of the mechanical compatibility of additively manufactured porous Ti–25Ta alloy for load-bearing implant applications

Authors(s): Nicolas Soro<sup>a</sup>, Hooyar Attar<sup>a</sup>, Erin Brodie<sup>b</sup>, Martin Veidt<sup>a</sup>, Andrey Molotnikov<sup>b</sup>, Matthew S. Dargusch<sup>a</sup>

Organisation(s): a. Centre for Advanced Materials Processing and Manufacturing (AMPAM), School of Mechanical and Mining Engineering, The University of Queensland, Brisbane, QLD, 4072, Australia  
b. Department of Materials Science and Engineering, Monash University, Clayton, VIC, 3800, Australia

Full article at: [https://www.researchgate.net/publication/333096814\\_Evaluation\\_of\\_the\\_mechanical\\_compatibility\\_of\\_additively\\_manufactured\\_porous\\_Ti-25Ta\\_alloy\\_for\\_load-bearing\\_implant\\_applications](https://www.researchgate.net/publication/333096814_Evaluation_of_the_mechanical_compatibility_of_additively_manufactured_porous_Ti-25Ta_alloy_for_load-bearing_implant_applications)

Summarised abstract: Integrating porous networks in load-bearing implants is essential in order to improve mechanical compatibility with the host tissue. Additive manufacturing has enabled the optimisation of the mechanical properties of metallic biomaterials, notably with the use of novel periodic regular geometries as porous structures. In this work, we successfully produced solid and lattice structures made of Ti–25Ta alloy with selective laser melting (SLM) using a Schwartz primitive unit-cell for the first time.

---

## Thermally stable amorphous tantalum yttrium oxide with low IR absorption for magnetophotonic devices

Authors(s): Takuya Yoshimoto<sup>1</sup>, Taichi Goto<sup>1,2,3</sup>, Hiroyuki Takagi<sup>1</sup>, Yuchi Nakamura<sup>1</sup>, Hironaga Uchida<sup>1</sup>, Caroline A. Ross<sup>3</sup> & Mitsuteru Inoue<sup>1</sup>

Organisation(s): 1. Department of Electrical and Electronic Information Engineering, Toyohashi University of Technology, 1-1 Hibari-Ga-Oka, Tempaku, Toyohashi, Aichi, 441-8580, Japan.  
2. JST, PRESTO, 4-1-8 Honcho, Kawaguchi, Saitama, 332-0012, Japan.  
3. Department of Materials Science and Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts, 02139, USA

Full article at: <https://www.nature.com/articles/s41598-017-14184-4>

Summarised abstract: Thin film oxide materials often require thermal treatment at high temperature during their preparation, which can limit them from being integrated in a range of microelectronic or optical devices and applications. In this study, a ~100 nm-thick amorphous film of tantalum oxide and yttrium oxide with an yttrium-to-tantalum atomic fraction of 14% was prepared by magnetron sputtering. The film demonstrated high resistance to annealing above 850°C without degradation of its optical properties. The film was incorporated into Bragg mirrors and it contributed to an order-of-magnitude enhancement at near-infrared wavelengths.

---

## Selective laser melting of pure tantalum: densification, microstructure and mechanical behaviours

Authors(s): Libo Zhou<sup>a</sup>, Tiechui Yuan<sup>a</sup>, Ruidi Li<sup>a</sup>, Jianzhong Tang<sup>b</sup>, Guohua Wang<sup>b</sup>, Kaixuan Guo<sup>b</sup>

Organisation(s): a. State Key Laboratory of Powder Metallurgy, Central South University, Changsha 410083, PR China  
b. Zhuzhou Printing Additive Manufacturing Co. LTD, Zhuzhou 412000, PR China

Full article at: <https://www.sciencedirect.com/science/article/abs/pii/S0921509317312418#>

Summarised abstract: In this study, selective laser melting (SLM) of pure tantalum (Ta) was systematically investigated, with emphasis on densification, microstructure and mechanical properties of Ta specimen. The high laser scanning speed resulted in micropores and discontinuous scan tracks, owing to the elevated instability of the liquid induced by Marangoni convection and the balling effect. However, the interlayer thermal microcracks were produced at a low scanning speed, due to the thermal stress and balling effect.

# Charles Hatchett and the origin of columbium

Following the publication of photos of tantalum and niobium minerals in [Bulletin #177](#) (right) T.I.C.'s Director, Roland Chavasse, and Technical Officer, David Knudson, were invited to see the original sample analysed by Charles Hatchett at the Natural History Museum in London, UK. During this trip other historical places connected to Hatchett were also discovered, including his grave.



## A rare and special stone

Visitors to the Natural History Museum in London, UK, can explore one of the world's largest collections of biological, geological and botanical samples, including a vast hall containing mineral samples of almost every size, shape and type.

But while the mineral gallery provides a dazzling display from adamite to zincite and includes many tantalum and niobium minerals, this is just the tip of the iceberg. Away from the public rooms there exists a warren of cabinets with further samples, including one with a particular relevance to the T.I.C.

To a casual observer there is nothing to make sample #60309 stand out. It is just a small, black rock. It has no obvious crystal geometry, no flashes of colour, no transparent beauty, nothing to make it stand out from a multitude of other small, black rocks.

Its only unusual feature is its unexpected weight and it was possibly this which first made Charles Hatchett pause as he sorted through a box of old samples from North America, and give it a second look. This sample is the very rock which in 1801 Hatchett analysed and discovered a "new earth" which he named Columbium (Cb) in honour of the North American origin of the sample. As such it forms a direct link to the very start of our industry and the man who first appreciated the unique properties of niobium.

The only trouble is that nobody knows where it came from...



Charles Hatchett (1765 - 1847), discoverer of niobium, which he called columbium

(Image: The Linnean Society, #EP/H/50)



Sample #60309 at the Natural History Museum, London, UK (Photo: T.I.C.)

## The origin of the sample in North America

The source of this small, black rock is cloaked in mystery and was even in Hatchett's time. It was first recorded as part of a collection of iron ore and other samples made by John Winthrop the Younger (1606 - 1676), an early governor of Connecticut Colony (now the US state) during the mid-seventeenth century. Winthrop was a metallurgist, manufacturing chemist, physician, avid rock collector and Fellow of the (British) Royal Society, the world's oldest independent scientific academy, dedicated to promoting excellence in science.



T.I.C. Director, Roland Chavasse, and Technical Officer, David Knudson, examine sample 60309 (Photo: T.I.C.)

During his long life Winthrop used his wealth and political status to gather mineral samples from across the present-day New England region of north-eastern USA. As governor, he was keen to develop industry, including metal-working, in Connecticut Colony and his mineral collection had a strong focus on iron ore and other commercially interesting minerals.

Winthrop maintained detailed records of where his samples came from and the source of #60309 has been handed down through history as “Nautneauge”, probably a place name used by the Pequots Native American people.

