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INTERNATIONAL STUDY CENTER

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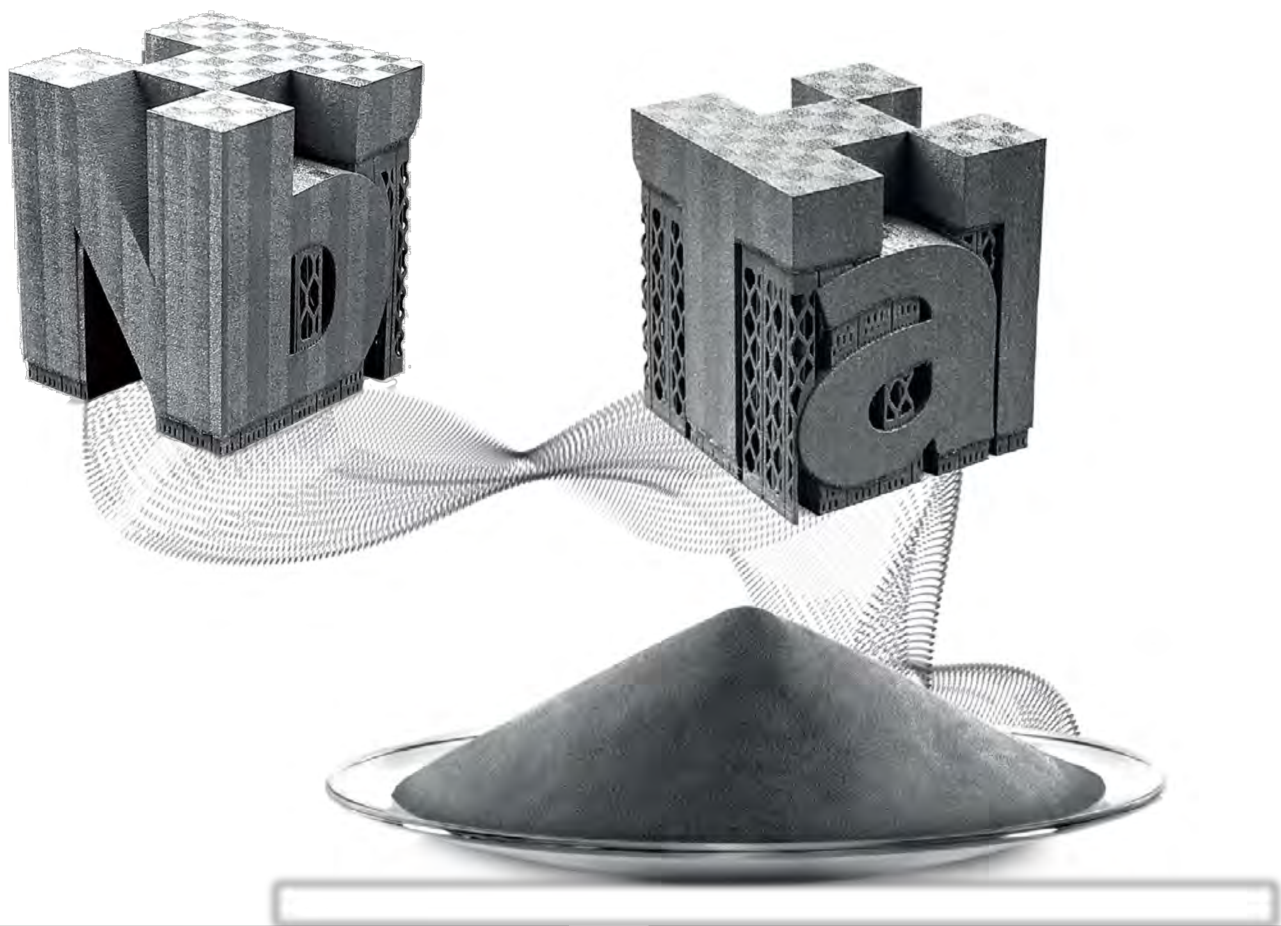
Has the time arrived for tantalum and niobium in additive manufacturing?

(p.16)



NORM transport

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Photo credit: AMtrinsic® powders for additive manufacturing by H.C. Starck Tantalum and Niobium GmbH

President's Welcome

Dear Members,

Welcome to a new decade...2020! I hope your holiday travels to see family and friends were all safe and enjoyable.

I want to thank you for the opportunity, once again, to represent all the members of the T.I.C. as your President.

For those who were able to attend the 60th General Assembly (GA60) in Hong Kong, I think you will all agree it was a very successful event... I only wish that the local protest activities had not deterred a few delegates from travelling. However, that said, GA60 went off without a hitch, as always thanks to Emma, Dave, Ally, Roland and the Meetings Subteam.

We had a total of 185 attendees (delegates from member and non-member organisations, and accompanying persons). The venue (Conrad Hotel, Hong Kong) was wonderful and the entertainment at the Gala Dinner was exceptional in both sound and spectacle. As for the excursion to the Hong Kong container port, those who attended were lucky enough to witness one of the largest container ships in the world capable of carrying the equivalent of some 21,400 twenty-foot containers and with a total length of 400 meters. Certainly a grand sight to behold from the water. The understanding that these huge ships get turned around in 3-4 hours is mind boggling (of course only specific rows of containers are removed and added, not every container). Certainly a logistics challenge but they do it every day… Just as interesting was the armada of much smaller container barges that go up and down the Pearl River to Shenzhen, etc., to bring down the electronics and other retail items that are produced in China so they can go out to the rest of the world. This is very important to certain T.I.C. members.

The Executive Committee and staff meeting in Hong Kong, in October 2019 (photo: T.I.C.)

Moving forward this year, we have a number of events where the T.I.C. and member companies will be participating, and in some cases presenting: the Argus Conference February 17th - 19th in London, MMTA April 22nd - 24th in Charleston, SC, USA, and the MIRU Tantalum Summit April 17th in Tokyo. If convenient, I strongly urge you to attend some of these meetings to both support the T.I.C. outreach efforts as well as better understand what is happening in associated business fields. Knowledge is power...and networking is key to business success.

Furthermore, with regards to specific efforts being undertaken by the T.I.C. on behalf of the membership, we are deeply engaged with the IAEA in efforts to raise the limit on allowable combined U/Th radioactivity in Ta ores, in order to diminish and/or eliminate issues associated with denial of shipment (see page 8). The consolidation of shipping lines, on a global basis, has given the few remaining global lines considerably more power. The Executive Committee, as the representative of the T.I.C. membership, is fully behind efforts to remove these issues and any other barriers that impede our members' ability to do business. We will keep you updated on this matter.

As we move through the year, I will be discussing other T.I.C. initiatives in my letters, initiatives such as outreach, greater focus on niobium, and more improvements in the T.I.C. statistics. As always, please do not hesitate to contact me directly should you have questions, comments and suggestions.

This is YOUR T.I.C.

Dr Daniel Persico

President

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The T.I.C. can be contacted at info@tanb.org; www.tanb.org; +32 2 649 51 58, or at the registered address: Chaussée de Louvain 490, 1380 Lasne, Belgium.

The T.I.C. is an international, non-profit association founded in 1974 under Belgian law that represents around 90 members from over 25 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 calendar year and full details of benefits are available at www.TaNb.org

Contents

Featured articles:

Regular articles:

The T.I.C.'s 60th General Assembly and 2019 AGM

The 60th General Assembly, including the 2019 annual general meeting (AGM), was held on October 13th - 16th 2019, at the Conrad Hotel in Hong Kong.

The event was attended by leading tantalum and niobium participants from around the world and was generously sponsored by Guangdong Zhiyuan New Material Co. Ltd (Platinum) and A&R Merchants Inc. (Silver), RC Inspection Group (Silver) and Yanling Jincheng Tantalum & Niobium Co. Ltd (Silver).

The T.I.C. General Assembly is the world's leading international conference for tantalum and niobium. This year, despite the negative journalism about Hong Kong in the preceding months, 185 delegates attended from over 100 companies and almost 50 countries. The city of Hong Kong was as spectacular as it always is, the event proceeded without incident and was a notable success.

Annual General Meeting (AGM)

During the AGM on October 14th members passed motions including:

- Agreeing the minutes from the 2018 AGM
- Approving seven corporate membership applications and one transfer of membership
- Passing the budget for the 2020 financial year, which included a modest cost-of-living increase in the membership subscription (the first increase since 2015).
- Adoption of the proposed Data Protection Policy.

All documents pertaining to the General Assembly and AGM, together with the presentations and photos from the event, are currently available on the members' area of the Association's website or from the T.I.C. office.

Executive Committee elections

At the elections to the Executive Committee, held during the AGM, Ms Kokoro Katayama, Mr Alexey Tsorayev and Mr Ben Mwangachuchu did not stand for re-election, but the nine other current committee members did stand and were re-elected, and Mr Ronald Gilerman was elected for the first time. Of those elected Dr Daniel Persico was elected President. Dr Persico is SVP, Mergers & Acquisitions at KEMET Electronics Corporation.

The Executive Committee 2019-2020 is (alphabetical by surname):

Fabiano Costa	fcosta@amgmineracao.com.br
John Crawley	jcrawley@rmmc.com.hk
Silvana Fehling	silvana.fehling@hcstarcktanb.com
Ronald Gilerman	ronald.gilerman@armerchants.com
David Gussack	david@exotech.com
Jiang Bin	jiangb_nniec@otic.com.cn
Janny Jiang	jiujiang_jx@yahoo.com
Raveentiran Krishnan	raveentiran@msmelt.com
Candida Owens	owens.candida@cronimet.ch
Daniel Persico (President)	danielpersico@kemet.com

The next AGM and elections will take place on October 12th 2020, during our 61st General Assembly in Geneva, Switzerland. The T.I.C. asks that Executive Committee members serve as individuals, not in their corporate roles.

The T.I.C. currently has the following subteams (chaired by): Marketing (Daniel Persico), Meetings (Candida Owens), Statistics (David Knudson) and Supply Chain (John Crawley). Employees of corporate members are always welcome to join a subteam or stand for election to the Executive Committee, and if you are interested please contact info@tanb.org.

