MRI: saving lives with niobium

(see page 12)
President’s Letter

Dear Fellow Members and Friends,

As we are starting to experience the joys of summer here in the northern hemisphere, it’s encouraging to see that overall markets for tantalum and niobium appear to be moving in a positive direction.

Your Executive Committee (or ExCom) is acutely aware of trying to offer our members value for money. Although a substantial deficit of over Euros 74,000 for 2017 was budgeted and approved at last year’s General Assembly in Toulouse, this direction was decided by the ExCom in light of our current strong balance sheet. Moreover, I am happy to report that the ExCom has decided not to increase the annual dues for 2018. While further details will be provided in Vancouver this October, we will have a deficit next year as well.

The T.I.C. has several ongoing initiatives, with an important one being in the supply chain area, particularly our ongoing efforts to improve the International Tin Supply Chain Initiative (or iTSCI Programme) in central Africa. As we believe sunlight is the best disinfectant, we are seeking to improve its transparency. You will therefore find an interesting article on its finances on page 6 of this Bulletin.

The topic of supply chain regulations, particularly of conflict minerals, is a never ending one and we continue to closely monitor this area. There are ongoing changes in the US, such as the suspension of Section 1502 of the Dodd-Frank act by the US Securities and Exchange Commission, but also by other government players there as well. At this stage, it’s difficult to predict where US regulations in this area will end up. The EU is taking a different tack and I am gratified to tell you that we will have a presentation on this in Vancouver.

During the course of this year, we have highlighted the issue of radioactivity, especially the transport of naturally occurring radioactive materials (or NORM). May I take this opportunity to remind all our members dealing with such materials to adhere to our transport policy of such, adopted in New York in October 2014. As part of our educational efforts on this topic, please note an article on this, starting on page 10. On a related note, several of our members have recently encountered shipping issues in this area and T.I.C. staff is investigating. If you have any questions or concerns in this area, you are encouraged to contact David Knudson, our Technical Officer.

Preparations for the 7th Technical Symposium in Vancouver are well underway. You will see, starting on page 18, that we have lined up what I believe to be quite a range of outstanding topics, presentations, and panel discussions. I look forward to meeting each of you there.

Finally, may I please ask each of our corporate members to consider volunteering to help improve our organization? In Vancouver, as we will have at least one vacancy on the ExCom, you might think about putting yourself forward as a candidate, for example. Further details on this will be issued later this summer, as there is a 16th September deadline for such submission (i.e. 30 days before the General Assembly starts). There are also various subteams, which you might be interested in joining, including Meetings, Marketing, Statistics, and Supply Chain.

Sincerely yours,
David Henderson
President

The T.I.C. Executive Committee meeting in Dublin, Ireland, in April 2017. (photo: T.I.C.)
Dear T.I.C. Members,

Standing in the baking heat at the Paris Air Show watching the vast Airbus A380 glide quietly across the sky, followed by a bone-shaking F-35 jet thundering past, low and fast, is to watch niobium and tantalum applications at the limits of human ingenuity; the modern jet engine is an object of supreme complexity made possible by a small handful of elements, including ours.

The air show was my second visit to Paris this quarter, the first having been to represent the Association at the OECD’s Forum on Responsible Mineral Supply Chains. These were two very different events but both told powerful and positive stories about our elements; one demonstrated how they are essential to modern technology, and the other showed how our industry can work together to overcome significant challenges.

It is sad, but true, that good news doesn’t sell newspapers or gather ‘likes’ as quickly as reports of murder and mayhem, and something I’ve heard from many members since I joined the T.I.C. last year is that historically we have fought negative myths hard but then fell short when promoting a positive narrative about industries. The benefits of niobium and tantalum are everywhere; they have made vast contributions to human health, safety and happiness, they have saved lives, minimised environmental impacts and given us essential and affordable gadgets.

Promoting positive messages about niobium and tantalum is something that the Executive Committee and I are passionate about and it is therefore with real pleasure that this Bulletin explores MRI, a life-saving technology that makes an immeasurable contribution to saving lives and improving human health. There are literally millions of people who are still alive today because of MRI, and this achievement is possible thanks to niobium-based superconductors.

Building bridges

This quarter your T.I.C. team has been on the road more than ever before, building bridges with key stakeholders, attending conferences and promoting the Association’s interests (see left). This included my colleagues David Knudson attending the Powdermet conference on additive manufacturing (3D printing) and Emma Wickens joining STRADE’s seminar on European raw materials. We are always keen to promote niobium and tantalum to new audiences so please let us know about events that you think we should attend.

Websites, emails and faxes

In other news, we have invested to upgrade both the T.I.C.’s main website (www.TaNb.org) and the online statistics database hosted by Miller Roskell Ltd, the 100% independent accountant who gathers and aggregates members’ data. Both websites are now on https protocol to improve security and have had minor redesigns to improve usability (see p.11 and p.27).

Also, each T.I.C. staff member now has an email based on their name (see page 27). This is to avoid the historic “info” address getting caught in recipients’ spam filters, including at T.I.C.’s lawyer. The historic emails will continue to work indefinitely and you may use either to contact us.

Finally, in the last few years the number of faxes we have received has fallen to around four per year. As a result our fax number (+32 2 649 6447) has been switched off and the number will join our telex line in digital retirement. Please delete this fax number from your records.

Best wishes,

Roland Chavasse, Director

Le Bourget Airport, Paris, France

The Airbus A380: a giant of the skies
(photo: T.I.C.)

F-35: a very noisy stealth aircraft
(photo: T.I.C.)

T.I.C.’s Director Roland Chavasse meeting Ethiopia’s State Minister of Mines, the Honourable Tewodros Gebre-Egziabher.

T.I.C.’s Technical Officer, David Knudson, with Trevor Dixon of World Nuclear Transport Institute (WNTI).
In 2007 when Emma Wickens took on the role of Secretary General, the T.I.C. was in a very different place than it is today. The storm surrounding tantalum was at full strength and a steady hand was needed to help the Executive Committee steer the Association through the choppy waters. It is a testament to Emma’s decade of dedicated service to the Association that the T.I.C. today is in a stronger position than it was when she arrived, allowing the T.I.C. to face the future with confidence.

Emma is a chemical engineer by training and prior to joining the T.I.C. she worked at the plastics division of Cabot Corporation in Belgium where she specialised in Conductive Applications (electrically conductive carbon black and compounds), rising from Technologist to Technical Manager within the R&D department. Emma’s technical background is perhaps one reason why she has enjoyed working at the T.I.C. for so many years.