However, this is not as helpful as it might be; in the 1650s there were very few European settlements (and place names) away from the coast and the town of New London,

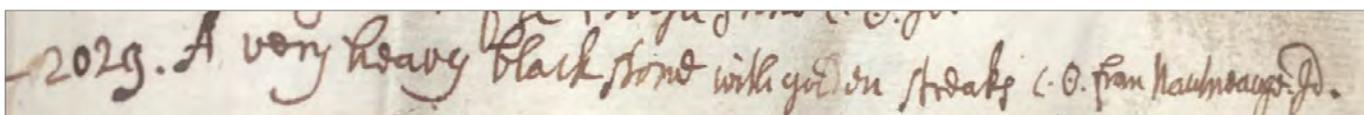
nor did detailed maps exist. With many samples, including this one, Winthrop simply recorded Native American names; names which have been replaced and forgotten during the next 250 years. Today there is not anywhere in New England called Nautneauge.

*The columbite sample was found at “Nautneauge”.  
Unfortunately, there isn’t anywhere called “Nautneauge” today*

The sample arrives in London

John Winthrop the Younger died in 1676 in Boston, Massachusetts Bay Colony, and for the next 58 years his mineral collection was packed away in storage. In 1734 the grandson of John Winthrop the Younger, who was also called John Winthrop, decided to send the entire mineral collection to his grandfather’s scientific academy, the Royal Society.

The President of the Royal Society at that time was Sir Hans Sloan, a gifted doctor who included King George I among his patients. Sloan is primarily remembered today for being a prolific collector of anything and everything to do with natural science and gladly accepted Winthrop’s gift. These minerals joined Sloan’s collection of some 71,000 other items from around the world. When the Winthrop collection arrived in London Sir Hans Sloan recorded the sample as “#2029. A very heavy black stone with golden streaks. C. O. from Nautneauge. JS”. It is unfortunate that his handwriting is barely readable as it only adds to the uncertainty of the origin of the sample.



Sir Hans Sloan’s hand-written catalogue entry<sup>3</sup> (Photo: T.I.C.)

Hatchett examines the stone

When Sloan died in 1753 his entire collection was donated to establish the British Museum; and Winthrop’s minerals entered another period of storage.

It was almost half a century later, in 1801, that Charles Hatchett, who was already a highly respected analytical chemist, was digging through the British Museum’s collection of minerals, looking for unusual samples to analyse, when he found one that caught his imagination. Here is how Hatchett described finding it: “Upon referring to Sir Hans Sloan’s catalogue, I found that this specimen was only described as ‘a very heavy black stone with golden streaks,’ which proved to be yellow mica”.<sup>4</sup>

However, the location was a mystery to Hatchett too: “in the catalogue; the writing however is scarcely legible - it appears to be an Indian name, (Nautneauge)”. Even by 1801 the named landscape of Connecticut had changed considerably from Winthrop’s time, some century and a half before. It would appear that historical records will not unlock the mystery of the origin of sample 60309.



A bust of Charles Hatchett at the Linnean Society, London, UK (Photo: T.I.C.)

## Columbite in Connecticut

Some historians suggest “Nautneauge” is a corruption of “Nameaug”, the Pequots’s name for the area that would become New London, arguing that Winthrop’s improvised spelling and Sloan’s spidery handwriting give a lot of room for mistaken interpretation.

Others argue that it is much more likely Winthrop found it in one of the many pegmatites in the Middletown district in or around East Hampton, where columbite is now known to be common<sup>1</sup> (see map, right). Certainly, his background in iron mining and his time spent mining a gold-bearing quartz vein at the foot of Great Hill near Cobalt in East Hampton, some 40 km from New London, would support this theory.



The State of Connecticut, showing New London, Hartford, Cobalt, Haddam, Middletown and the Swanson Mine. Inset: east coast USA (Pictures: Google Earth, TUBS, T.I.C.)

## Could geological fingerprinting help?

An analytical comparison of Hatchett’s sample with samples from Swanson mica mine (now closed) and an outcrop near Haddam by Dr James L. Marshall at the Department of Chemistry, University of North Texas, adds depth to the discussion but, unfortunately, not conclusive proof<sup>2</sup>:

	Nb <sub>2</sub> O <sub>5</sub>	Ta <sub>2</sub> O <sub>5</sub>	FeO	MnO	TiO <sub>2</sub>	SnO <sub>2</sub>	WO <sub>3</sub>	Y <sub>2</sub> O <sub>3</sub>
Hatchett’s specimen	54.2	24.7	15.0	3.5	0.6	-	0.2	-
Haddam sample	60.2	16.6	16.8	4.3	0.8	1.3	-	-
Swanson sample	56.0	25.8	8.2	9.3	-	-	-	0.7

Since it was first collected some three and a half centuries ago the map of North America has changed a lot, many mineral deposits have been mined out, and what few historical records still exist are far from clear. Unfortunately it seems likely that the exact source of the stone Hatchett analysed will remain a mystery forever.

## Footnote about Charles Hatchett’s London

While researching this article we have discovered several places in and around London that have strong historical connections to Charles Hatchett, including his favourite pub (see page 3) and his grave (below and right).

In a future edition we will explore more of Hatchett’s London (as we did for Ekeberg in [Bulletin #175](#)), but for now we leave you with this picture of his final resting place at St Laurence’s church, Slough, a town some 30 km west of London. **TIC**

**Notes:** Many people helped in the research for this article and special thanks must go to The Linnean Society of London; Robin Hansen at the Natural History Museum; and the Reverend Alistair Stewart, Julie and all the team at St Laurence’s church, who also wrote this charming clerihew:

*Charles Hatchett  
was not buried in Datchet,  
due to the opprobrium,  
of the discovery of niobium.*

(Note: Datchet is a small town nearby)

## Further reading:

1. Minedat.org, “Columbite locality (Nautneauge; Naumeag; Naumeaug), New London, New London Co., Connecticut, USA”, <https://www.minedat.org/loc-234868.html>
2. Marshall, Dr J, and Marshall, V; “Rediscovery of the Elements: Niobium and Tantalum”, Dept. Chemistry, UNT, USA; 2013. <https://chemistry.unt.edu/sites/default/files/users/owj0001/niobium%20and%20tantalum.pdf>
3. Sloan, Sir Hans; “Catalogue of Minerals, Vol.II”; Natural History Museum Library, UK.
4. Hatchett, Charles; “An Analysis of a Mineral Substance from North America, Containing a Metal Hitherto Unknown”; *Philosophical Transactions of the Royal Society*, 1802



## Is pure tantalum (Ta) radioactive?

Recently a T.I.C. member asked for help regarding a shipment of pure tantalum metal which a customs official had blocked because he had incorrectly thought it was radioactive. The position of this Association is that pure metallic tantalum (Ta) is not considered to be radioactive by any objective measurement. But what is the science behind our position?