New members

At the AGM seven new corporate members were elected and one company transferred corporate membership. The transfer was from CNMC Ningxia Orient Group Co. Ltd to Ningxia Orient Tantalum Industry Co. Ltd.

Corporate membership of the T.I.C. is open to organisations actively involved in any aspect of the niobium and tantalum industries, from explorers to miners, traders and processors, through to end users and suppliers of goods and services to the industry. Associate membership is available to organisations that are not commercially involved in our industries, such as academia, associations, government bodies and civil society.

ArrowMetals Asia Pte Ltd
Address: 3 Anson Road, #14-02 Springleaf Tower, 079909, Singapore
Website: www.arrowmetals.com
Delegate: Mr Martín Núñez
Email: mnunez@arrowmetals.com

Chepetsky Mechanical Plant ("ChMZ")
Address: 7 Belov, Glazov city, Udmurt Republic, 427622, Russia
Website: www.chmz.net
Delegate: Mr Sergey Syrtsov
Email: seysyrtsov@rosatom.ru

Globe Metals & Mining Ltd
Address: 137 Lake Street, Northbridge, Western Australia 6003, Australia
Website: www.globemm.com
Delegate: Mr Alistair Stephens
Email: ajs@globemm.com

Hunan Huaran Technology Co. Ltd
Address: Building 8th, Golden Century Pioneer Park, Lukou Economic Development Zone, Zhuzhou, Hunan 412100, China
Website: www.huarantech.com
Delegate: Ms Hannah Dan
Email: danhongmei@huarantech.com

Jiangxi Dinghai Tantalum & Niobium Co. Ltd
Address: 98 Hujiabian Road, Fengxin County, Jiangxi Province, 330703, China
Website: www.dhtn.cn
Delegate: Ms Jocelyn Lau
Email: jocelynliu@qq.com

RFH Recycling Metals Co. Ltd
Address: 1507 Huijie Plaza, NO.268 Zhongshan Road, Nanjing 210008, China
Website: www.rfh-metals.com
Delegate: Mr Gu Mingdao
Email: polo@richwinchina.com

SXMINTEC ("SMT")
Address: 5th Floor Tien Chu Commercial Building, 173-174 Gloucester Road, Wanchai, Hong Kong SAR, China
Website: www.sxmintec.com
Delegate: Mr George Song
Email: george.song@sxmintec.com

If you are interested in T.I.C. membership please visit https://www.tanb.org/view/join-today or contact the office for details on the benefits of membership and an application form.

Photos from the 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

Plenary sessions included lively question and answer sessions after each presentation. Since 2017, the General Assembly has featured English-Chinese simultaneous translation for the benefit of delegates.

The **Gala Dinner** on Monday evening was a spectacular Chinese banquet with entertainment provided by Guangdong Zhiyuan New Material Co. Ltd, our platinum sponsor. During the event, incoming President Dr Daniel Persico presented the winner of the Anders Gustaf Ekeberg Tantalum Prize 2019, Mr Nicolas Soro, with a medallion made form pure tantalum metal in recognition of his great achievement (below, centre).

Following the plenary sessions of the General Assembly many delegates joined a field trip to visit Hong Kong's container port, one of the busiest in the world.

Our boats were dwarfed by the OOCL Hong Kong (left), the largest container ship ever built at the time she was delivered in 2017. She is 400m long and can hold the equivalent of over 21,400 twenty-foot shipping containers (TEU).

All photos are © T.I.C. 2019 and many more are available at www.TaNb.org.

Sponsorship opportunities at the T.I.C.'s 61st General Assembly

Sponsorship puts your company in front of the global leaders in tantalum and niobium in a targeted and cost-effective way.

Opportunities for sponsorship at the 61st General Assembly are now available on a first-come, first-served basis. Contact info@tanb.org for details.

NORM transport: time to increase the exemption level

Executive summary

The safe transport of tantalum- and niobium-containing raw materials (which can be naturally radioactive) is essential to human life and health and the environment, and also to industry and society as a whole.

However, the T.I.C. believes that the current cut-off (exemption) level of 10 Becquerels per gram (Bq/g) for transport of radioactive tantalum/niobium containing materials is set unrealistically low; at a level that is unnecessarily cautious and a detriment to industry.

We propose an increased exemption level of 30 Bq/g and have data to show this level would still be safe.

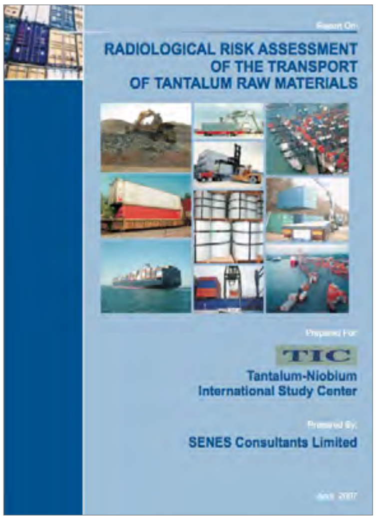
This issue is relevant because the International Atomic Energy Agency (IAEA) has recently created a new working group to examine the current exemption level and its recommendation will be submitted by June 2020. This is a rare opportunity to reconsider how best to regulate global NORM transport. We encourage all members and stakeholders to provide their support so that the IAEA's working group can reach the best possible decision.

Photo: Shutterstock

An increased exemption level of 30 Bq/g would be safe and sensible.

Background to the safe transport of NORM

Radioactivity is a natural phenomenon and some mineral raw materials contain traces of thorium (Th) and uranium (U), making them <u>n</u>aturally <u>o</u>ccurring <u>r</u>adioactive <u>m</u>aterials (NORM). This includes some niobium- and tantalum-containing minerals, uranium ores, monazite for rare earth elements, zircon concentrates, and certain phosphate fertilizers. International sea transport of NORM is common since processing facilities are often far from mine sites.



The T.I.C.'s 2007 study of NORM transport contains comprehensive data about NORM shipments and their radioactivity (photo: T.I.C.)

The IAEA sets the international transport exemption level for defining radioactive and non-radioactive materials, and this level is often, but not always, adopted by countries for their internal transport regulations too.

Today the cut-off for sea transport is 10 Bq/g and materials below 10 Bq/g are considered to be normal non-radioactive cargo. Materials over 10 Bq/g must be transported as "radioactive" in full compliance with the Class 7 regulations set out by the International Maritime Organisation's (IMO) International Maritime Dangerous Goods (IMDG) Code.

However, the exemption level has only been 10 Bq/g since 1996; before then it was 70 Bq/g, and in Brazil and many other countries 70 Bq/g is still considered as a safe and reliable exemption level for internal transportation. In recent decades consolidation in the global shipping industry has significantly decreased the number of shipping lines that accept Class 7 shipments, further increasing the importance of appropriate NORM exemption levels.

Time for change

Since 1996 vast quantities of data on NORM shipments and the safety of those who handle them have been generated. Increasingly, NORM transport safety experts are asking if it is time to examine all the data and reconsider what is the most appropriate exemption level.

The most recent evidence of this growing interest in NORM occurred last September at the IMO's annual conference when Germany proposed changing the IMDG Code to include a NORM exemption level of 30 Bq/g for certain tantalum-bearing materials.

The IMO reached no decision, but asked IAEA for advice. In December IAEA created a special working group within its Transport Safety Standards Committee (TRANSSC) to consider the issue and make a recommendation at the 40th TRANSSC meeting in June 2020.

As an observer at TRANSSC the T.I.C. has been invited to join the working group. This project could have a major impact on how our industry transports materials for decades to come. One industry expert has called this project "the biggest thing to happen in NORM for 20 years".

T.I.C.'s team at TRANSSC-39: Ulric Schwela (Salus Mineralis Ltd), Christian Cymorek (H.C. Starck Tantalum & Niobium GmbH) & Roland Chavasse (photo: U.Schwela)

The IAEA's transport meeting in June 2020 offers us a rare opportunity to help shape NORM transport regulations for decades to come.

How can you get involved?

The T.I.C. has spent considerable time and effort building a strong network in the NORM community, but our biggest strength comes from you, the T.I.C. members and stakeholders. If you share our view that IAEA should increase the NORM exemption level from 10 Bq/g to 30 Bq/g we strongly request you support this initiative:

- Tell your national regulators* who attend TRANSSC that you support an increase to 30 Bq/g

and / or

- Share your data on NORM / Class 7 shipments with TRANSSC* to help inform their decision.

National regulators need to be fully aware of this issue because their voices at TRANSSC's June meeting will decide whether the exemption level is changed or not. The IAEA sets the international standards for radiation safety, but regulating that safety is still a national responsibility handled by each country individually. An exemption level of 0 Bq/g is unworkable due to natural background radiation so there is a vital need for the IAEA to set a realistic exemption level which provides safety to human life, health and the environment, but at the same time does not throttle industry either.

Your support on this issue is important and appreciated.

The T.I.C. proposes an increased NORM exemption level of 30 Bq/g

* contact details of national regulators and the TRANSSC working group are available from director@tanb.org

Measuring NORM

From an assay of the material giving the concentration of Th and U it is possible to calculate the radioactivity concentration of the material measured in Becquerels per gram (Bq/g). The conversion factors applied are as follows:

For elemental Th/U:	For Th/U oxide:
1% Th = 40.6 Bq/g	1% ThO_2 = 35.6 Bq/g
1% U = 123 Bq/g	1% U_3O_8 = 104 Bq/g

Material below 10 Bq/g is exempt from radioactive transport (Class 7) regulations and can be shipped as general cargo, but material above this level must be transported fully Class 7 compliant. The higher regulatory burden and the risks involved may deter a carrier or port from accepting NORM shipments, resulting in a denial of shipment (DoS). Over the last decade DoS has increased due to many shipping lines merging. Further guidance is available in eight languages from the T.I.C. office or online at https://www.tanb.org/view/transport-of-norm.