Upon arrival at the T.I.C. in July 2007 Emma immediately took control of organising the 48th General Assembly, which was to be held less than 4 months later in Rio de Janeiro, Brazil, a country she had never visited before. Having survived this trial by fire she has not looked back.

Emma is the first point of call for many people when they contact the T.I.C. and this is especially true when it comes to arranging the General Assembly, our annual general meeting (AGM) and technical conference. The success of our conferences over the years is almost entirely down to Emma’s organisational skills and her commitment to creating unique and special events for our community. This year’s event, in Vancouver, Canada, promises to be among the best yet (see also p.18*).

The T.I.C. is registered under Belgian law as an international not-for-profit association (an AISBL) and as such the figure of Secretary General, as stipulated in our Charter of Association, is central to the Association. Emma is the third Secretary General and the second longest-serving. The first, Mrs Jan Goodyear, served from our inception in 1974 until 1977 when she moved abroad, and she was followed by Mrs Judy Wickens who served for 30 years, until her retirement in 2007.

Emma Wickens is a great asset to the T.I.C. and long may she continue in the role. Emma, thank you. TIC

* https://www.tanb.org/event-view/58th-general-assembly

(left to right) Luc Houben, T.I.C.’s legal counsel, former President Richard Burt and Emma Wickens at the 51st General Assembly at Lake Tahoe, NV, USA, in 2010. (photo: Niotan)

Ms Emma Wickens, Secretary General to the T.I.C. since July 2007, holding a hunting eagle in Almaty during the 52nd General Assembly in 2011. (photo: Ulba)

Emma (right) with Mr Razman Griffin, Mr David Henderson, Mr Chua Cheong Yong and Mr Raveentiran Krishnan visiting Malaysia Smelting Corporation during the 56th General Assembly in 2015. (photo: MSC)
Hello, and greetings from Rwanda!

On arrival in Kigali it is very quickly clear why Rwanda is called the "land of a thousand hills". My first few days here have been spent meeting the field office of the iTSCI Programme, inspecting mineral processors and visiting artisanal tantalite mines as part of T.I.C.’s work on the iTSCI Governance Committee. I’ve also visited hotels that could be potential future General Assembly venues (there are several excellent options). But once business had been taken care of, it was time to focus on the serious matter of tourism, and I must thank our local members, Cronimet Central Africa AG and the Rwanda Mining Association, for being such good hosts during my time here.

Gorillas and other wildlife

The crown jewels of Rwandan tourism are the mountain gorillas that live in Volcanoes National Park. It is estimated that Rwanda is home to one third of the world’s remaining mountain gorillas, and the country also has sizeable populations of chimpanzees, hundreds of bird species, and also big game in the Akagera National Park.

Food and drink

Rwandan cooking includes a lot of sweet potatoes, beans, corn, peas, millet, plantain, cassava, and fruit. Chicken and goat (delicious!) are popular and beef is increasingly available too. Rwandan food is neither especially spicy nor hot, unless you decide to add some akabanga chilli oil, which is liquid fire.

Rwanda grows world-class coffee, although I found Rwandans often preferred tea served with honey, milk and ginger that is wonderfully refreshing. After work there are several good local beers to choose from, with Virunga Mist and Mützig standing out. Mützig is brewed to a German recipe and is perfect after a day on the road.

Getting to Rwanda

Kigali airport is well served by international flights and has direct flights from many major hubs, including London Brussels, Dubai, Istanbul and Johannesburg. Once in Kigali taxis are everywhere and getting around the city is cheap and efficient. The city really is remarkably safe and young international backpackers commonly walk around alone.

If you get the opportunity to visit Rwanda then I recommend that you do; you'll not be disappointed!

Roland
iTSCI in focus: lifting the lid on finances

The iTSCI Programme aims to work within the OECD’s framework and to comply with the UN guidelines to create a system that assists companies with traceability, due diligence and audit requirements that arise from purchasing 3T minerals, particularly from the DRC, Burundi, Uganda and Rwanda. The T.I.C. and ITRI sit on the iTSCI Governance Committee; there is also a third (vacant) seat for a tungsten representative.

The iTSCI Programme has seen significant growth since the first pilot project was started in 2010; more mines to monitor, more processors to assist, more tags to monitor, more administration and inevitably more costs. Rigorous financial management is vital to the success of the Programme. Its costs are covered by four main sources of income: levies on minerals, iTSCI membership fees, donor payments for field implementation (for example, from the Dutch Ministry of Foreign Affairs (MFA)) and direct payments.

Although the day-to-day financial management, such as liaising with subcontracted field implementers, is the responsibility of the iTSCI Secretariat (a role performed by ITRI), the Governance Committee receives monthly budget updates and forecasts since several of its functions have a financial dimension, including the review and change of joining fees, membership fees and the mineral levies, and also to agree an appropriate cost-sharing mechanism between the three minerals.

Although legally iTSCI is a division of ITRI Ltd (a company registered in England and Wales), iTSCI is financially separate with its money held in trust in unique accounts that are not used for ITRI’s non-iTSCI funds. Accounts for iTSCI and ITRI are audited each year by Rayner Essex LLP, an independent chartered accountant.

Each year iTSCI publishes summary financial information and a statement from the auditor. This is a summary of the latest report, for the financial year January-December 2016:

All figures are in 000 of US Dollars ($)  

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<tr>
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<th>2016</th>
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<td>Upstream member fees</td>
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<td>Upstream direct payments</td>
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<td><strong>TOTAL</strong>²</td>
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<td><strong>Sub-total via ITRI</strong></td>
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<td>Secretariat</td>
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<td><strong>TOTAL</strong>³</td>
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<td><strong>Sub-total via ITRI</strong></td>
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iTSCI’s growth is clearly seen in the financial reports 2011-2016 (the apparent dip in 2014 is down to changes in accounting procedure and timing of invoices). Note that all information provided in this article is publicly available⁴.
All figures are in 000 of US Dollars ($)

### Funding

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### Expenses

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### Notes

1. “Donation/other” mainly resulting from sterling-dollar exchange rate change following Brexit. Also includes US$161,000 from EICC and some member companies following discussion on fair sharing of costs associated with more responsible production.

2. ‘Total’ includes MFA donor funding directly to Pact for ‘Scaling up Traceability’ objective 1 relating to extension of due diligence and traceability; [http://www.pactworld.org/projects/scaling-itsci](http://www.pactworld.org/projects/scaling-itsci).

3. In 2015 the Programme suffered a large loss. In 2016 bad debts were US$158,625 and 2016 annual surplus was US$1,411,773 resulting in an on-going programme balance of US$1,790,372 (equivalent to 4 months’ operating reserve).