Here docent Mark R. StJ. Foreman PhD ARCS BSc CChem MRSC, an associate professor in the department of Chemistry and Chemical Engineering at Chalmers University of Technology in Sweden, examines the facts. Dr Foreman's research interests include both nuclear chemistry and the recycling of materials. He also has a strong interest in the solvent extraction of metals. He represents Chalmers University on the Tarantula program (see page 14).



Dr Foreman

*This article is for information only. All views and opinions in this article are those of the author and not the T.I.C.*



Low-sodium salt,  
detectably radioactive,  
but not dangerous

When we consider whether a substance is radioactive we need to consider the question of how many radioactive events per kilo per hour are needed before we consider it as radioactive or not. This is not an academic question with no application to industry and society, instead it is a very important question with potentially far-reaching effects.

With advances in measurement it is now possible to measure many things, including radioactivity, far below the level at which it is either dangerous or of concern.

For example I have measured the natural radioactivity in a packet of low-sodium table salt (typically a blend of KCl and NaCl) bought from a supermarket, but my ability to measure an isotope of potassium ( $^{40}\text{K}$ ) in the salt does not mean it is dangerous, it merely means it is detectable.

Equally, it is clear that ordinary sugar contains radioactivity.

If we consider a kilo of table sugar (sucrose,  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ ), this is a single simple substance which is 42 % by mass carbon. So one kilo of sugar contains 420 grams of carbon. All substances containing carbon which were formed by contemporary living things contain 1.2 parts per trillion ( $1.2 \times 10^{12}$ ) of the naturally occurring  $^{14}\text{C}$ . This is formed in the atmosphere by the action of cosmic rays on the air.

From the atomic mass of carbon and Avogadro's number we can calculate that the kilo of sugar will contain  $2.527 \times 10^{13}$  atoms of carbon-14 ( $^{14}\text{C}$ ). From the half life we can obtain the radioactive decay constant ( $\lambda$ ). It is the natural logarithm of 2 divided by the half life in seconds of  $^{14}\text{C}$ .

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

Next if we multiply the number of atoms of  $^{14}\text{C}$  by the decay constant we will get the number of radioactive events which occur per second (becquerels) from the number (N) of atoms. We use the following equation.

$$A = \lambda N$$

This gives us 97 Bq per kilogram of sugar.

Now if we repeat the calculation for the  $^{180\text{m}}\text{Ta}$  content of natural tantalum metal using the lower limit on the half life ( $4.5 \times 10^{16}$  years) given by Lehnert *et. al*. I calculated for the  $^{180\text{m}}\text{Ta}$  content of tantalum metal that it will be 0.00044 Bq per kilogram.

This means for a kilogram block of the metal you should expect about 1.6 radioactive decays of  $^{180\text{m}}\text{Ta}$  per hour. This is hardly what would be regarded as being "radioactive" to any practical purpose.



Sugar, more radioactive than pure tantalum metal

## “the sugar in our food is more radioactive than pure tantalum”

With such a low radioactivity level I hold the view that the radioactivity induced by cosmic rays is more important than that of the  $^{180\text{m}}\text{Ta}$ .

If we assume that all cosmic ray neutrons which reach sea level are thermal neutrons and that the flux<sup>ii</sup> is  $0.0134$  neutrons  $\text{cm}^{-2} \text{s}^{-1}$  then we can calculate the activity of a range of substances which will be reached if thin sheets of the substances are left outside for an infinite time. Here we need the neutron flux ( $\phi$ ), the activation cross section ( $\sigma$ ) and the number of atoms of the substance ( $N$ ). We will also need the half life of the radioactive product of the neutron activation.

When the formation rate is equal to the rate of radioactive decay we will reach an equilibrium

$$\phi\sigma N = N'\lambda$$

We can rearrange this to give us  $N'$  (number of radioactive atoms).

$$N' = \frac{\phi\sigma N}{\lambda}$$

Based on these calculations I predict for a kilo of tantalum metal hammered out into a foil and left outside for a long time then it will contain  $0.92$  Bq of  $^{182}\text{Ta}$  which is formed by the neutron activation of  $^{181}\text{Ta}$ . This radioactivity level does not matter for the vast majority of uses, the only use I can think of where it matters is if you want to use the tantalum for a nuclear physics experiment in which you will attempt to observe the decay of  $^{180\text{m}}\text{Ta}$ .

### What this might mean for workplace safety

Now back to the question of what does radioactive mean in terms of workplace safety. If we check the UK's radiation law from 2017 (IRR 2017) the most important parts are sections 5 and 6 plus schedules 1 and 8. If you were to want to process tantalum metal to exploit its radioactive or nuclear properties then schedule 1 and schedule 7 part 1 state that you can have up to  $10$  Bq  $\text{kg}^{-1}$  of  $^{180\text{m}}\text{Ta}$  or  $100$  Bq  $\text{kg}^{-1}$  of  $^{182}\text{Ta}$  before you need to inform the Health and Safety Executive under sections 5 or 6. I have calculated using the summation rule in the law that pure tantalum metal is more than 100 times too non radioactive for you to need to contact the Health and Safety Executive to register radiation work or practices. But if you make no attempts to exploit the radioactive / nuclear properties of tantalum the UK law becomes even more relaxed.

Now if you had the vast budget and the will to make a pure sample of  $^{180\text{m}}\text{Ta}$ , then the UK would allow you to have up to  $1000$  Bq of  $^{180\text{m}}\text{Ta}$  without having to obey sections 5 or 6. I have worked out the mass of  $1000$  Bq of  $^{180\text{m}}\text{Ta}$  would be  $2.732$  tons. And if your “radioactivity” is either below the amount limit or the concentration (Bq  $\text{kg}^{-1}$ ) limit you do not need to register under sections 5 or 6. As the radioactivity of pure  $^{180\text{m}}\text{Ta}$  is less than  $1$  Bq  $\text{kg}^{-1}$  you would not need to file a report to the Health and Safety Executive.

Some years ago it was shown that irradiation of natural tantalum with high energy X-rays or  $^{60}\text{Co}$  gamma rays can stimulate the emission of photons from  $^{180\text{m}}\text{Ta}$ .<sup>iv</sup> There was even the idea of a gamma ray laser using hafnium which was discussed in New Scientist in 1999.<sup>v</sup> One view of the UK law was that the writers might have wanted to create laws which cover new technology. It will be interesting to consider tantalum further, but for now suffice to say that pure tantalum is not radioactive.

In a future essay I will consider the lack of radiation consequences of carrying a kilo of tantalum around with you in your pocket (a typical scenario which might be studied by the IAEA).