The T.I.C. annual statistics presentation

These statistics were presented by David Knudson, T.I.C. Technical Officer, on October 15th 2019, as part of the 60th General Assembly. Additional input and leadership regarding international trade data were provided by the T.I.C. Statistics Subteam chaired by Mr Alexey Tsorayev. The T.I.C. makes no claim as to the accuracy or completeness of these statistics and no liability whatsoever is accepted by the T.I.C. in connection with these statistics.

Introduction

Tantalum (Ta) and niobium (Nb) statistics are a core purpose of the T.I.C., as mandated by article 3.2 of our Charter. Each quarter, member companies submit their data to an independent third party and receive back an updated report. Annual summaries of this information are shared with non-members at our General Assemblies and thereafter in the Bulletin.

Since 2017 members' data has been augmented with international trade data to provide a fuller and broader understanding of the market. This paper provides a summary for the calendar years 2009 to 2018 inclusive.

Members' data is collected by Miller Roskell Ltd, a fully independent accountant.

Data sources and interpretation

Members' data forms the core of the T.I.C. statistics service. The data has been collected from members by a 100% independent chartered certified accountant, Miller Roskell Ltd, since 2015. T.I.C. staff have no access to an individual member's data, only the aggregate totals and international trade data.

The T.I.C. statistics service, based on members' quarterly data, has provided a useful guide to trends in the industry for many years. Table 1 shows the total number of T.I.C. members reporting in each data category in 2018.

Data Set Groups (2018)	Reporting members	Metric tonnes of
Ta raw materials: mining production and trading receipts	33	Ta_2O_5
Ta receipts by processors	43	Ta_2O_5
Ta product shipments by processors	43	Ta contained
Nb raw materials: mining production and trading receipts	34	Nb_2O_5
Nb product shipments by processors	45	Nb contained

Table 1: 2018 reporting members by category

Augmenting members' data with international trade data

The T.I.C. purchases international trade data from Global Trade Tracker (GTT) and uses it to complete occasional gaps in members' reporting, generate additional charts and as an analytical tool to provide deeper meaning for members.

All physical international trade is recorded according to categories that are defined by the Harmonized System (HS) set out by the World Customs Organization (WCO). All the main tantalum and niobium producing, trading and consuming countries participate in this system and use the HS codes to determine their tariff schedules.

Additional data sources are used to add additional depth and verify primary data whenever possible. In 2018 the primary data sources for T.I.C. statistics reports were member companies and Global Trade Tracker (GTT), but additional sources of international trade data studied by the Association included, but were not limited to companies' annual reports, press releases and other publications; national governments; geological institutes; and international institutions (see Bulletin #176 for more details).

Some notes on the use of international trade data

It is essential to all statistics reports that the data can be defended and this means that we constantly check and cross-reference our statistics to create what we believe is the most robust data set possible. However, no statistics can claim to be infallible and when you use international trade data it is important to appreciate that:

- International trade data only records cross-border shipments. Domestic shipments are not recorded.
- Some HS codes cover several products, e.g. code 261590 includes Ta, V and Nb ores and concentrates.
- HS codes hold 6 internationally standardised digits; but many countries add unique additional suffix digits.
- Customs data may be presented in different units such as weight or monetary value.

In many cases informed assumptions have to be made as to being gross weight and the average grade, as well as the historical market price, in order to estimate the most probable net weight of Ta or Nb units contained. Given these and potentially other issues, care must necessarily be applied in using such data. Nevertheless these additional sources of data constitute a potentially useful source of information and we confidently report the following information.

Tantalum annual statistics 2009 - 2018

Production of tantalum-bearing raw materials in 2018 was slightly below 2017, making the fifth year in a row of declining production. A significant change took place in the total tantalum pentoxide (Ta_2O_5) units produced as 'Ta concentrates' by mining and from tin slag between 2014 and 2018. Tantalum concentrates are increasing while both tin slags and other concentrates are dropping significantly. Tin slags in particular have been mostly decreasing since 2011. This may be due to the availability of low-cost tantalum concentrates, making tin slags and low concentration tantalum ores uneconomical to process.

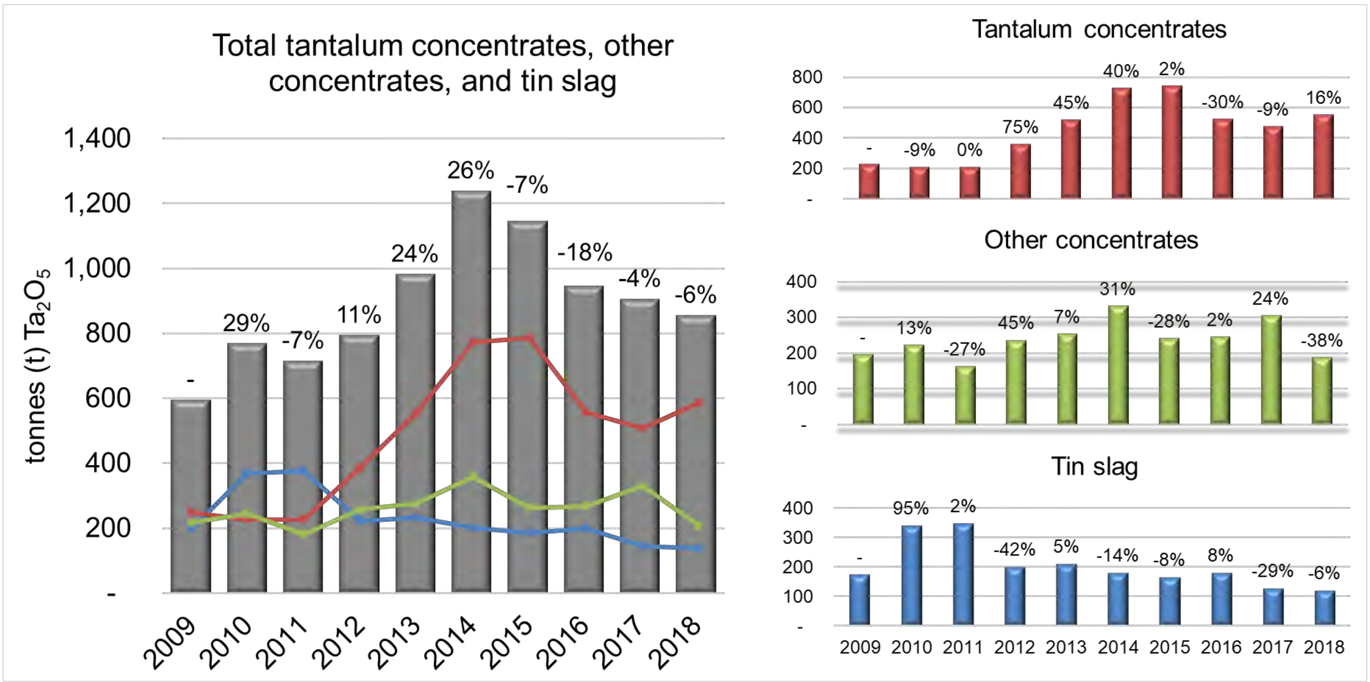


Figure 1: Tantalum raw materials: mining production and trading receipts (t Ta_2O_5)

While changes to the T.I.C.'s membership have an impact on what members' data is collected, the Association is fortunate in having a broadly stable membership among the processors of tantalum- and niobium-bearing primary and secondary raw materials around the world. The high level of participation from this category of member has contributed significantly to the quality of their statistical data.

Processor receipts of primary and secondary tantalum concentrates (see Figure 2) saw a slight correction in 2018 after seeing significant variation in 2016 and 2017. Since 2017 the T.I.C. has been augmenting missing members' data using international trade data (which is why 2017 and 2018 are red in Figure 2). The level of processor receipts of primary raw materials, typically containing >20% Ta_2O_5, has oscillated since 2012, averaging about 2,000 metric tonnes (t) per year. Over the last several years, primary raw material receipts have remained relatively flat. Secondary raw materials receipts represent roughly 35% of primary raw materials receipts.

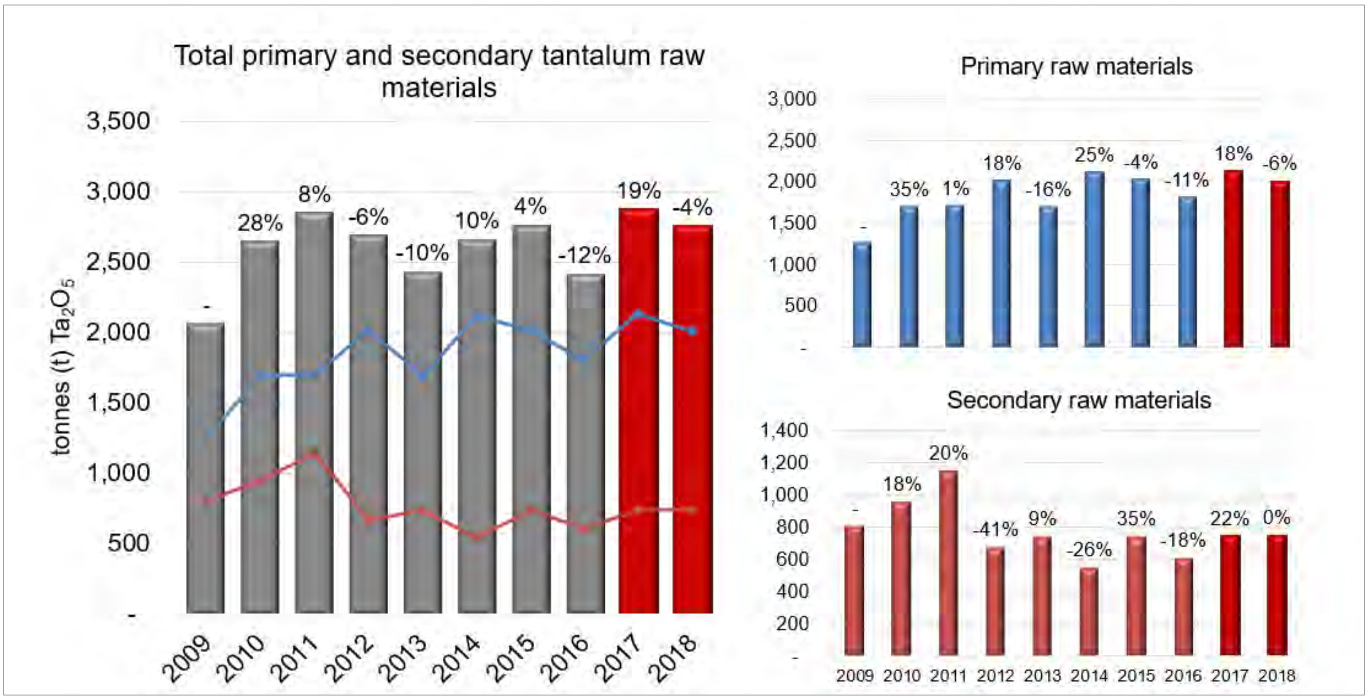


Figure 2: Tantalum receipts by processors (t Ta_2O_5)

Tantalum product shipments witnessed a slight decline in 2018, following a year of strong growth in 2017. In Figure 3 the relationship between different categories of material is shown. Processor shipments are dominated by capacitor-grade ('Cap') and metallurgical-grade ('Met') powders, which together with chemicals account for some 70% of shipments in 2018. Shipments of ingots and mill products account for most of the balance, with just 3% of shipments being carbides.