4. The following reports are publicly available online from the iTSCI Programme:
   - 2015 at [https://www.itri.co.uk/index.php?option=com_mtree&task=att_download&link_id=55620&cf_id=24](https://www.itri.co.uk/index.php?option=com_mtree&task=att_download&link_id=55620&cf_id=24), and

5. Expenses associated with donor contributions are managed directly by Pact and not via ITRI. Such expenses are included in the total figures but excluded from the sub-total shown for expenses managed via ITRI.
The Charles Hatchett Award: Promoting excellence in niobium

The Charles Hatchett Award, named after the first person to identify the element niobium (or columbium as he called it), was originally conceived in 1977 by Companhia Brasileira de Metalurgia e Mineração (CBMM) to be an annual award that recognised the best published scientific or technical paper relating to the metallurgy of niobium. This first Bulletin article looks at this prestigious prize where we examine the origins of the Charles Hatchett Award and how it has developed since the first prize was awarded in 1979.

About Charles Hatchett

Charles Hatchett was born in London, UK, in 1765 to a family of successful coachbuilders. From an early age, he was fascinated by the chemistry of minerals and the elements they contained. At 35 years of age, he established a small chemical plant in Chiswick, on the outskirts of London and this meant he was often consulted by the British Museum when specimens of newly discovered minerals arrived from around the world.

In 1801, a batch of samples arrived for analysis that included what Hatchett described as “heavy black stone with golden streaks” found near New London, in eastern Connecticut¹, USA. The sample had been sent to the British Museum by one of its regular contributors, Mr John Winthrop, who was the first Governor of Connecticut and a part-time alchemist, physician, and rock collector.

Hatchett’s analysis of the sample quickly determined that while the “golden streaks” were common mica, the black mineral was highly complex and contained a previously unidentified element. Throughout the summer of 1801, Hatchett experimented to rule out the possibility that it was any other known element and in November he announced his discovery of a “new earth” before the Royal Society. Hatchett chose to name the element columbium (Cb) after Christopher Columbus, as a tribute to the American location where the mineral had been found.

Today, despite having his element renamed niobium (Nb) some 43 years later by the German chemist Heinrich Rose, the legacy of Charles Hatchett lives on and there can be no doubt that he would be pleased to know future generations of metallurgists are continuing to study element 41 so many years later.

The Charles Hatchett Award

The Charles Hatchett Award was originally conceived at a meeting in 1977 between Friedrich Heisterkamp, the then Head of the European Office of CBMM, Dr. Malcolm Gray, technical adviser to CBMM’s niobium technical development programme and Dr. Bob Keown OBE, who was an independent metallurgical consultant to CBMM.

A proposal was put to the Metals Society to request they administered the Award on behalf of CBMM. This proposal was approved and the first Award was presented in May 1979. The first recipients of the Award were Gil Speich and Don Dabkowski of US Steel’s Research Laboratory in Monroeville, USA, for their paper: Effect of Deformation in the Austenite and Austenite-Ferrite Regions on the Strength and Fracture Behaviour of C, C-Mn, C-Mn-Cb and C-Mn-Mo-Cb Steels, Proceedings of The Hot Deformation of Austenite Conference, American Institute of Metallurgical Engineers, (1979), p.557-579.

¹ - The precise source of the samples is unknown and may have actually been in southern Massachusetts.
The 2016 Award

The 38th annual Award, sponsored by CBMM, was awarded to a team from Brunel Centre for Advanced Solidification Technology (BCAST) at Brunel University, UK, for their work on the use of niobium as a grain refiner in cast aluminium alloys. The technique they described allows the manufacture of lighter aluminium parts, contributing to lowering the overall weight of vehicles, reducing fuel consumption and emissions.

Over the last 20 years significant progress has been made in vehicle light-weighting through the use of advanced high strength steels, allowing automotive manufacturers to meet increasingly stringent vehicle emission targets. Further progress in this area will require the use of other light-weight materials, including aluminium alloys.

To maximise the benefits available from the use of cast aluminium components it is important to optimise strength levels and minimise property variability. This can be achieved by refining the microstructure in the cast product.

Marcos Stuart, CBMM’s Director of Technology also noted “This international award is part of our activities to recognise excellence in research on niobium and its applications. There is no single solution to vehicle light-weighting, the important thing is to have the right material in the right place. There are technical and cost challenges to the adoption of large aluminium alloy castings, such as engine blocks, which include efficiently filling the moulds during the casting process. The Nb-B inoculant refines the grains, improving the fluidity of the material being cast, and therefore making it easier to completely fill the moulds, leading to a higher integrity product. It is now up to the supply chain to act to ensure the adoption of this exciting new technology”.

Looking ahead

Over the years recipients of the Charles Hatchett Award have included many of the leading metallurgists of the late twentieth and early twenty-first centuries, establishing the Charles Hatchett Award as the undisputed international benchmark for published research and development on niobium.

Since 1979 winning papers have come from 12 different countries and the dominant topic has been that of High Strength Low Alloy (HSLA) or Microalloy Steels. Most Awards have involved multiple authorship, except when Professor K.K. Schulze was the single author of the 1983 Award. Only one person, Wolfgang Bleck, has won the Award twice, in 1990 and in 2001. In 2008, to mark the 30th anniversary of the Award, a new Lifetime Achievement Award was initiated to recognise long-term commitment to niobium metallurgy.

The Charles Hatchett Award is sponsored by CBMM and managed by Beta Technology Ltd.

Further information about the Charles Hatchett Award, including information about past winners and how to submit your research for consideration, can be found at http://www.charles-hatchett.com/ or by visiting CBMM’s website http://www.cbmm.com.br/.

In Bulletin no.171 we shall report on the Award’s 2017 winning paper.
Transporting NORM: exemption levels and conversion factors

Recently the T.I.C. published a booklet on transporting naturally occurring radioactive materials (NORM, available at https://www.tanb.org/view/transport-of-norm). Raising the awareness of this issue with both industry and the public, while keeping potential risks in context, is an important part of any NORM transport strategy. The T.I.C.’s Transport Policy is that members strive to comply with international, national and local regulations governing the safe and secure transport of radioactive materials. Here Ulric Schwela of Salus Minerals Ltd, a NORM consultancy, explains how exemption levels were decided and how to work out conversion factors with regard to a sample of tantalum- or niobium-containing minerals.

Exemption Levels

Some niobium (Nb) and tantalum (Ta) raw materials contain traces of thorium (Th) and uranium (U) and are therefore naturally occurring radioactive materials (NORM). Wherever materials contain natural thorium (Th) and/or uranium (U), it becomes necessary to measure how much is present, as their radioactivity can present a hazard if the host materials are handled inappropriately.