### Sources:

- i. A. Bayliss, G. McCormac and H. van der Plicht, “An illustrated guide to measuring radiocarbon from archaeological samples”, *Physics Education*, 2004, **39**, 1-8.
- ii. M. S. Gordon, P. Goldhagen, K. P. Rodbell, T. H. Zabel, H. H. K. Tang, J. M. Clem, and P. Bailey, “Measurement of the Flux and Energy Spectrum of Cosmic-Ray Induced Neutrons on the Ground”, *IEEE Transactions on Nuclear Science*, 2004, **51**, 3427-3434.
- iii. <http://www.legislation.gov.uk/uk/si/1999/3232/schedule/1/made>
- iv. I. Bikit, L. Lakosi, J. Sáfár And Lj. Čonkić, “De-excitation of  $^{180\text{m}}\text{Ta}$  by  $^{60}\text{Co}$  Gamma Rays”, *The Astrophysical Journal*, 1999, **522**, 419-423.
- v. M. Chown, “Gamma Force”, *New Scientist*, 1999 (3 July)

# Tarantula: recovery of niobium, tantalum and tungsten occurring as by-products in mining and processing waste streams

The Tarantula project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.821159. This article reflects only the author's views and neither Agency nor the Commission are responsible for any use that may be made of the information contained herein.



Since 2018 the T.I.C. has been part of a consortium of 16 organisations to be awarded funding to study innovative new ways to recover niobium (Nb), tantalum (Ta) and tungsten (W) from mine by-products and processing waste streams, materials which are currently considered to be uneconomical. Last month Tarantula held its first meeting and work

commenced.

## What is Tarantula?

Tarantula is not just the name for a family of large hairy spiders, it is also the name of a new European Union (EU) project to explore ways to recover critical raw materials from previously uneconomical materials generated during the actions of mining and ore processing. The extraordinary properties of refractory metals, the unlikelihood of their future substitution and their use in booming industries will sustain a high EU demand for niobium, tantalum and tungsten. Despite all three being classified as 'critical raw materials' (CRM) by the European Commission (EC) in 2017<sup>1</sup>, fractions of these indispensable metals are dissipated as by-products in mining waste streams as well as processing waste.

## Who is participating?

The T.I.C. will be joined by two T.I.C. member companies, Strategic Minerals Spain and Cronimet, and thirteen other organisations from a range of industrial and academic backgrounds, together forming a team with considerable resources. One of these partners is Chalmers University, Sweden, and their representative, Dr Mark Foreman, has written an article about radioactivity for this Bulletin (see page 12). The program is coordinated by Tecnalia, an applied research and technological development centre based in Spain.



A full list of consortium members can be found at the Tarantula website <https://h2020-tarantula.eu/>.

The T.I.C.'s involvement will be led by our Technical Officer, David Knudson, and supported by the Director, Roland Chavasse. Here they are seen attending the first Tarantula meeting at the Tecnalia Research and Innovation Center in San Sebastian, Spain, in June. (Photo credit: Tarantula, 2019)

## What is the goal of Tarantula?

The key purpose of Tarantula is to stimulate recovery of niobium, tantalum and tungsten from these complex, low-grade resources, and to develop a suite of cost-effective, scalable and eco-friendly (bio-, hydro-, iono-, solvo-, pyro- and electro-metallurgical) processes with high selectivity and recovery rates.

These novel technologies, each representing an alternative for one or more process steps of state-of-the-art processing lines, will form new routes towards market-ready metals, metal oxides and metal carbides. Flexibility will be the cornerstone of the overall process flowsheet to enable recovery of all three elements (W, Nb, Ta), thereby minimising the capital expenditure required for future processing installations.



The Penouta Mine was one of the most important tin mines in Spain until it closed in 1985. The tailings, seen here, contain tin, niobium and tantalum.

(Photo: Strategic Minerals Spain)

## T.I.C.'s role in Tarantula

The T.I.C. is a junior partner in the consortium, but plays an important role in two key areas:

- Work package (WP) 2: Identification of European resources of refractory metals. There are over 3600 occurrences of W, Nb and Ta recorded in Europe. Each record will need to be checked, standardised and incorporated into the Tarantula database.
- WP8: Communication and dissemination of results to stakeholders. This will include developing training materials and coordinating workshops that target industrial audiences, such as T.I.C. member companies.

Future editions of the Bulletin will contain more information as the project develops.



An aerial photo of the Penouta Mine site showing the old tailings that are being re-processed in the gravity plant.

(Photo: Strategic Minerals Spain)

## Looking ahead

Following systematic research and innovation activities at lab scale, the envisioned technologies will be brought to technology readiness level 3 to 5<sup>2</sup> and, based on performance, validated at prototype level by experienced industrial partners. In parallel, future by-product recovery will be supported by carrying out a comprehensive identification and assessment of existing un/underexploited secondary sources of W, Nb and Ta.

The generated information - in compliance with all pertinent laws and regulations - will feed into the Raw Materials Information System (RMIS) which will boost the impact of the project far beyond the current consortium.

Finally, Tarantula will create tailored communication, dissemination and civil society engagement strategies with respect to obtaining and maintaining the “Social License to Operate” for future heavy-duty metallurgical processing. TIC

## Notes

1. European Commission website on Critical raw materials: [https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical\\_en](https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en). This subject was also featured in Bulletin 171 [https://www.tanb.org/images/T\\_I\\_C\\_Bulletin\\_no\\_171\\_\(October\\_2017\)\(1\).pdf](https://www.tanb.org/images/T_I_C_Bulletin_no_171_(October_2017)(1).pdf)
2. Technology readiness levels (TRL) are a method for estimating the maturity of technologies. There are 9 TRLs with 9 being the most mature technology.
  - TRL-3 is proof-of-concept demonstrated, analytically and/or experimentally.
  - TRL-4 is component and/or breadboard laboratory validated
  - TRL-5 is component and/or breadboard validated in simulated or real-space environment

Héder, M; “From NASA to EU: the evolution of the TRL scale in Public Sector Innovation”, The Innovation Journal, Volume 22(2), 2017.



# 60th General Assembly: Technical Programme Abstracts



Photos: T.I.C., Shutterstock

Generously sponsored by: **Platinum sponsor: Guangdong Zhiyuan New Material Co., Ltd**



Silver sponsors: **A&R Merchants Inc., RC Inspection Group and Yanling Jincheng Tantalum & Niobium Co., Ltd**



The T.I.C.'s 60th General Assembly will be held in Hong Kong from October 13th to 16th 2019. The event is generously sponsored by Guangdong Zhiyuan New Material Co., Ltd (Platinum), A&R Merchants Inc. (Silver), RC Inspection Group (Silver) and Yanling Jincheng Tantalum & Niobium Co., Ltd (Silver). The event is now open for booking and full information, including the booking form, is available at [www.tanb.org](http://www.tanb.org). The final booking deadline is Friday October 4th 2019.

A special "early bird" booking rate is available for bookings received by August 16th 2019.