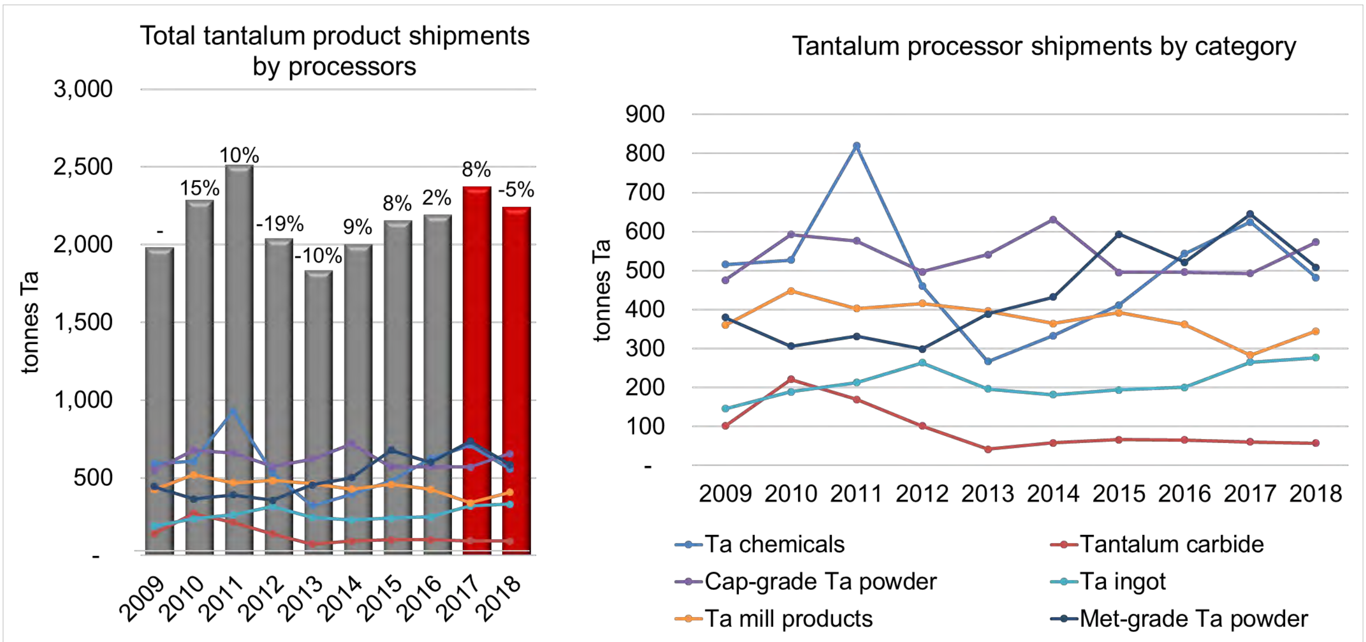


Figure 3: Tantalum product shipments by processors (t Ta)

A comparison of processors' tantalum receipts and shipments

By normalizing the processor-members' receipts of tantalum-bearing raw materials we can compare the figures to the quantities they shipped (see Figure 4). Over 40 T.I.C. members report data in this category, and yet the total difference during the 10-year period is 136 t Ta, a difference of less than 1%, which supports the conclusion that the T.I.C. has a mature, robust system in place well suited for year over year comparisons.

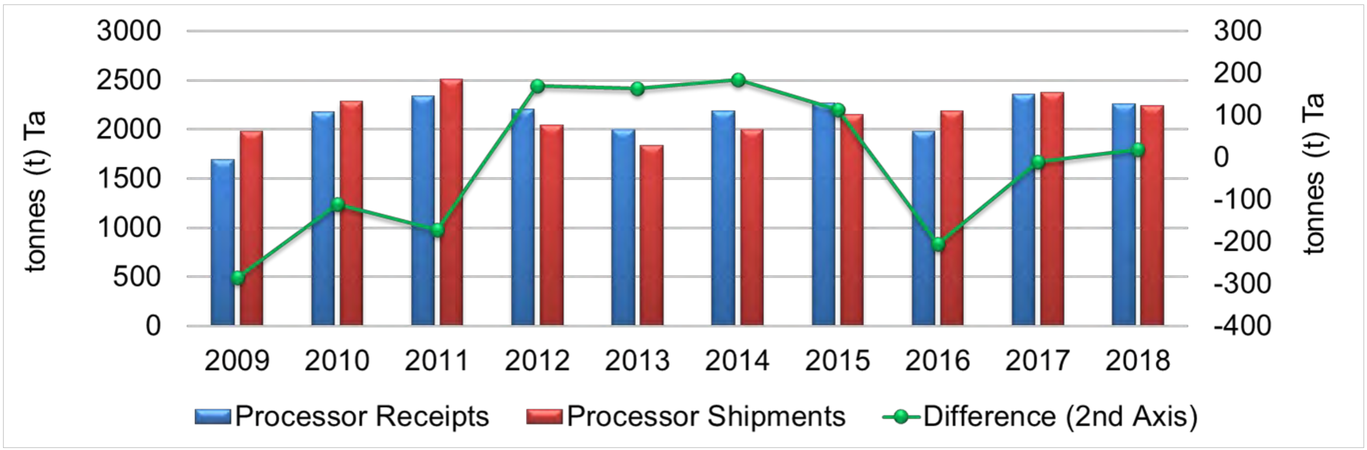


Figure 4: Statistical testing of processors' data

An example of international trade data adding value to members' data

International trade data of material shipped under HS code 261590 can help one understand cross-border shipments of tantalum concentrates. Here we focus on material >20% Ta_2O_5 content, identified by its value per unit volume against known values which allows an estimation of the Ta_2O_5 percentage to be made.

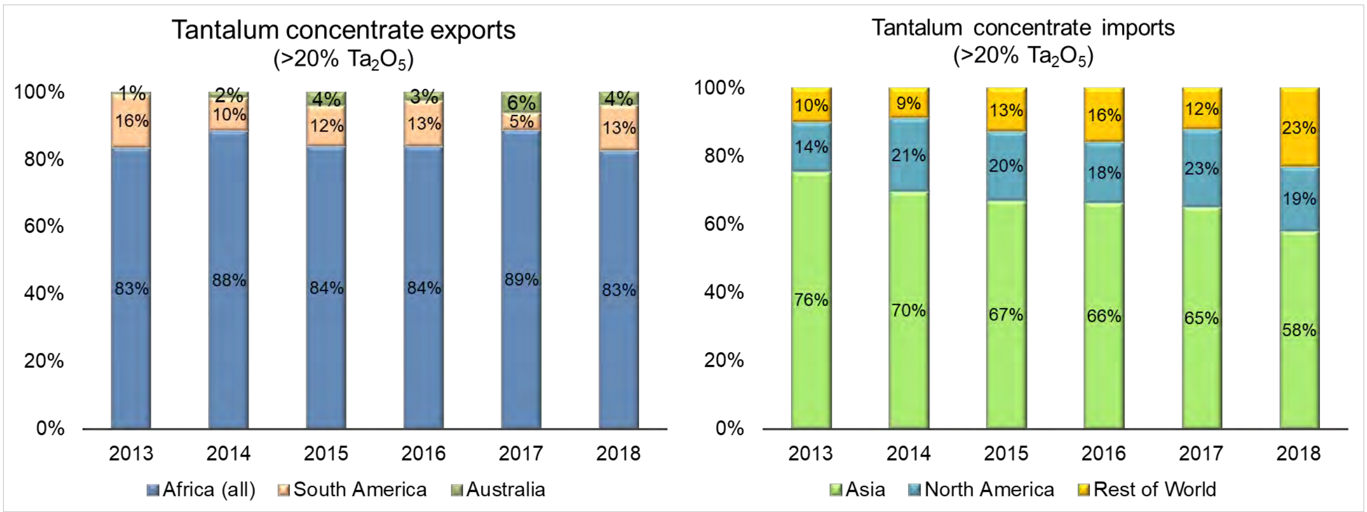


Figure 5: Key exporting (left) and importing (right) regions of tantalum-bearing minerals

The export data shows how after 5 years of increasing shipments Australia dropped slightly in 2018. Africa is still the dominant source of tantalum concentrates and South America has recovered its market share in 2018 after dipping in 2017 following an industrial accident at a key producer. The import data shows how Asian imports of tantalum concentrates have steadily decreased since at least 2013, while imports to North America and the rest of the world have been gradually increasing.

Niobium: annual statistics 2009 - 2018

Mine output of niobium has seen a compound annual growth rate (CAGR) of almost 5% in the period 2009 to 2018, slightly ahead of global economic growth and due to the continued increase in demand for niobium in many applications. Of particular note is the increase in production of niobium-bearing concentrates from 2016 to 2018, an increase of over 20,000 t (Nb in FeNb).