As thorium and uranium are naturally present in the world around us, exemption levels have been set for those materials for whose thorium and uranium content is sufficiently low as to be of no regulatory concern. Materials with thorium and uranium levels below the exemption level may therefore be shipped without needing to comply with Class 7 requirements.

These exemption levels are set by the regulatory body the International Atomic Energy Agency (IAEA), based in Vienna, and the levels set for transport are listed in the document SSR-6 of 2012 (available at: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1570_web.pdf).

The levels for thorium and uranium have not changed since 1996, when isotope specific levels were first introduced. Each radioactive isotope has its own exemption level listed, and natural thorium and uranium each have their entry as “Th (natural)” and “U (natural)” respectively.

While natural thorium is present as one isotope, Th-232, it does also have a chain of decay products, a process by which each thorium atom converts to stable (non-radioactive) lead. Natural uranium consists of two isotopes: U-235 being 0.72% of natural uranium by mass, while U-238 forms 99.28%, and each of these forms its own series of radioactive decay chains just like thorium. The IAEA simply lists the parents and their decay chains as “Th (nat)” and “U (nat)”. Note that while U-234 is also naturally present in uranium, it is a daughter of U-238 and is therefore already accounted for in the exemption values; if U-234 was considered separately, it would be counted twice.

| Table 1: Parent and daughter radionuclides for “Th (natural)” and “U (natural)”.
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Th-natural: Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64).</td>
</tr>
</tbody>
</table>

(source: IAEA Safety Standards, SSR-6, page 45)

The exemption levels for radioactivity concentration are set in units of Becquerels per gram (Bq/g), and these refer to the parent radionuclide only.

This is noted in SSR-6 in Table 2 Footnote (b) (page 45), which states “Parent nuclides and their progeny included in secular equilibrium are listed in the following:” (see Table 1, left).

The interpretation of this footnote was confirmed to the author in 2002 by a senior IAEA representative and has since been reconfirmed on numerous occasions by IAEA experts and other NORM professionals.

Where the radioactivity concentration of thorium and uranium can be measured directly (e.g. by gamma spectroscopy) the resulting figures in Bq/g can be compared directly against the exemption levels for Th (natural) and U (natural).
Should only thorium or uranium be present, the comparison is straightforward. If both are present, Para. 405 in SSR-6 states that a formula should be applied to determine the exemption level for such ‘mixtures’. In practice, given that the exemption level for Th (natural) and U (natural) are the same, the exemption level for that ‘mixture’ is the same as for either the thorium or uranium.

It is not necessary to use the paragraph 405 formula when only dealing with Th and U in secular equilibrium with the decay chains, as noted in the last sentence of para 107 (f). Instead the radioactivity concentration for Th and U is simply combined before comparing against the exemption level, as comparing each result separately for Th and U would effectively double the exemption level. The full exemption level for each radionuclide assumes that there are no other radionuclides present.

Conversion Factors

Where the radioactivity concentration for thorium and uranium can not be measured directly, it is possible to convert chemical assays in % or ppm of Th or ThO₂, and U or U₃O₈, to the radioactivity concentration in Bq/g. The conversion factors are based on the specific activity of the natural radionuclides Th-232 for thorium, and U-235 and U-238 for uranium, only. The specific activities for Th-232, U-235 and U-238 are fixed properties of those radionuclides. The values can be found in various literature or calculated from the half lives, and are:

- Th-232: 4055 Bq/g
- U-235: 80000 Bq/g
- U-238: 12300 Bq/g

For each radionuclide above, the specific activity is for 100% pure material, therefore the conversion factor for a given percentage is 100 times less.

For thorium this is:

\[ \text{Th [rad.act.]} = 40.6 \ \text{Bq/g per} \ % \ \text{Th} \]
\[ \text{Th [rad.act.]} = 35.6 \ \text{Bq/g per} \ % \ \text{ThO₂} \]

For uranium a weighted average is calculated to account for the natural ratio of U-235 to U-238, i.e. 0.72% and 99.28% respectively. This gives:

- U [rad.act.] = 123 Bq/g per % U
- U [rad.act.] = 104 Bq/g per % U₃O₈

These conversion factors were first established by the UK’s National Radiological Protection Board in the late 1990s and have subsequently been checked by the Transport Safety Unit at the IAEA and endorsed as a tool for determining the radioactivity concentration of NORM containing thorium and uranium for the purpose of checking against the exemption values in the transport regulations.

Update to the T.I.C. website

At the start of July the T.I.C. website (https://www.TaNb.org/) was updated to improve its usability and security.

Key changes:

- The log in area is now at the very top of the page.
- The site is now https rather than http, for increased security.
- The colour scheme and design have been updated slightly to be more in line with the current ‘material-design’ practice of website design.

We hope that you agree that these changes improve the site, but please ask if you have any questions. Over the next twelve months the team will be overhauling, improving and adding content throughout the website. If you have any feedback or suggestions for improvements/additions please contact a staff member today.
Magnetic resonance imaging (MRI): an introduction

Following our obituary of MRI pioneer Sir Peter Mansfield in Bulletin no.169, here Roland Chavasse looks in more detail at this remarkable, lifesaving technology. Unfortunately, due to space constraints this article is not able to discuss the history and wider applications of superconductors in detail, but this will be examined in a future Bulletin.

Introduction

Magnetic resonance imaging (MRI) makes an immeasurable contribution to saving lives and improving human health. Every day MRI machines help medical professionals save and improve countless lives around the world. There are millions of people who are still alive today as a direct consequence of MRI, an achievement made possible by niobium-titanium superconductors.

MRI is used in hospitals as a precise and non-invasive diagnostic tool to examine patients. It is widely used in the diagnosis of cancers, neurological and cardiac disorders because, unlike conventional radiography (x-ray) and computed tomography (CT) scanning, MRI imaging techniques do not expose patients to potentially harmful ionising radiation. The market is growing steadily and today there are some 36,000 MRI machines in hospitals and medical centres around the world.

MRI is a radiology technique that uses magnetism, radio waves and a computer to create images. The principles behind it were once elegantly described by the legendary Danish physicist Niels Bohr in the following way: “They put little spies into the molecules and send radio signals to them, and they have to radio back what they are seeing”. It is a summary that is hard to improve.