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.

## Overview of fabrication of tantalum explosion clad equipment

by Olivier Sarrat<sup>1</sup> and Olivier Lallement<sup>2</sup>

1 - NobelClad; 2 - Tantec GmbH

Tantalum is the ideal metal for most severe corrosion situations. It offers a superior technical choice in installations where glass lined equipment is subject to mechanical damage or thermal shock failures. The high cost of tantalum has traditionally been a major impediment to its broad use in large pressure vessels and heat exchangers. Tantalum/steel explosion clad offers a commercially viable alternative. The tantalum cladding surface offers all the benefits of wrought tantalum; the steel base metal is low cost and readily fabricable. The world's largest, heaviest, tantalum clad heat exchanger to date has been recently fabricated by Tantec. The presentation shows the different steps in manufacturing techniques, both cladding and fabrication, which made this success possible.

## Evolving expectations for due diligence – a legal and customer update

by Hillary Amster and Leah Butler

Responsible Minerals Initiative (RMI)

In the spirit of progressive improvement, the expectations for due diligence for responsible mineral supply chains have evolved over the past 10 years and company understanding of their supply chains continues to deepen. Working together, the RMI and its stakeholders, including the T.I.C., continue to develop programs and tools to meet the expectations of actors along mineral supply chains. 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 Responsible Minerals Assurance Process's (RMAP) application for recognition by the European Commission, and opportunities for future collaboration with the tantalum industry.

## **High temperature tantalum polymer capacitors**

by James Chen, Antony Chacko, Chris Stolarski, Cristina MotaCaetano and Philip Lessner

KEMET Electronics Corporation

In recent years, there has been significant increase of passive components in automotive systems due to real time sensing and automation for advanced driver assistance and ultimately autonomous vehicles. Some of these automotive applications require tantalum polymer capacitors with operational temperatures at or above 150°C. Tantalum polymer capacitors are desirable for several of these applications due to their low equivalent series resistance (ESR), lower derating, and benign failure mode compared to tantalum MnO<sub>2</sub> capacitors. This paper focuses on the performance of the new 150°C capable surface mount tantalum polymer capacitors and the enabling technologies. Oxygen permeation into the conducting polymers through several primary and secondary pathways in the molded capacitor causes polymer oxidation leading to ESR failures in high temperature life tests. The development of a new cathode and protective coating material technology which decreased oxygen permeation and polymer oxidation is presented. Their effectiveness in providing high temperature ESR stability is demonstrated by 150°C temperature life test of 33uF/35V, 22uF/50V and 15uF/75V tantalum polymer capacitors. Extended life tests at 150°C for 7000 hours demonstrate the enhanced high temperature capability of these new products.

## **T.I.C. 2019 annual statistics presentation with augmented trade statistics**

by David Knudson

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

It is the T.I.C.'s goal to be the pre-eminent source for published statistics on the tantalum and niobium trade. This presentation will provide a comprehensive report on collected T.I.C. member data for calendar years 2009 through 2018 along with international public trade data on tantalum and niobium raw materials and products. Also covered will be the collection 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 our members by an independent intermediary (Miller Roskell Ltd, a chartered accountant). This data is then verified and certified by Miller Roskell, aggregated 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.

## **Trends and new challenges: how future technologies may impact tantalum- and niobium-based capacitors**

by Tomáš Zedníček

European Passive Components Institute (EPCI)

We are living in a time of dramatic technological changes related to fast growth of services based on digitalization. Capacitors are among the top electronic components needed for further electronic design evolution. What is the chance for tantalum and niobium capacitors to be included in the new challenges? This presentation will cover benchmarking of tantalum- and niobium-based capacitors to other capacitor technologies and their ability to answer today's electronic hardware requirements in a wide range of applications.

## **Development and prospect of tantalum & niobium hydrometallurgical technology and equipment**

by Lu Dong, Zhang Wei-ning and Zheng Pei-shen (presented by Jiang Bin)

Ningxia Orient Tantalum Industry Co., Ltd

The development of tantalum-niobium hydrometallurgical technology in China was analyzed. The crushing, decomposition, extraction, separation of tantalum and niobium, synthesis of potassium fluorotantalate, precipitation and washing of niobium hydroxide, drying, roasting equipment and process were introduced. The opportunities and challenges for the development of tantalum-niobium metallurgical industry in China are analyzed. Only by continuing to improve metallurgical technology, reduce process flow, reduce the use of harmful substances, improve the utilization level of tantalum-niobium and other resources, and reduce the impact of tantalum-niobium hydrometallurgy on the environment, can the sustainable development of tantalum-niobium hydrometallurgy and the coordinated development of economy and environment be realized.

## **Upgrading resource efficiency on the whole life cycle from green manufacturing to recycling**

by Xiao Lin, Chenmin Liu, Shuhao Wang, Xue Wang, Zhi Sun and Yang Dai

Institute of Process Engineering, Chinese Academy of Sciences

Tantalum and niobium are critical metals with a wide range of applications. However, their primary production from minerals is energy intensive and associated with significant environmental impacts since their concentration in minerals is very low. Sustainability initiatives are becoming more important, as is proper end-of-life product waste management. In this research, an entire life cycle metallic resource strategy is proposed that considers the whole-process cost and resource utilization, by upgrading resource efficiency on the whole life cycle and optimizing whole-process pollution control in materials engineering, waste management, and metal recycling, with an aim to achieve lower cost processes throughout. More than 30 demonstration industrial projects in tantalum, niobium, and other metals have demonstrated how sustainable supply chain and value chain can be built within the whole processes from novel life cycle resources utilization eco-design, greener manufacturing with minimum waste/emissions, more metal extraction, better material, to closed loop spent products recycling. New technologies and processes covering metal separation with novel extraction systems, deep removal and recovery of heavy metals and ammonia, and spent waste resourceful recycling have been developed and scaled up from lab to industrial plant implementation in other nonferrous metals using similar processes and could find applications in the tantalum and niobium industries.

## **Tantalum - a market overview**

by Sophie Damm

German Mineral Resources Agency (DERA / BGR)

The supply and demand of tantalum has undergone significant shifts over the past few decades. Supply up until the early 2000s was dominated by conventional mining in Australia but has since been replaced by artisanal and small-scale mining in Central Africa, with the Great Lakes Region currently accounting for over 50% of global supply. This is likely to change again: tantalum as a by-product on the back of increased lithium mining is set to play an increasingly important role in future supply thus potentially reducing reliance on artisanal suppliers. Currently mine production is concentrated in countries with high governance risks, there are low recycling rates and limited potential for substitution in key applications, which together have increased the likelihood and severity of supply disruptions on the German economy. As a major industrialised nation, Germany is a leading consumer of tantalum and tantalum-containing products. With no domestic mine production, Germany is entirely reliant on imports of tantalum raw materials. A commodity risk analysis on tantalum published by the German Mineral Resources Agency (DERA, part of the German Federal Institute for Geosciences and Natural Resources (BGR)) is aimed at increasing market transparency and is directed at German companies to help identify potential price and supply risks and assist with mitigation and supply strategies for mineral raw materials. The report presents a comprehensive review of the tantalum market, the status quo and potential future supply over the next few years.