As in previous years the proportion of niobium-bearing materials other than concentrates (e.g. tantalite, Strüverite and tin slags), has played a minor role in the supply of units to market.

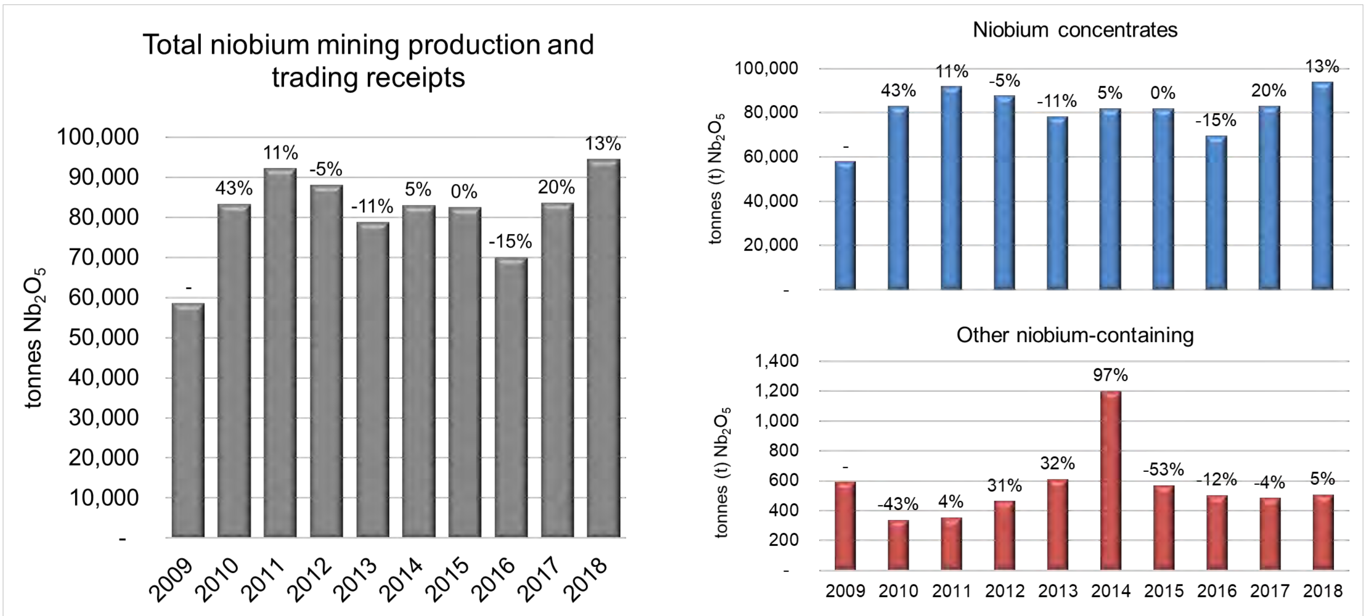


Figure 6: Niobium raw materials: mining production and trading receipts

The vast majority of niobium units continues to go into ferro-niobium destined for high-strength, low-alloy (HSLA) steel. Niobium products realized a significant increase obtaining their highest shipped rate by weight since 2014. All categories of niobium (chemicals, vacuum grade, pure metal, and HSLA-grade) enjoyed increased volumes, except for alloys. The latter category appeared to fall by 58% but the tonnages are so small for this category of material that such large percentages should be read with caution.

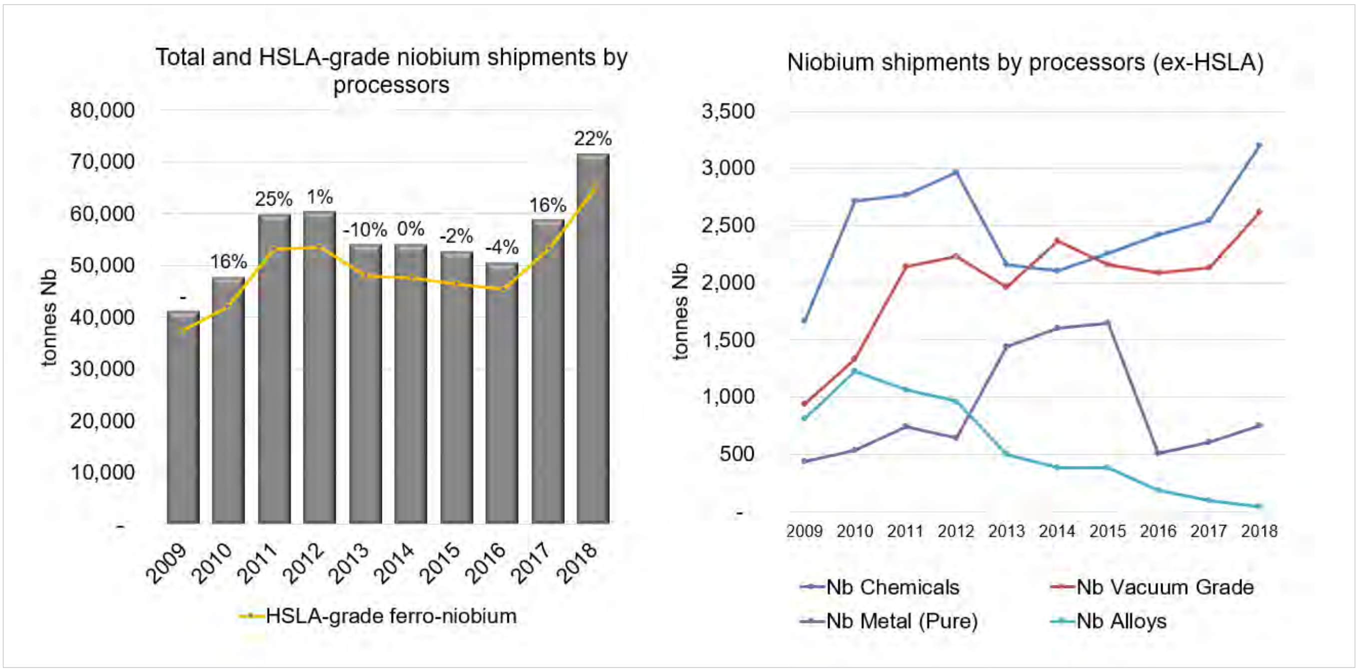


Figure 7: Niobium raw materials: mining production and trading receipts

Closing remarks

From the T.I.C.'s statistical analysis for the period in question the tantalum and niobium markets both appear to be enjoying a period of growth in supply overall, albeit in the single-figure percentages. The supply of tantalum has been stable for the last decade and continuity of supply from a wide range of sources is one of the core strengths of the market. In niobium the picture also shows every characteristic of strong and stable supply, but with a higher level of growth.

Regarding the T.I.C.'s quarterly statistics service for its members, it appears that the addition of international trade data to members' data has been welcomed, but we constantly strive to improve it further, adding new information and analysis as our expertise develops further. As always, we welcome your feedback.

Data for the T.I.C. annual statistics presentation

Tantalum raw materials: mining production and trading receipts (t Ta_2O_5)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR
Tin slag (over 2% Ta_2O_5)	175	342	349	201	211	181	166	180	128	120	-4%
Ta concentrates	226	205	205	359	520	727	741	522	475	550	9%
Other concentrates	196	222	163	235	253	332	240	245	304	90	-7%
Total	**597**	**769**	**716**	**795**	**983**	**1,240**	**1,148**	**947**	**907**	**760**	**2%**

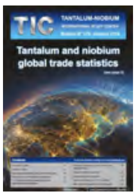
Tantalum receipts by processors (t Ta_2O_5)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR
Primary raw materials	1,258	1,696	1,708	2,016	1,694	2,114	2,019	1,807	2,133	2,009	5%
Secondary raw materials	808	953	1,146	676	740	551	744	612	745	747	-1%
Total	**2,065**	**2,650**	**2,854**	**2,693**	**2,434**	**2,665**	**2,763**	**2,419**	**2,878**	**2,756**	**3%**

Tantalum product shipments by processors (t Ta contained)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR
Ta chemicals	515	527	819	461	267	333	412	544	624	482	-1%
Ta carbide	102	221	170	102	42	58	66	66	61	58	-5%
Cap-grade Ta powder	475	592	576	497	541	631	495	496	493	573	2%
Ta ingot	146	189	213	264	197	182	194	201	265	277	7%
Ta mill products	360	448	403	416	396	364	392	362	283	345	0%
Met-grade Ta powder	380	306	331	299	389	432	594	521	645	508	3%
Total	**1,979**	**2,284**	**2,512**	**2,038**	**1,832**	**2,001**	**2,153**	**2,189**	**2,371**	**2,243**	**1%**

Niobium raw materials: mining production and trading receipts (t Nb_2O_5)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR
Nb concentrates	57,990	82,857	91,697	87,486	78,070	81,720	81,790	69,434	82,990	93,835	5%
Other Nb containing	595	339	353	464	611	1,204	570	503	484	508	-2%
Total	**58,585**	**83,196**	**92,050**	**87,950**	**78,681**	**82,924**	**82,360**	**69,937**	**83,475**	**94,342**	**5%**

Nb product shipments by processors (t Nb contained)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	CAGR
Nb chemicals	1,665	2,720	2,772	2,964	2,159	2,108	2,261	2,421	2,541	3,202	7%
Nb vacuum grade	942	1,331	2,144	2,233	1,962	2,366	2,163	2,084	2,131	2,616	11%
Nb metal (pure)	433	539	738	644	1,442	1,603	1,645	509	610	748	6%
Nb alloys	811	1,225	1,067	961	496	383	382	185	99	41	-26%
HSLA-grade FeNb	37,253	41,877	53,125	53,516	47,932	47,566	46,275	45,292	53,332	64,929	6%
Total	**41,104**	**47,692**	**59,847**	**60,318**	**53,991**	**54,026**	**52,725**	**50,491**	**58,712**	**71,536**	**6%**

CAGR: compound annual growth rate from 2009 to 2018



Join our mailing list to receive the Bulletin by email 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** to join our mailing list and keep up to date with the T.I.C.