The science behind MRI is nuclear magnetic resonance (NMR) which describes how the protons and neutrons in an atom do not behave like the clusters of small balls as is taught in schools, but more like “gyroscopes that spin about their axes in random directions, generating their own minute magnetic fields”¹. If one can measure those magnetic fields then it becomes possible to know what type of atom is at that one-dimensional point. NMR first changes the orientation and energy level of atoms by placing the sample in a strong magnetic field and exciting them with a pulse of radio waves. Then it listens for the faint but characteristic radio frequency energy (resonance) which the atoms emit as they relax. Since different atomic nuclei resonate at a different radio frequency in a given magnetic field NMR spectroscopy is able to determine the molecular make-up of chemical compounds.

MRI uses the principles of NMR to focus mainly on the hydrogen nuclei in water molecules. The relaxation times of hydrogen vary according to the type of body tissue in which they are found. Water constitutes about two thirds of the human body by weight and, crucially, water content levels are different between the various tissues and organs, and between healthy and diseased body parts. MRI gathers vast quantities of data from multiple slices through the sample to make two- and three-dimensional images showing the different body tissues present in the sample.

And underpinning it all, giving health and longevity to millions of people, are cryogenically cooled niobium-titanium superconducting electromagnets.
The development of nuclear magnetic resonance (NMR)

Our story begins with Professor Isidor Isaac Rabi, a remarkable physicist working at Columbia University during the 1930s and 1940s who was fascinated by the magnetic properties of crystals and especially the magnetic properties of atomic nuclei. Rabi’s pioneering work discovered the magnetic properties of atomic nuclei and their ‘resonance’ and in 1944 he was awarded the Nobel Prize in Physics. Subsequent breakthroughs in 1946 by Edward Purcell and Felix Bloch, working respectively at Harvard and Stanford universities in the USA, improved techniques for making resonance measurements. Their work made it possible to study different materials’ compositions and the chemical structure of substances, an achievement that won them the 1952 Nobel Prize in Physics.

In the 1960s NMR was at the cutting edge of physics, attracting visionary scientists and fostering strong competition between research teams. Two of those pioneers were Dr Raymond Damadian, a medical doctor at State University of New York's medical centre in Brooklyn, and Professor Paul Lauterbur at the State University of New York at Stony Brook. Damadian's focus was initially concerned with how sodium and potassium in living cells responded to NMR. Then, as now, NMR can analyse a single one-dimensional point, but Damadian realised that he could use NMR to distinguish whether the sample was a tumour or normal body tissue. In 1972 he filed a US patent for "An Apparatus and Method for Detecting Cancer in Tissue" (US patent 3,789,832)², but, critically, this did not mention a method for generating pictures from such a scan.

Lauterbur’s breakthrough came in 1971 when he realised it was possible to make a two-dimensional image using enough NMR signals by adding a gradient to the magnetic field. NMR normally used a uniform magnetic field but a gradient, or small variations, affects the resonance frequency of nuclei in direct proportion, and can thus be used to collect spatial information. The intensity of the resonance signal at a particular frequency then indicates the quantity of a given kind of nucleus in a particular location. Lauterbur published his theory in 1973, in which he described the possibility of obtaining images of the human body non-invasively from a living subject, giving the basic methodology used in MRI ever since.

Simultaneously, across the Atlantic Professor (later, Sir) Peter Mansfield, at the physics department of Nottingham University, UK, was moving away from studying the structure of crystals using NMR and was focusing on biological samples, with promising results. After successfully scanning various vegetables that he bought on his way to work Mansfield found himself curious about imaging the human body. His breakthrough came in 1976 with the first MRI scan of a human body part, in this case the finger of his research student Dr Andrew Maudsley³. It took 23 minutes to take a single scan a few centimetres square (see left). Later the same year Damadian obtained an image of a tumour in the thorax of a mouse and a year later he performed the first full-body scan: on July 3rd 1977, after four hours and 45 minutes of collecting data from 106 points, a picture was created of the chest cavity of a live man.

To the MRI pioneers data and time were significant problems. Generating data was a slow and difficult process and so too was processing it on vast computers that were less powerful than a modern phone. For the rest of his career Mansfield dedicated himself to improving image resolution and speed; his “echo-planar” imaging technique. Mansfield’s work laid the foundations for fast imaging and over the next decades computer technology and visualisation software gradually caught up. Today, the processing power and algorithms are so advanced that three-dimensional scans are possible and a specialist called ‘Functional MRI’ can even look at real-time blood flow to measure oxygen levels and, from that, monitor brain activity⁶, although here the element of interest is iron, not hydrogen.

For their discoveries concerning MRI Mansfield and Lauterbur shared the 2003 Nobel Prize for Physiology or Medicine, but controversially Damadian did not (he called on the Nobel committee “to correct its error”, but to date it has not replied).
MRI comes of age

Since the late-1980s MRI machines have become increasingly commonplace in hospitals. They have become a vital tool for diagnosing brain tumours and other diseases of the central nervous system, and for locating soft-tissue injuries in muscles and ligaments.

In 2003 some 22,000 MRI machines were installed and by 2015 this figure had grown to 36,000 units. According to Roskill’s 2017 niobium report, annual sales are about 3,500 units, with 80% sold into the US, Europe and Japan. A growing global population is likely to increase demand for all medical technology in the future, especially given the aging, wealthy populations in North America, Japan and Europe.

According to a detailed survey by the OECD in 2015 Japan has, by far, the highest number of hospital-based MRI scanners per capita, followed by the United States, respectively 46.9 and 35.5 per million people. The United States, Europe and South-East Asia hold about 80% of the market share, but China, India and other rapidly developing countries are making large investments in healthcare and are expected to require significant numbers of MRI machines in the foreseeable future.

The MRI market can be segmented by resolution (low field, mid field and high field), applications (neurological, gastrointestinal, cardiology and oncology) and geography. The market leaders of MRI machines include GE Medical Systems (USA), Hitachi Medical Corporation (Japan), Philips Healthcare (The Netherlands), Siemens (Germany) and Toshiba Medical Systems (Japan). GE, Siemens and Philips have in-house production of superconducting magnets at factories in the USA and Europe.

Most hospital MRI machines until 1999 were up to 1.5 tesla (T) and while these are still common, the trend since then has been for 3T machines. Price information of MRI machines is hard to come by, but 2014 investigation by Time magazine suggested that a state-of-the-art 3T hospital MRI machine was in the region of US$3 million.

The MRI machine in action

At the heart of an MRI or NMR machine is a system of magnets. They can be high-strength permanent neodymium-iron-boron magnets, but usually in MRI machines they are electromagnets which generate the magnetic field from electricity passing through a magnetic coil. Typically, the coil is made from a copper-coated niobium-titanium (NbTi) alloy and to achieve superconductivity it is bathed in up to 2000 litres of liquid helium cooled to its ‘critical temperature’ just above absolute zero of 4.2 kelvin (K), equal to minus 268.8°C. At this cryogenic temperature liquid helium enters a state called superfluidity, at which point it ceases to be governed by the classical laws of physics and is instead governed by quantum mechanics. As a superfluid, helium at this temperature flows without friction and, remarkably, it can transfer some of those properties to other materials, such as changing niobium-titanium wire into a superconductor.