## **The ITSCI Programme: a journey through the implementation of due diligence for conflict-free minerals in the Great Lakes Region**

by Mickaël Daudin<sup>1</sup> & Samantha Munro<sup>2</sup>

1 - Pact; 2 - International Tin Association (ITA)

Since 2010, the ITSCI traceability and due diligence programme for 3T minerals has been implemented in the Great Lakes Region, covering today more than 2,100 sites/pits in four countries (DRC, Burundi, Rwanda and Uganda) and allowing around 80,000 artisanal miners to have access to the international market. Performing due diligence is a continuous process that requires ongoing monitoring and mitigation of risks along the entire supply chain. This paper provides concrete examples of how the ITSCI programme, and in particular ITSCI on-the-ground teams, are critical to monitor security situations; to record, verify, and report information; to engage with local stakeholders; and to provide guidance to companies; which is key to successful incident mitigation and due diligence. In order to maintain high standards fully aligned with OECD Due Diligence Guidance, and continuously improve efficiency, ITSCI has put in place new mechanisms, implemented procedures adapted to local environments and needs, and conducted regular training, thus contributing to enhancing accountability of local actors, companies and governments. The paper also showcases new developments such as the implementation of electronic data collection in several countries and future plans to expand and cover the entire GLR.

## **Trading places: niobium and vanadium in steel applications**

by Willis Thomas and Aleksander Popovic (presented by Ashley Wang)

CRU International Ltd

Ferroalloys, each of them with various qualities, are one of the multiple methods to increase the strength of steel. Steel can be strengthened through work hardening, precipitation hardening, alloying, and transformation hardening. These strengthening processes can be broadly listed as either process-related refinements or ferroalloy additives, although they can be, and often are, used together. Each method results in slightly different product strengths, though separate methods can be used to come to the same end product strength. Two of the principal ferroalloy additives for increasing steel strength are niobium (Nb) and vanadium (V). While these elements have been used together in steel alloying, resulting in impressive strength profiles, there are many times when these ferroalloys compete directly for exclusive use in an alloy. This paper from CRU will compare and contrast them as exclusive elemental additives. Vanadium- and niobium-based ferroalloys are not complete or easy substitutes for each other in all cases, both from a fundamental technical basis, as well as from a regulatory basis in regard to the updated Chinese rebar standards (introduced in late 2018). Not all users of ferroalloys are able to technically substitute niobium for vanadium without processing changes requiring capital investment – raising the breakeven price difference for substituting. Not all consumers of steel can accept material with ferroalloys substituted for one another - no matter the final properties of the metal. Intensity gains are expected to be semi-permeant in China, with substitution being less likely to retreat in the world outside China.

## **Tantalum and niobium – what will the next decade bring?**

by Suzanne Shaw and Erik Sardain (both presenting)

Roskill Information Services Ltd

Roskill estimates tantalum production totalled 1,925t Ta<sub>2</sub>O<sub>5</sub> in 2018, with Africa, South America and China accounting for the bulk of primary supply. Australia, accounting for just over 4% of supply in 2018, could see its share jump to over 10% of world production in 2019, and to just under 20% in 2020, as a result of rising production from new lithium-tantalum mines. It is likely that new Australian supply will soon begin to take market share from operations in the rest of the world, particularly those with a higher cost position. Artisanal mines, which are not typically “swing producers”, are likely to continue operating during periods of lower prices. Mechanised operations, therefore, may be more likely to see production curtailments. Meanwhile, the niobium market finds itself in interesting times. Little has changed on the supply side, save for recent announcements related to new capacity. Almost all production derives from pyrochlore that is mined and converted into FeNb. However, demand-side trends are proving interesting. The introduction of new Chinese reinforcing bar standards in November 2018, which banned the use of Grade II rebar and promoted the use of higher quality materials, has created new demand for ferroalloys. New standards sent demand for FeV, and thus vanadium prices, soaring in 2018, which in turn led to significant substitution of FeV by FeNb at Chinese mills. Chinese imports of FeNb remain high, although this is also a reflection of strong demand from the energy and automotive sectors. Roskill will present a 10-year outlook for tantalum and niobium supply and appraise the key demand trends over this period.

## **Optimizing supply chain transparency for greater goods**

By Lily Asia

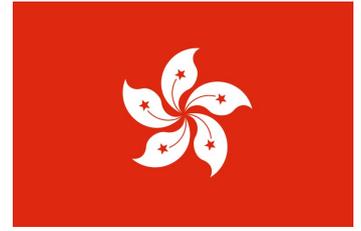
IBM

In today's business environment, stakeholders are increasingly aware of the social responsibility challenges associated with the mining and processing of minerals used in the electronic, jewelry, home appliance, and battery powered products. Globally, consumers are increasingly demanding Brands to produce conflict-free products through ethically sourced means. At the business level, firms selling the US, EU, and AP markets are required to adhere to legal and reporting regulations within these regions. As such, businesses must comply with rising consumer demands and legal requirements for greater transparency to mineral sourcing. The complexity within the global supply chain, a shortage of skilled supply chain professionals, and limits on corporate funding make it very challenging for companies of all-sizes to meet the demands of a more transparent supply chain. This paper will discuss methods implemented in IBM, HP, and Apple to optimize supply chain transparency. Ms Asia's best practices have been well received and described as “innovative, intuitive, and practical”. Ms Asia will also speak on the importance for smelters and refiners of 3TG (and now cobalt) to remain engaged with industry initiatives, such as, the Responsible Minerals Assessment Program. She will conclude by discussing state-of-the art technology being used in supply chains used to support a responsibly sourced supply chain.

## Hong Kong: host city of the 60th General Assembly

Hong Kong is one of the vibrant cities on the planet and brands itself as “Asia’s World City”. Visitors can find anything they are looking for here, from historical highlights to breath-taking views to incredible dishes from many international cuisines.

Hong Kong is also an important city for business, supported by its thriving stock exchange and vast container port (which delegates may visit during the General Assembly). Whether you are visiting for business or pleasure a trip to Hong Kong is always memorable.



Hong Kong’s container port is one of the busiest in the world  
(photo: Shutterstock)

Although Hong Kong is technically a Special Administrative Region of the People’s Republic of China visitors do not need a Chinese visa to visit. Hong Kong was a British colony until 1997 and to this day remains a bridge city between East and West.

The majority of citizens are ethnic Chinese, but many expats reside in the territory and English is widely spoken. There is also extensive English signage on maps, the public transport system and other public areas, making Hong Kong an easy city for visitors to navigate.