Tantalum and niobium in additive manufacturing: a report from FORMNEXT 2019

This report is for information only and does not set out to provide an exhaustive account of all aspects of FORMNEXT exhibitors' businesses. Any misunderstanding is accidental.

There is no doubt that additive manufacturing (AM) has grown considerably in recent years and, if you believe the publicity, has the potential to disrupt the metals industry in many applications. But what does it mean for tantalum and niobium?

The intrinsic properties of a material will determine the range of accessible AM applications and in this context tantalum and niobium show great potential. Due to their unique properties such as high melting points, high corrosion resistance, excellent chemical resistance as well as high thermal and electrical conductivity, tantalum and niobium (or their alloys) are suitable for a wide range of applications, including chemical process equipment, nuclear reactors, aerospace parts and automotive components. Moreover, tantalum and tantalum-based alloys are a promising alternative for optimization of mechanical and biological performance parameters in medical implants (as demonstrated by the winner of the 2019 Anders Gustaf Ekeberg Tantalum Prize).

To find out more about this subject, the T.I.C. visited FORMNEXT in Frankfurt, Germany, one of the largest annual AM events in the world.

A tantalum timer made using AM by Elementum 3D (photo: T.I.C.)

First impressions

When you arrive at FORMNEXT what you notice first is the buzz in the air. The atmosphere is alive with thousands of voices talking at the same time. Four huge halls are filled with hundreds of exhibitors offering solutions to every aspect of AM technology, ranging from powder manufacturers and computer-aided design (CAD) experts to the latest AM machines with six figure price tags.

AM is a relatively new industry and is growing in double-digit percentages each year. Companies working in AM report difficulties in keeping up with new business opportunities and job vacancies outnumber qualified candidates. Reflecting the growth in AM, FORMNEXT is growing fast too and this year it occupied four vast halls and counted over thirty thousand delegates, including several T.I.C. members.

To an observer from outside the AM industry, the level of noise surrounding AM, both in the halls at FORMNEXT and more generally in the media (where it is often called 3D printing), can be dizzying. Is there substance behind all the sound and fury? Who is actively using tantalum and niobium in AM?

Photo credit: FORMNEXT

A very brief introduction to additive manufacturing*

The ASTM standard F2792-10 defines additive manufacturing as the "process of joining materials to make objects from three dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining”. This innovative technology leads to entirely new ways of manufacturing custom-made components and highly complex elements that would have been unthinkable to produce with conventional technologies.

While the concept of building something in a series of layers from the bottom up is not itself new — people have been constructing stone buildings this way for thousands of years — until recently such techniques could not easily be applied to metalwork. What has made metal AM possible is the availability of affordable computers which gave rise to computer-aided design (CAD) and control systems. As computer power grew and programming improved, AM technology rapidly advanced and, since the first commercial system was launched in 1986, AM has grown rapidly.

There are several AM technologies and they are typically categorised according to the motion system, feedstock and heat source they employ. Feedstocks are typically powder or wire, and heat sources are usually electron beams, lasers or electric arcs (see Figure 1). Each technology has strengths and weaknesses (see Figure 2), but in general they all aim to reduce part cost by reducing material wastage and decreasing time to market.

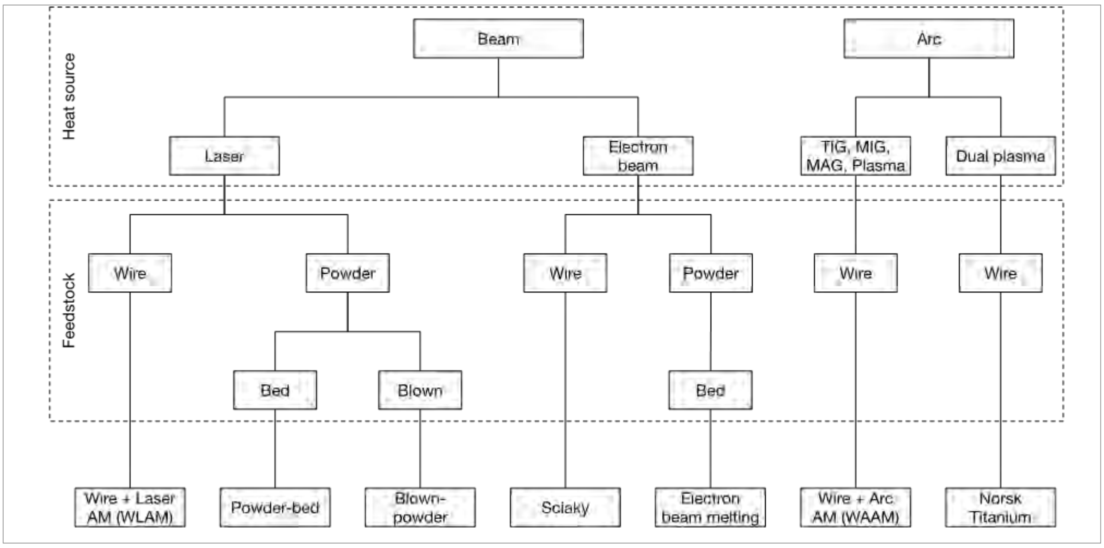


Figure 1: Comparison of additive manufacturing processes (Marinelli et al, 2017, first published in Bulletin #173)

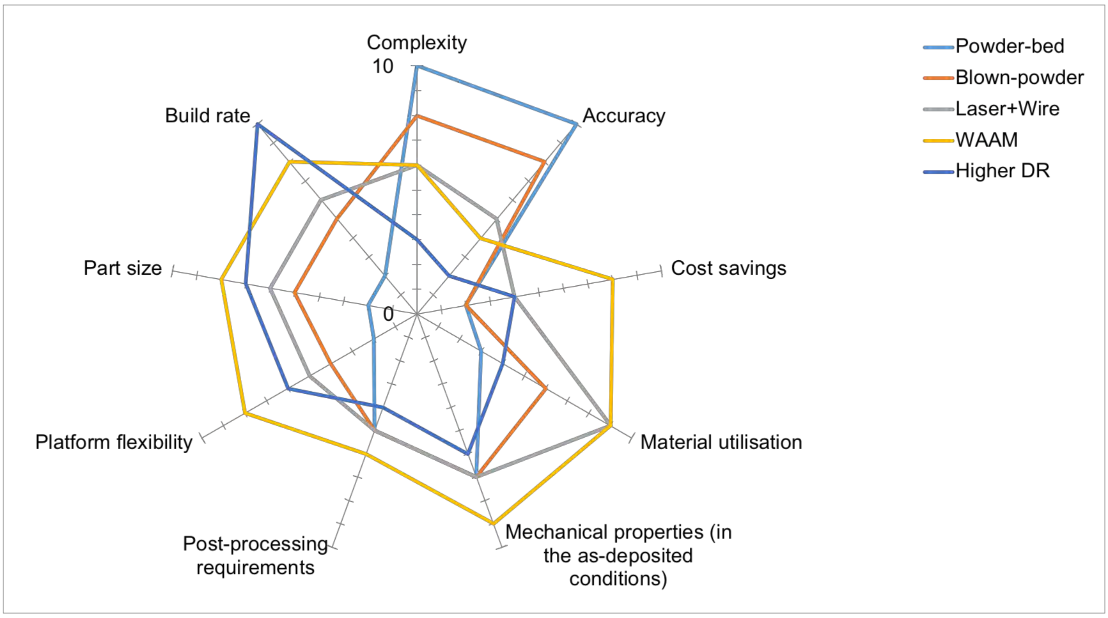


Figure 2: Comparison of additive manufacturing processes (Marinelli et al, 2017)

* For an excellent, detailed introduction to AM see “Introduction to Additive Manufacturing” by the European Powder Metallurgy Association (EPMA) available free to download at https://www.epma.com/epma-free-publications/product/introduction-to-additive-manufacturing-brochure.

Seeking tantalum and niobium at FORMNEXT

Finding out who is involved with tantalum and niobium in AM requires diligence, curiosity and time. Leaving aside the ~40% of exhibitors at FORMNEXT who focus exclusively on non-metallic AM, the majority of the metallic AM companies work on the ‘big five’ metal groups: titanium alloys, copper alloys, stainless steels, aluminium alloys and nickel alloys. Time and again technical staff would be happy to discuss the subject of refractory metals and how well they can work in AM, but then they would explain that they had so much business in the ‘big five’ metals that there were no resources for anything else.

However, with a bit more digging a subtly different picture began to emerge...

Tantalum and niobium in nickel-based superalloys for AM

AM technology has seen particular growth in the aerospace, automotive, medical (both surgical implants and dental applications) and tooling industries. In each of these industries there are existing applications for tantalum and niobium which could be impacted by AM, perhaps none more so than in aerospace.

The aerospace industry has invested vast sums in AM, attracted by the reduced buy-to-fly ratios on offer, reduced weight of redesigned parts and rapid prototyping. Two of the biggest names in AM owe their creation to makers of aerospace engines: GE Additive, part of General Electric, and Renishaw which was established by ex-Rolls Royce engineers.

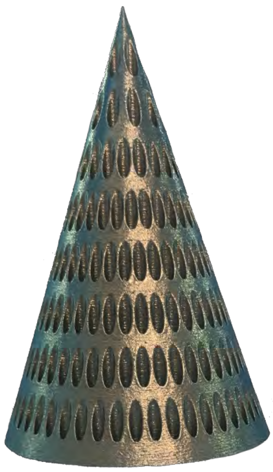
Nickel-based superalloys containing tantalum and niobium have a long history of use in aerospace applications and in the last decade several have become well-established as AM materials too.

GE Additive’s stand at FORMNEXT (photo: T.I.C.)

Of the nickel-based superalloys which are well understood in AM processes, three stand out: 247, 625 and 718.