In a room-temperature electricity conducting wire some electrons passing through the wire interact with the wire’s atoms, causing electrical resistance and a loss of current. But in superconductors the electrons pass through the wire without any electrical resistance at all and so no electricity is lost.
This property allows superconductors to be able to carry a very large current and generate a very high magnetic field without the wires heating or any loss in current flow. Typically, a hospital MRI machine will be 1.5T or 3T, although some hospitals and medical teaching schools employ 7T machines. The MRI machines with the highest field strength are usually those found in research laboratories and these units can reach up to 20T. Needless to say, such strong magnets are shielded in many tonnes of concrete and steel to contain the forces they generate.

However, the temperature margin of error is just 1K and even small mechanical disturbances can cause the wire to heat beyond its critical temperature. Should this occur then it immediately becomes resistive, the current cannot be held and the magnetic field is lost. This phenomenon is commonly referred to as a “quench”.

The MRI machine uses the magnetic field to generate powerful pulses of energy that change the orientation of the magnetic fields of the atoms in the patient under examination, in particular the hydrogen in water molecules. Hydrogen has one proton and no neutron, and when in an ionic state (H+) it is nothing more than a positively charged subatomic particle, spinning on an axis with a random polar orientation.

However, when subjected to the MRI’s magnetic field, the protons are forced to align, comparable to a compass aligning north-south. The next step is to increase the energy level of those protons, making them spin faster using pulses from radio frequency (RF) coils embedded in the MRI machine; the same principle behind a microwave oven.

The final step is to turn off the magnetic field and measure the faint RF energy emitted by the protons as they return to their random polar orientation and decelerate, respectively called the T1 (spin-lattice) and T2 (spin-spin) relaxation times. The energy emitted by each resonant nucleus is miniscule, but there are so many nuclei involved that a viable signal is produced. These emissions are detected by the radiofrequency coils acting as antennas.

Creating images is possible because each type of body tissue has different T1 and T2 relaxation times. Once enough data have been collected and enhanced, by mapping the relative relaxation times of different regions detailed images are generated showing the internal structures of a human body.

Thanks to the work of Peter Mansfield and modern computer power, today MRI can create three-dimensional images in close to real-time; a modern MRI machine, supported by appropriate software can take a single scan in 15 milliseconds, or some 66 scans per second.

There are some problems still to overcome with MRI, mostly concerned with patients’ welfare. An MRI scan is still a very noisy and claustrophobic experience which holds a minute risk of electrocution.

A three-dimensional representation created from multiple MRI scans showing a jaw-bone tumour (an odontogenic keratocyst). (photo: Shutterstock)
Superconductivity was first identified in 1911, but for many years remained a laboratory curiosity while metallurgical and manufacturing technology struggled to catch up. A future Bulletin will explore superconductors in greater detail, including uses beyond MRI (such as magnetic levitation trains, mass spectroscopy, particle accelerators and nuclear fusion research equipment) and the many important contributions to this field made by scientists around the world, (such as the Tokamak ‘doughnut’ magnetic confinement device, the ITER nuclear fusion project and the significant contribution made by scientists from around the world).

The first niobium-based superconductor developed was niobium-tin (Nb$_3$Sn) by Bell Telephone Laboratories in 1961 and this prompted many others to be developed, including niobium-germanium and niobium-aluminium. Although initially disregarded, in time niobium-titanium (NbTi) alloys emerged to become the most widely used, making it possible to fabricate magnets that generate magnetic fields of up to 10.5T with unprecedented efficiency and economy. NbTi is relatively inexpensive, has excellent mechanical properties and produces reliable, stable and extremely uniform magnetic fields. Today NbTi is the standard commercial ‘work horse’ of superconducting magnets, including for over 95% of MRI applications. In MRI machines, the standard commercial alloy is 53% niobium by mass with the balance 47% titanium (Nb47Ti), although wires with 46% to 48% Ti have also been developed.

In comparison to NbTi, Nb$_3$Sn is a brittle intermetallic compound with poor mechanical properties and is several times as expensive. However, Nb$_3$Sn can generate far higher magnetic fields (up to 20T) and because of this it is used widely in NMR spectroscopy, general research and also in a range of very high-strength (≥ 9T) MRI machines made by GE Healthcare.

**NbTi**

To describe how to make NbTi makes an exceptionally difficult process sound relatively straightforward, but don’t be fooled; it takes around 18 months from melting the Nb and Ti together through to winding the superconducting wires on an MRI frame and total process control is vital throughout.

First ultra-high purity niobium with a high residual resistivity ratio (RRR) is vacuum melted with high purity titanium metal and cast into alloy billets. The billets undergo hot extrusion to form rods. Then the rods are stacked in a drilled copper billet depending on the desired multi-filamentary design and then extruded again to form a multi-cored rod. The copper matrix is essential to provide electromagnetic and thermal stability to the finished wire.

The multi-cored rod is cold-drawn and then heat treated to precipitate alpha-Ti phases as flux pinning centres. For very fine filaments (as thin as 5 microns) it is critical to avoid the formation of brittle CuTi intermetallic compounds during heat treatment and this is usually done by enclosing the NbTi in a thin diffusion barrier shell made from high purity niobium or tantalum sheet.

**NbTi**

(Chart: Martin N. Wilson, CERN, Switzerland. 1996)
Finally, the wire is twisted to avoid coupling, it is annealed, tested and despatched to the MRI manufacturer. There is a wide range of wire diameters, but they typically range from 0.3 - 6 mm, while the diameter of NbTi filaments ranges from 5-100 μm. Some alloy-makers also produce wire and there are over two-dozen downstream producers of superconducting wire from the alloy, such as Oxford Instruments, Siemens and Kyushu Electric Power.

In terms of quantity, the wide range of MRI specifications makes generalisations difficult, but a rule of thumb is that a typical 3 T MRI machine will use around four times more NbTi in the electromagnet than a 1.5 T MRI machine. The magnet in a 1993 1.5 T Oxford Unistat MRI machine made by Oxford Instruments in Oxford, United Kingdom used 36.9 km of NbTi wire for the large superconducting coil. However, the tonnage of alloy that goes into an MRI machine is a closely guarded secret and generalisations are difficult due to the wide range of wire diameter, copper-to-NbTi ratio and machine size. However, industry experts, familiar with the MRI market, suggest that the production of NbTi alloys for MRI machines is in the region of 500 to 800 tonnes per year.