There are a many memorable views within Hong Kong’s limited land area, not least of which are views of the skyline. For the best vantage point, ascend Victoria Peak (Mount Austin), the tallest hill in the city and its most popular landmark. The easiest way up is to take the tram from close to the Conrad Hotel (our conference venue) to the Peak. Emerging 428 m above sea level you’ll be rewarded with a 360° view of the city; lush mountains, ocean, islands and over a thousand skyscrapers comprising the city skyline.

We look forward to seeing you in Hong Kong for the T.I.C.’s 60th General Assembly! **TIC**



Hong Kong Island at night viewed from Kowloon (photo: Shutterstock)



To whom it may concern,

An open letter concerning synthetic tantalum concentrates (for information only)

Recently it has come to the T.I.C.'s attention that a small number of countries consider tantalum-containing by-products of mining and mineral processing to be "waste" (i.e. an unwanted substance with no value). This Association disagrees with this categorisation and we wish to explain that this material has value and is an important source of tantalum units to the global market.

The T.I.C. members represent all aspects of the industries we cover including mining, trading, processing, metal fabrication, and capacitor manufacturing. We have members from over 25 countries and since 1974 we have been the industry organization of the tantalum industry. In 2018 our members produced over 90% of global tantalum supply, which included a significant quantity of tantalum recovered from low-grade feedstock.

Low-grade tantalum-bearing materials, including synthetic tantalum concentrates, have long been an important source of tantalum units. Tantalum (Ta) is a relatively high-priced element and this means that it can be economically recovered from raw materials containing as little as 2% tantalum pentoxide ( $Ta_2O_5$ ). The recovery of tantalum from low-grade tantalum ore is well-established and has been commonplace for over half a century. Please note that within our industry low-grade tantalum ore is sometimes by habit called by the slang name "tin slag" (a low-grade tantalum-bearing feedstock generated from processing cassiterite).

Synthetic tantalum concentrate is an economically valuable feedstock material that provides essential tantalum units to the market. Synthetic tantalum concentrate has been used by many international tantalum processors in China, Europe and the USA. Synthetic tantalum concentrate is a high value material containing between 2 - 20% tantalum which is regularly and routinely processed or used as a feedstock material for primary processing.

Broadly speaking, there are two kinds of synthetic concentrate that are common in our industry:

1. Synthetic concentrate generated from nickel-based superalloy gas turbine engine parts (blades, vanes, etc) containing tantalum. This includes scrap from both manufacturing (foundry revert) and end-of-life (engine revert). Processors melt the metallic scrap in an electric furnace to generate a pyrometallurgical synthetic concentrate. This material does not contain any acids or other harmful contents.
2. Synthetic concentrate generated during the processing of various kinds of raw materials using chemicals. This typically creates a clean concentrate with a higher  $Ta_2O_5$  level, although traces of processing chemicals may remain. We call this hydrometallurgical synthetic concentrate.

Both types of synthetic concentrate have been used by the tantalum industry for decades and are considered to be an important source of tantalum units.

Further, synthetic concentrates are not considered waste under most customs regimes around the world. Shipments of tantalum and niobium synthetic concentrates fall under HS Code 261590 "niobium, tantalum and vanadium ores and concentrates". In some countries it is further clarified under sub-code 261590.30.00 "synthetic tantalum-niobium concentrates". Tantalum and niobium concentrates in this category are considered non-waste primary feed products to primary processors for production of intermediate products such as potassium heptafluorotantalate ( $K_2TaF_7$ ) and tantalum pentoxide ( $Ta_2O_5$ ).

Finally, the T.I.C. collects quarterly statistics from its members and trade data. For our statistics reporting purposes the key production category is for "primary raw materials (e.g. tantalite, columbite, struverite, tin slag, and synthetic concentrates)". This clearly indicates that we consider this a primary feed material and an important part of the global material flow of tantalum.

Over coming months the T.I.C. will be exploring this issue in detail and we welcome all feedback.

Yours sincerely,

Roland Chavasse, Director, Tantalum-Niobium International Study Center

# Tantalum and niobium intellectual property update

Historically the T.I.C. reported those patents and papers that were relevant to the tantalum and niobium industries (2000-2007, available in the members' area at [www.TaNb.org](http://www.TaNb.org)). Information here is taken from the European Patent Office ([www.epo.org](http://www.epo.org)) and similar institutions. Patents listed here were chosen because they mention "tantalum" and/or "niobium". Some may be more relevant than others due to the practice by those filing patents of listing potential substitute materials. 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 contained here.

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

## TANTALUM

Amorphous thin metal film US2019100007 (A1)	HEWLETT PACKARD DEVELOPMENT CO [US], THE STATE OF OREGON STATE BOARD OF HIGHER EDUCATION ON BEHALF OF OREGON STATE UNIV [US]	2019-04-04
High performance and reliability solid electrolytic tantalum capacitors and screening method EP3465237 (A1)	VISHAY SPRAGUE INC [US]	2019-04-10
Coating for an implant AU2017314997 (A1)	LINK WALDEMAR GMBH CO	2019-04-18
Amorphous thin metal film US2019119101 (A1)	HEWLETT PACKARD DEVELOPMENT CO [US], THE STATE OF OREGON STATE BOARD OF HIGHER EDUCATION ON BEHALF OF OREGON STATE UNIV [US]	2019-04-25
Magnetic random access memory US2019148628 (A1)	TAIWAN SEMICONDUCTOR MFG CO LTD [TW]	2019-05-16
Manufacturing method of tantalum carbide powder using self-propagating synthesis and tantalum carbide powder for hard metal using the same KR20190053026 (A)	KOREA INST IND TECH [KR]	2019-05-17
Flaky microcapsule and method for preparing same EP3486338 (A1)	NINGXIA ORIENT TANTALUM IND CO LTD [CN]	2019-05-22
Cobalt-based alloy with a high resistance at high temperatures, spinner for the production of mineral fibers comprising said alloy and process for the production of mineral fibers which uses such a spinner WO2019096619 (A1)	STM TECH S R L [IT]	2019-05-23
Ultra-fine grain size tantalum sputtering targets with improved voltage performance and methods thereby US2019161850 (A1)	TOSOH SMD INC [US]	2019-05-30
Tantalum powder and preparation method therefor WO2019127200 (A1)	NINGXIA ORIENT TANTALUM IND CO LTD [CN]	2019-07-04