%	Ni	C	Cr	Co	Mo	W	Nb	Ta	Ti	Al	B	Hf	Other
Mar M 247	base	0.16	8.2	10	0.6	10	-	3	1	5.5	0.015	1.15	0.05 Zr
Inconel 625	base	0.2	21.6	-	8.7	-	3.9	-	0.2	0.2	-	-	
Inconel 718	base	0.04	18	-	3	-	5.2		0.9	0.5	-	-	18.5 Fe

Table 1: Three nickel-based superalloys used in aerospace AM (sources: Aubert & Duval, Cannon-Muskegon)



A conic filter made of 718 alloy by Eramet / Volum-e (photo: T.I.C.)

A lobbed nozzle for a gas turbine engine made of 625 alloy by EOS (photo: T.I.C.)

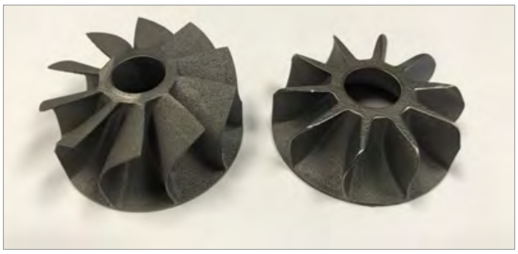
Many delegates at FORMNEXT reported that nickel-based superalloys, such as these, have become well established in the aerospace industry and are likely to grow significantly in the foreseeable future.

One exhibitor even predicted that demand for AM parts from aerospace was about to 'take off like a rocket' because so many parts are currently undergoing approval processes. While it is hard to say how this could impact the tantalum and niobium markets (increased demand weighed against more efficient manufacturing techniques), it was encouraging to see both elements being applied in AM applications with such vigour.

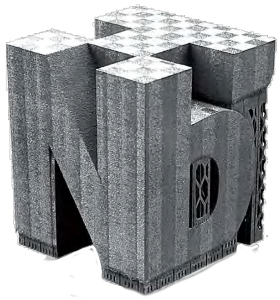
Companies at FORMNEXT that were talking about tantalum and niobium

Tantalum and niobium are specialist metals with particular applications, and so it shouldn't be surprising to discover that these elements should occupy niches in AM applications too; it just takes time to find them. During our non-exhaustive visit to FORMNEXT we found four companies which reported to be openly discussing tantalum and niobium, and the two most active were both T.I.C. members: H.C. Starck Solutions and H.C. Starck Tantalum & Niobium GmbH.

H.C. Starck Solutions (www.hcstarcksolutions.com) sees AM as a real "game changer" because it opens completely new possibilities for many industries. Applications where tantalum AM could provide an edge over traditional manufacturing include heat exchangers, rocket nozzles, dental applications and prosthetic implants. The company produces a range of powders for powder bed AM machines, including C103, pure Ta, NRC76, Ta10W, Ta3W. They have also developed a technique for screen printing with metal powders in which printing is done layer by layer pushing a UV-curable emulsion paste (containing metal powder) through a screen.



H.C.Starck Solutions's pure tantalum pump impellers (photo: H.C.Starck Solutions)



LBM printed with AMtrinsic® Ti-42Nb powder (photo: H.C. Starck Tantalum & Niobium GmbH)

H.C. Starck Tantalum & Niobium GmbH (www.hcstarck-tantalum-niobium.com) has recently introduced a new range of spherical tantalum and niobium AM powders called AMtrinsic®. This powder portfolio includes elemental Ta/Nb powders and ranges from binary over complex multinary to high-entropy alloys (with additional alloying elements like Ti, Zr, Hf, Mo, W, V, Sn or Al) also in customer specific compositions. Among others, fields of applications for AMtrinsic® powders include chemical process engineering, superconductive and aerospace applications as well as medical implants. For the latter market AMtrinsic® powders offer attractive alternatives to the current go-to implant alloys like Ti-6Al-4V (Ti 64). Alloys such as Ti/Nb/Ta or Ti42Nb have significantly higher biocompatibility and reduce mechanical mismatch between implants and human bone by optimizing the interplay of elasticity and tensile strength values.

Elementum 3D (www.elementum3d.com), formerly Sinter Print, is an AM research and development company that specializes in the creation of advanced metals, composites, and ceramics. They are actively researching tantalum and had several items on display (see the timer on page 16).

Sciaky, Inc. (www.sciaky.com) is a US-based manufacturer of metal AM printing systems and industrial welding systems. Their 'Electron Beam Additive Manufacturing'® (EBAM) technique uses wire fed into an electron beam to create near-net shape objects that are ready for machine finishing. While much of their business focuses on titanium and nickel-based alloys, they can also use tantalum wire and had items on display at FORMNEXT to prove it (see right).

Sciaky's tantalum chalice (photo: T.I.C.)

Summary

The AM industry is growing extremely fast and new applications are constantly being developed to take advantage of the opportunities it offers. There is considerable potential for tantalum and niobium in AM applications, both within nickel-based alloys and individually. While neither tantalum nor niobium are used extensively in AM at present, that could all be about to change. There is a wealth of evidence that tantalum and niobium are highly suitable for AM processes and many powder manufacturers confirmed they are technically able to produce spherical tantalum and niobium AM powders (e.g. TEKNA) whenever the demand appears.

At FORMNEXT there seemed to be a genuine belief that once the right application was found, our elements will quickly be adopted by the AM community. Serious investments are being made in finding AM applications for tantalum and niobium, with new powders constantly in development.

The time for tantalum and niobium in AM is just around the corner and T.I.C. is following developments with great interest. Watch this space!

Niobium in fuel cells

On November 7th the T.I.C. was invited to attend a seminar on niobium-based materials for advanced electrochemical energy storage and fuel cells hosted by CBMM at the University of Warwick, UK. Two presentations looked at fuel cells: by Dr Alex Martinez of Johnson Matthey Technology Centre, and by Dr Barr Zulevi of Pajarito Powder, LLC. This article draws from their presentations and also a presentation given by Ford Motor Co. et al (2017) available at www.hydrogen.energy.gov.

Much has been written in recent years about the potential mass-electrification of cars and other vehicles. All the major car manufacturers have announced plans to produce battery electric, hybrid-electric or plug-in hybrid electric vehicles in the foreseeable future and some countries and states have even set out ambitious targets to ban traditional vehicles from their roads altogether, including Norway (2025), Israel (2030), and California (2040).

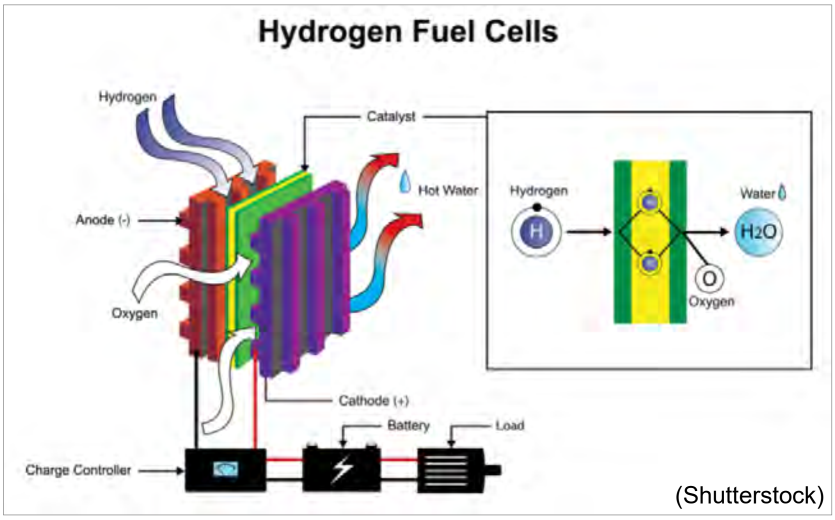
This has lead some industry commentators to forecast the end of the internal combustion engine altogether.

However, quite aside from the uncertainty of sourcing enough lithium and cobalt to make the batteries to support this paradigm shift away from petrol and diesel, there is an equally fundamental question regarding the infrastructure which would support a transport economy based on electric vehicles: a comprehensive network of charging stations will be needed because battery electric vehicles (BEVs) have a limited range.

A sign of the future?
(photo: Shutterstock)

Fuel cell-powered electric vehicles (FCEVs)

An alternative to BEVs is FCEVs, or fuel cell electric vehicles. Hyundai Motors, the South Korean automobile manufacturer is one of several industry leaders developing FCEVs. Toyota and General Motors have forecast that BEVs will likely dominate in personal mobility and light delivery vehicles, while FCEVs will be found in heavy trucks, longer range vehicles and for those operating in situations where charging stations are few and far apart.



(Shutterstock)

How a hydrogen fuel cell operates

i) hydrogen is dissociated and oxidized on the anode catalyst;

ii) the membrane carrying the catalyst conducts protons;

iii) the electrons are made to do useful work, such as powering a FCEV;

iv) oxygen is reduced on the cathode catalyst;

v) the protons and reduced oxygen are combined to produce water.

A fuel cell is only as good as its catalyst, and this is where niobium can play an important role.

Using niobium in fuel cells

Current state-of-the-art catalysts for fuel cells are comprised of platinum (Pt) nanoparticles on a high surface area carbon support. They are highly efficient, but over time they are susceptible to platinum dissolution and carbon support corrosion. Adding niobium oxide (NbO_x) to the support material can support and stabilize the catalyst material, producing a fuel cell that stays at peak performance for longer.

Niobium makes this possible because of its stability in acidic environments (fuel cells can be below pH 1) and resistance to oxidation up to 2.5 V. An additional potential benefit is that adding niobium oxide can decrease the amount of platinum required. At around USD 30,000 per kg, platinum is one of the more expensive metals and even a small reduction in use could result in considerable savings.