What next for MRI?

MRI technology is continuing to develop rapidly. Even as this article went to print a team from Cardiff University, UK, along with engineers from Siemens, revealed that they had developed an MRI technique to map the individual fibres within a brain (axons); a feat that could give new insights into many neurological conditions, including schizophrenia, dementia and epilepsy.

Every day hundreds of thousands of MRI scans are taken around the world, allowing millions of people to live longer, healthier lives.

There are many applications for niobium (and tantalum) that improve human health and happiness, but the MRI machine and its niobium-based superconductors must surely stand out as being among humanity's supreme achievements.

Notes:

Special thanks to all those who have contributed to this report, including Barry Valder, Martin Wilson for his essays on superconductors, John Talbot at Anglia Ruskin University for sharing his expertise on MRI, and the Sir Peter Mansfield Imaging Centre at the University of Nottingham.

5. Dr Keshav Kulkarni, Consultant Radiologist https://www.slideshare.net/keshrad/basics-of-mri
11. The current market leader for NbTi for use in MRI machines is ATI Specialty Alloys & Components (USA), a company with a reputation for quality and consistency since the earliest days of NbTi (then as Wah Chang Corporation). Other companies that can produce the alloy include CNMC Ningxia Orient Group (China), Global Advanced Metals (USA), H.C. Starck Group (USA / Germany), Ulba Metallurgical Plant (Kazakhstan), TVEL / Chepetsky Mechanical Plant (Russia), and Western Superconducting Technologies Co., Ltd. (WST, China).
12. Ultrapure RRR niobium producers include Heraeus Precious Metals (Germany), NPM Slitnom AS (Estonia), Ningxia Nonferrous Metals Import & Export Corporation (China), Ulba Metallurgical Plant (Kazakhstan), TVEL Corporation / Chepetsky Mechanical Plant (Russia), Global Advanced Metals Pty Ltd (USA), Tokyo Denkai (Japan), Plansee SE (Austria) and H.C. Starck Group (USA and Germany).
16. Cu:NbTi ratios range from less than one to >10-to-1.
The T.I.C.’s 58th General Assembly and 7th Technical Symposium will be held in Vancouver, Canada, from October 15th to 18th 2017. The event is generously sponsored by KEMET Electronics Corp., Exotech, Inc., A&R Merchants Inc., and Krome Commodities Ltd. The event is now open for booking and full information, including the booking form, is available at www.tanb.org. A special “early bird” booking rate is offered exclusively to T.I.C. members and applicants who book by August 18th 2017. The final booking deadline is October 6th 2017.

The following papers are expected, and there will also be a panel discussion entitled ‘Downstream perspectives on minerals due diligence procedures’.

The announced presenter is the first author listed, unless otherwise specified. Please note that this list is subject to change. The papers are shown in alphabetical order of first author (not in running order):

Advancing responsible sourcing through the CFSI
by Hillary Amster, Conflict-Free Sourcing Initiative (CFSI)
Tantalum was the first industry to embrace conflict minerals assurance approaches for smelters/refiners, including the Conflict-Free Smelter Program, with the first two compliant smelters in 2010. Now in its 8th year, the program has grown substantially, including the latest addition: a revised protocol that aligns more closely with the OECD Guidance. This presentation will begin with a brief overview of the past 8 years, with a focus on tantalum. Next, it will cover the updates that comprise the evolution of the CFSP, new tools available for company due diligence and risk assessment, collaboration across initiatives, and legislative updates.

The iTSCI programme: bringing more transparency in the 3Ts supply chain
by Yves Bawa, Marlene Wafler, Karen Hayes (Pact Inc.) and Kay Nimmo (ITRI Ltd)
Since 2010, the iTSCI programme has grown from an initial pilot project to a fully scaled up traceability and due diligence programme, covering over 1700 ‘3Ts’ mine sites, and ensuring livelihood for over 60000 miners in four countries of the Great Lakes Region (Democratic Republic of Congo, Rwanda, Burundi and Uganda). The programme’s evident success in ensuring stable tantalum supply from this challenging region can be attributed to the effective combination of practical on-the-ground assistance for small scale operators and authorities in high risk areas, with understanding of market requirements and leadership in discussion of appropriate international policies. The challenging political and security context with limited governance and infrastructure, as well as high demands from the OECD guidance and metal users, determines the need for a close monitoring of activities. Programme credibility requires day to day management, constant field visits and access to a range of high level expertise which is reflected in operational costs. With this in mind, we will describe how the iTSCI field team has strived to improve its standards as well as functioning by reviewing its implementation plan in response to risk and need to minimise costs as much as possible, while retaining the credibility and sustainability of the programme. In 2016, the programme has also conducted a full review of its incident reporting mechanism, and published a report which outlines trend risks in areas where it operates, as well as outcome obtained thanks to the running of the programme since 2010. This review shows that the programme has been instrumental in bringing more transparency in the 3Ts supply chain in the GLR, as well as a safer environment for miners working in iTSCI mines, though highlighting challenges that still need to be tackled. The paper will also discuss the EU regulation and iTSCI’s OECD conformance.
The re-birth of tantalum in Western Australia
by Ken Brinsden and Anand Sheth, Pilbara Minerals Ltd
The re-birth and significance of tantalum production from Western Australia as one of the largest, low cost stable suppliers globally. In the past 3 decades, tantalum production from hard rock resources in Western Australia carried the cost for lithium production, as a by-product, but this is now changing with the advent of e-transportation (electric vehicles and e-bikes) and Energy Storage Solutions for the renewable energy sector, made possible by use of lithium batteries. The demand for lithium primarily in these new and burgeoning industries is expected to triple in the next 10 years. Lithium hard rock deposits will become a significant supplier to this sector and several new lithium projects will be commissioned within the next 2 years in Western Australia and a few more in Canada. Some of these new projects, including the existing largest lithium operations, have a significant capacity to produce tantalum as a by-product, at a very commercially profitable cost. These companies are located in risk free jurisdictions / countries, with operations that can produce and supply a high-quality product consistently at competitive prices. These operations will be sustainable and meet all the environmental and ‘conflict-free’ regulatory requirements. The presentation will discuss the production volumes and costs of tantalum concentrates as a by-product of several hard rock lithium mines and shall provide an update on Pilbara’s Pilgangoora lithium – tantalum project, soon to become one of the largest producers and suppliers of lithium and tantalum concentrates.