## NIObIUM

Amorphous thin metal film US2019100007 (A1)	HEWLETT PACKARD DEVELOPMENT CO [US], THE STATE OF OREGON STATE BOARD OF HIGHER EDUCATION ON BEHALF OF OREGON STATE UNIV [US]	2019-04-04
Nitriding of niobium steel and product made thereby US2019100827 (A1)	NUCOR CORP [US]	2019-04-04
High-strength steel plate for pressure vessel having excellent toughness after post weld heat treatment and manufacturing method thereof US2019100818 (A1)	POSCO [KR]	2019-04-04
Amorphous thin metal film US2019119101 (A1)	HEWLETT PACKARD DEVELOPMENT CO [US], THE STATE OF OREGON STATE BOARD OF HIGHER EDUCATION ON BEHALF OF OREGON STATE UNIV [US]	2019-04-25
Structural cryogenic steel and method of its production RU2686758 (C1)	PUBLICHNOE AKTSIONERNOE OBSHCHESTVO SEVERSTAL PAO SEVERSTAL [RU]	2019-04-30
High-strength corrosion-resistant steel RU2687619 (C1)	OBSHCHESTVO S OGRANICHENNOJ OTVETSTVENNOSTYU KHARD METALL OOO KHARD METALL [RU]	2019-05-15
Cold rolled heat treated steel sheet and a method of manufacturing thereof WO2019092576 (A1)	ARCELORMITTAL [LU]	2019-05-16
High-strength bainitic steel US2019161838 (A1)	GM GLOBAL TECH OPERATIONS LLC [US]	2019-05-30
Graphene-enabled niobium-based composite metal oxide as an anode active material for a lithium-ion battery US2019165364 (A1)	NANOTEK INSTRUMENTS INC [US]	2019-05-30
Method and systems for metal doping on battery cathode materials WO2019104099 (A2)	A123 SYSTEMS LLC [US]	2019-05-31

## Diary of forthcoming events to be attended by T.I.C. staff \*

- Passive Components Networking Symposium (PCNS), Bucharest, Romania, September 10th to 13th 2019
- **T.I.C.'s 60th General Assembly and AGM in Hong Kong, China, October 13th to 16th 2019**
- RMI's Annual Conference in Santa Clara, CA, USA, October 21st to 23rd 2019
- London Metals Week 2019 in London, UK, October 28th to 30th 2019
- IAEA's 39th TRANSSC meeting in Vienna, Austria, October 30th to November 1st 2019
- EU Raw Materials Week, Brussels, Belgium, November 18th to 22nd 2019
- FORMNEXT, Frankfurt, Germany, November 18th to 21st 2019
- Mining Indaba, Cape Town, South Africa, February 3rd to 6th 2020

\* correct at time of print

## Member company and T.I.C. updates

### Changes in member contact details

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

- **Alliance Mineral Assets Ltd:** The postal address is PO Box 2275, Churchlands, Western Australia, 6018, Australia. All other details remain unchanged.
- **H.C. Starck Tantalum & Niobium GmbH** has a new website address <https://www.hcstarck-tantalum-niobium.com> and the delegate, Ms Silvana Fehling, has a new email, [silvana.fehling@hcstarcktanb.com](mailto:silvana.fehling@hcstarcktanb.com).
- **Heraeus Deutschland GmbH & Co. KG** has a new delegate, Mr Sergej Schander, who replaces Bernd Spaniol. Mr Schander can be contacted on [sergej.schander@heraeus.com](mailto:sergej.schander@heraeus.com).
- **Imerys Ceramics France** has a new delegate, Dr Chandresh Agarwal. He can be contacted on [chandresh.agarwal@imerys.com](mailto:chandresh.agarwal@imerys.com). Dr Agarwal replaced Mr Pierre Sierak.
- **Ulba Metallurgical Plant JSC:** Mr Samrat Daulbayev is the new delegate, replacing Mr Alexey Tsorayev. Mr Daulbayev can be contacted at [DaulbayevSK@ulba.kz](mailto:DaulbayevSK@ulba.kz).

## Members of the Executive Committee of the T.I.C. 2018-2019

The Executive Committee is drawn from the membership and committee members may be, but need not also be, the delegates to the T.I.C. of member companies. The Executive Committee that was approved by the T.I.C. members at the Fifty-ninth General Assembly consists of (alphabetical by surname):

Fabiano Costa	<a href="mailto:fcosta@amgmineracao.com.br">fcosta@amgmineracao.com.br</a>
John Crawley (President)	<a href="mailto:jcrawley@rmmc.com.hk">jcrawley@rmmc.com.hk</a>
Silvana Fehling	<a href="mailto:silvana.fehling@hcstarcktanb.com">silvana.fehling@hcstarcktanb.com</a>
David Gussack	<a href="mailto:david@exotech.com">david@exotech.com</a>
Jiang Bin	<a href="mailto:jiangb_nniec@otic.com.cn">jiangb_nniec@otic.com.cn</a>
Janny Jiang	<a href="mailto:jiujiang_jx@yahoo.com">jiujiang_jx@yahoo.com</a>
Kokoro Katayama	<a href="mailto:kokoro@raremetal.co.jp">kokoro@raremetal.co.jp</a>
Raveentiran Krishnan	<a href="mailto:raveentiran@msmelt.com">raveentiran@msmelt.com</a>
Ben Mwangachuchu	<a href="mailto:bmwangaceo@smb-sarl.com">bmwangaceo@smb-sarl.com</a>
Candida Owens	<a href="mailto:owens.candida@cronimet.ch">owens.candida@cronimet.ch</a>
Daniel Persico	<a href="mailto:danielpersico@kemet.com">danielpersico@kemet.com</a>
Alexey Tsorayev	<a href="mailto:alexey.tsorayev@mail.ru">alexey.tsorayev@mail.ru</a>

Of these twelve, Mr John Crawley was elected President of the T.I.C. until October 2019. The T.I.C. currently has the following subteams (chaired by): Marketing (Daniel Persico), Meetings (Candida Owens), Statistics (Alexey Tsorayev) and Supply Chain (John Crawley).

We are always looking for enthusiastic T.I.C. members to join the Executive Committee or one of our subteams. If you are interested in doing so and have a couple of hours each month spare, please contact [director@tanb.org](mailto:director@tanb.org).

SAVE 15%\*



# T.I.C.'s 60th General Assembly

will take place in

## Hong Kong

from October 13th to October 16th 2019.

Members and non-members are welcome to attend this event, our annual conference. \*Early bird discount is available until August 16th. Full details, including the booking form, are available online at <https://www.tanb.org/event-view/60th-general-assembly>.

Generously sponsored by: Platinum sponsor: Guangdong Zhiyuan New Material Co., Ltd



Silver sponsors: A&R Merchants Inc., RC Inspection Group and Yanling Jincheng Tantalum & Niobium Co., Ltd



A list of the technical programme abstracts is on pages 16 to 19 of this journal. This event will include the Ekeberg Prize award ceremony and an optional tour of Hong Kong container port.

Questions about the event and delegate's booking forms should be sent to Emma Wickens at [info@tanb.org](mailto:info@tanb.org).



There will be simultaneous translation during plenary presentations