Although fuel cell electric vehicles are not widely used today, if their growth accelerates then niobium could play a key role in their progress going forward. TIC

Tantalum and niobium intellectual property update

This information is taken from the European Patent Office (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 / Publication #	Applicant(s)	Publication date

TANTALUM

Title / Publication #	Applicant(s)	Publication date
Tantalum chloride and method for producing tantalum chloride		
WO2019187836 (A1)	TOHO TITANIUM CO LTD [JP], JX NIPPON MINING & METALS CORP [JP]	2019-10-03
Memory element with a reactive metal layer		
US2019305047 (A1)	HEFEI RELIANCE MEMORY LTD [CN]	2019-10-03
Method and apparatus for preparing tantalum carbide powder		
KR102030007 (B1)	KOREA INST MACH & MATERIALS [KR]	2019-10-08
Flaked tantalum powder and preparation method thereof		
US2019308247 (A1)	NINGXIA ORIENT TANTALUM IND CO LTD [CN]	2019-10-10
Separator for lithium metal based batteries		
US2019319242 (A1)	GM GLOBAL TECH OPERATIONS LLC [US]	2019-10-17
Target and method for producing a target		
WO2019201795 (A1)	PLANSEE COMPOSITE MAT GMBH [DE]	2019-10-24
Lanthanum and calcium complex lithium tantalate producing method		
RU2704990 (C1)	FEDERALNOE GOSUDARSTVENNOE BYUDZHETNOE UCHREZHDENIE... [RU]	2019-11-01
Cemented carbide material		
US2019345589 (A1)	ELEMENT SIX GMBH [DE]	2019-11-14
Method for manufacturing bone staples		
WO2019226248 (A1)	HUANG STEVE X [US]	2019-11-28
Medical member and method for treating soft tissue		
US2019358021 (A1)	NIPPON PISTON RING CO LTD [JP]	2019-11-28
Bismuth chlorofluorotantalate, preparation method therefor and use thereof		
WO2019227538 (A1)	ZHANGJIAGANG INSTITUTE OF INDUSTRIAL TECH. [CN], UNIV SOOCHOW [CN]	2019-12-05

NIOBIUM

Title / Publication #	Applicant(s)	Publication date
System and method of concentrating niobium ore		
AU2018247578 (A1)	ALEY CORP [CA]	2019-10-03
Electrode group, battery, and battery pack		
WO2019187131 (A1)	TOSHIBA KK [JP]	2019-10-03
Molybdenum-vanadium-tellurium-niobium-based ODH catalyst calcination process		
WO2019186329 (A1)	NOVA CHEM INT SA [CH]	2019-10-03
Pipe of oil grade from corrosion-resistant steel of martensitic class		
RU2703767 (C1)	PUBLICHNOE AKTSIONERNOE OBSHCHESTVO TRUBNAYA… [RU]	2019-10-22
High refractive index titanium-niobium phosphate glass		
US2019322571 (A1)	CORNING INC [US]	2019-10-24
Self-stressing shape memory alloy-fiber reinforced polymer patch		
US2019330849 (A1)	UNIV HOUSTON SYSTEM [US]	2019-10-31
High strength titanium alloys		
US2019338397 (A1)	ATI PROPERTIES LLC [US]	2019-11-07
A nickel-based alloy		
WO2019215450 (A1)	OXMET TECH LIMITED [GB]	2019-11-14
Additive for laser-markable and laser-weldable polymer materials		
US2019351622 (A1)	MERCK PATENT GMBH [DE]	2019-11-21
Nickel-base superalloy		
US2019360077 (A1)	ROLLS ROYCE PLC [GB]	2019-11-28
Synthesis of a MoVNbTe catalyst having a reduced niobium and tellurium content ...		
EP3576873 (A1)	CLARIANT PRODUKTE DEUTSCHLAND [DE]	2019-12-11

Director's Notes

London, UK

Dear T.I.C. Members,

Welcome to the first Bulletin of 2020 and our updated design which I hope you'll agree is clearer and easier to navigate. The new look to the Bulletin is the first step in a process which will see our website, the Bulletin and our other publications become more easily accessible, searchable and integrated over the coming months.

This is part of a strategy to increase awareness and promote the remarkable properties of tantalum and niobium both among members and the wider stakeholder community.

It is our longer-term goal to create an online database of tantalum and niobium information, weaving the T.I.C.'s knowledge resources and extensive historical records together to offer a single knowledge platform for members to access at their leisure.

Hong Kong container port: the best GA field trip ever, according to some delegates (photo: Shutterstock)

On a different subject, it was very good to catch up with so many members at our 60th General Assembly in Hong Kong. The event was a great success and my sincere thanks to all members who participated in the AGM, providing the T.I.C. with the guidance and mandate for the year ahead.

Our annual light-hearted vote on which presentations delegates found the most technical and most entertaining produced a lot of feedback, with most votes going to:

- Most technical: **3D-printed porous tantalum** by Professor Tang Huiping, Xi'an Sailong Metal Materials Co. Ltd , presented by Dr Wang Hui.
- Most entertaining: **Trends and new challenges: how future technologies may impact tantalum- and niobium-based capacitors,** written and presented by Tomáš Zedníček Ph.D., European Passive Components Institute (EPCI)

Their prize will be a copy of "The Elements" by Theodore Gray, a beautiful illustrated guide to the periodic table. Presentations from the 60th General Assembly are available for members to download from www.TaNb.org.

Anders G. Ekeberg's renovated grave (right) and how it was in September 2018 (above) (photos: Thomas Fredengren, Uppsala University; T.I.C.)

Which only leaves me to praise the renovation work on Anders Gustaf Ekeberg's grave by Uppsala University. It's a big improvement since my visit there in 2018 (when it was sorely in need of some care and attention) and a fitting commemoration for the discoverer of tantalum*.

Best wishes for the year ahead,

Roland Chavasse,

Director

* further information from the Swedish Church in Uppsala https://kulturpersoner.uppsalakyrkogardar.se/en/anders-gustaf-ekeberg/

tarantula

41 Nb niobium | 73 Ta tantalum | 74 W tungsten

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 tech@tanb.org.

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

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

- Mining Indaba, Cape Town, South Africa, February 3rd to 6th 2020
- Argus Metals Week, London, UK, February 17th to 19th 2020
- OECD Forum on Responsible Mineral Supply Chains, Paris, France, April 7th to 9th 2020
- MIRU Tantalum Summit, Tokyo, Japan, April 17th 2020
- MMTA International Minor Metal Conference, Charleston, South Carolina, USA, April 22nd to 24th 2020
- IAEA's 40th TRANSSC meeting in Vienna, Austria, June 1st to 5th 2020
- Tarantula (Month 12), Salamanca, Spain, June 4th to 5th 2020
- Preparing for the EU 'conflict mineral regulation' with Levin Sources, London, UK, June 23rd 2020
- **T.I.C.'s 61st General Assembly and AGM in Geneva, Switzerland, October 11th to 14th 2020**
- 4th Space Passive Component Days, Noordwijk, The Netherlands, October 13th to 16th 2020
- International Conference on Managing NORM in Industry, Vienna, Austria, October 19th to 23rd 2020

* correct at time of print

Member company updates

Successful applications for membership

At the 60th General Assembly the following corporate membership applications were approved: ArrowMetals Asia Pte Ltd, Chepetsky Mechanical Plant ("ChMZ"), Globe Metals & Mining Ltd, Hunan Huaran Technology Co. Ltd, Jiangxi Dinghai Tantalum & Niobium Co. Ltd, RFH Recycling Metals Co. Ltd and SXMINTEC ("SMT"). There were no associate membership applications. Full details of the new member companies can be found on page 5.

Transfers of membership

At the 60th General Assembly the following membership transfer was approved: from **CNMC Ningxia Orient Group Co. Ltd** to **Ningxia Orient Tantalum Industry Co. Ltd**. The delegate is Mr Jiang Bin and he can be contacted on jiangb_nniec@otic.com.cn. The company address is 119 Yejin Road, Dawukou District, Shizuishan City, Ningxia 753000, China, and the website is www.otic.com.cn.

Changes in member contact details

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

- **Guangdong Rising Rare Metals-EO Materials Ltd** has moved office to 2 Kaifa Avenue, South District, Qingyuan Huaqiao Industrial Park, Yingde, Guangdong Province, 511500 China.
- **Jiujiang Tanbre Co. Ltd**: The new delegate is Mr Feng Meibing. He can be contacted at fengmeibing@jjtanbre.com.cn. All other details remain unchanged.
- **Niobras Mineração Ltda**: The new delegate is Mr Robert Sidders. He can be contacted at robert.sidders@ixmetals.com. All other details remain unchanged.
- **NPM Silmet OÜ**: The new delegate is Ms Julia Ignatova. She can be contacted at j.ignatova@neomaterials.com. All other details remain unchanged.
- **RFH Recycling Metals Co. Ltd**: Mr Gu Mingdao has a new email address, gumingdao@rfh-metals.com.
- **Roskill Information Services Ltd:** The new delegate is Ms Jessica Roberts, jessica@roskill.com.

Terminations of membership

The Executive Committee terminated the following company's corporate membership due to non-payment of membership invoices: King-Tan Tantalum Industry Ltd.

Resignations of membership

The following corporate members resigned from the Association at the 2019 AGM: AMR Gold Ltd, Better Sourcing Program (BSP), Ethiopian Mineral, Petroleum and Biofuel Corporation (EMPBFC), Global Advanced Metals (GAM), Mineração Taboca S.A., Mitsubishi Corporation RtM Japan Ltd, New Material Corporation and Société Minière de Bisunzu (SMB).

The art of tantalum and niobium

It is well known in our industry that tantalum and niobium metal can present a range of different colours by thickening the normally transparent native oxide layer, but what happens when this characteristic is used to create art?

James Brent Ward is a pioneering artist working with tantalum, niobium and titanium and is author of the seminal text “The Colouring and Working of Refractory Metals”. Here he shares some of his latest niobium and tantalum creations with us.

No paints or pigments were used at all in these pieces. The apparent colouration is solely created by manipulating the thickness of the oxide layer.

In the next Bulletin we will discuss how it is that tantalum, niobium, titanium and other refractory metals exhibit interference colours when their surface oxide layer is a certain thickness.

Further examples of Mr Brent Ward’s work can be found at The Goldsmith’s Company
www.thegoldsmiths.co.uk

Image credits to James Brent Ward and Roy Pritchard.