James Bay niobium project: the next ferro-niobium producer
by Claude Dufresne, NioBay Metals Inc.
The James Bay niobium project is located in northern Ontario, Canada. The deposit was discovered in 1966, and a full feasibility study, including metallurgical testing, was completed in 1969. The project has remained dormant since then. NioBay Metals discovered its existence and acquired the asset in June 2016. The historical estimate is 62,000,000 t @ 0.52% Nb₂O₅, and pilot plant trials indicate a 78% recoverable rate in a high-grade niobium concentrate grading 64% Nb₂O₅. The presentation will describe the deposit & historical results and the step forward towards the development of the project.

Improvements in tantalum capacitor volumetric efficiency
by Y. Freeman, P. Lessner, C. Guerrero, S. Hussey and C. Stolarski, KEMET Electronics Corporation
High volumetric efficiency is the key selling point of tantalum capacitors that allows for continued miniaturization of the capacitor and the end electronic device. This paper discusses two major obstacles to maximize the volumetric efficiency of tantalum capacitors and technological means to overcome these obstacles. One of the obstacles is over sintering and, thereby, surface area loss in hi-CV tantalum anodes because of the requirement to achieve a strong mechanical bond between the tantalum powder and the embedded tantalum wire. A new technique discussed in this paper improves this bond radically without surface area loss. It’s applicable to conventional sintering in vacuum and sintering in deoxidizing atmosphere (d-sintering). The latter provides super high energy efficiency never seen before in tantalum capacitors. The other obstacle for high volumetric efficiency is 50% de-rating of Ta/MnO₂ capacitors to improve their reliability. This de-rating causes up to 10x loss in volumetric efficiency, reducing it to the level of the ceramic capacitors. KEMET developed new flawless technology (F-Tech) and simulated breakdown screening (SBDS) that allow manufacturing of Ta/MnO₂ capacitors with low/no de-rating and exceptional reliability. The advantages of F-Tech/SBDS capacitors in comparison to industry average was confirmed in a paper published by a manufacturer of defence/aerospace electronic systems.

The annual T.I.C. statistics report
by David Knudson, Tantalum-Niobium International Study Center (T.I.C.)
The complete and timely collection of industry statistics for niobium and tantalum has always been and continues to be a primary concern of the T.I.C. While statistics are collected via an independent intermediary to reassure reporting companies that their commercial confidentiality is preserved, other seemingly unavoidable obstacles will prevent one company or another from reporting in a timely manner and so hold up the entire reporting process. These issues continue to be tackled head on by the T.I.C. Additionally, a new statistics subteam has been formed from members of the Executive Committee, to better analyze, discuss and resolve the issues that have been affecting the completeness and timeliness of the industry’s statistics. The T.I.C. statistics are issued to the members every quarter, with two main categories for niobium and four main categories for tantalum: - Niobium primary production - Niobium processor shipments - Tantalum primary production - Tantalum processor receipts - Tantalum process shipments - Tantalum capacitor producer receipts. Each of these is further sub-divided into two to six sub-categories. The presentation will look at the figures for the last decade to reveal past trends, as well as highlight differences between various categories.
Pyrometallurgy and hydrometallurgy as key points to make feasible a mining project with an ore complex type of tin, tantalum and niobium in the Penouta Mine (Spain)

by Francisco Javier López Moro, Francisco García Polonio, Teresa Llorens González, Félix López and Irene García Díaz, Strategic Minerals Spain

Some of the most important Ta-Nb primary deposits worldwide are low-grade high-tonnage Sn-Ta-Nb-bearing albitic leucogranites (e.g. Abu Dabbab, Nuweibi, Beauvoir, Penouta). This kind of deposit shows a disseminated mineralization, where the tin mineral (mainly cassiterite) is more abundant than Ta-Nb oxides. The separation of cassiterite from Ta-Nb oxides using gravimetric and magnetic methods may not be an easy issue due to the occurrence of iron oxides locking cassiterite or Ta-Nb oxides, or the existence of Ta-Nb oxides as microinclusions in cassiterite crystals. The impossibility of separation of Sn oxides from Ta-Nb oxides may result in making a mining project not viable for three metals of high interest in technological industries. Here, it is exposed how this problem was solved in the second most important Ta deposit in Europe, namely the Penouta deposit. The best solution found consists of a combination of carbothermic reduction and hydro-lixivation processes that allowed very pure tin-ingots and Ta and Nb oxides to be obtained, making feasible the exploitation of an ore complex type.

Shifts and trends in the global anthropogenic stocks and flows of tantalum

by Nedal Nassar, U.S. Geological Survey, National Minerals Information Center

The supply and demand of tantalum has undergone a number of significant shifts over the past few decades. The purpose of this work is to quantify how these shifts have affected tantalum’s global material cycle. A global stocks and flows model for tantalum has thus been developed for the years 1970-2015. The results indicate that the overall quantity of tantalum prompt scrap generated during manufacturing has increased notably due to tantalum’s increased use as an alloy additive and sputtering target. In contrast, the amount of tantalum contained in recycled obsolete scrap, mainly in the form of used carbides, is estimated to have remained relatively constant since the late 1980s. Moreover, tantalum’s overall end-of-life recycling rate (EoL-RR) seems to have declined from a high of 22-25% in the 1990s to approximately 18% today. This decline is also attributable to the shift in tantalum’s use from carbides to sputtering targets and chemicals that, along with tantalum’s use in capacitors, have not been recycled at the end of life (EoL) in significant quantities. The results also indicate that 21-25% of tantalum produced since 1970 is still in use today, with the remainder having been lost during processing, manufacturing, use, or at the EoL. However, a portion of the EoL “discards” may actually still be retained by the end-user as “hibernating” stocks that could potentially be recycled if the economic, technical and behavioural challenges of recycling obsolete electronics are overcome.

The mysterious life of the tantalum atom

by Joel Nields (Exotech, Inc.) and Kokoro Katayama (Metal Do Co., Ltd) (both presenting)

The authors’ paper will trace the trajectory of the tantalum atom from “cradle - to grave - to resurrection”. Inquiry will consider extraction and beneficiation of Ta₂O₅ as it exists in its mineral state (including geography/geology of deposits), outline its path through a smelter - including identification of the various chemical avenues and processes (tantalum-hydroxide to tantalum-pentoxide vs. potassium-tantalum-fluoride to tantalum metal powder), and identify the many resulting mill or powder products and the processes involved in their genesis. It will then cover the major downstream tantalum applications (capacitors, alloy additive, thin film deposition, mill product, carbide, chemicals…) and explain the fate of a tantalum or tantalum containing “widget” once it reaches end of service and enters the recycle loop. Using two tantalum-containing recycle items (Ta capacitors and Ta sputtering targets), the paper will briefly touch on various thermal, mechanical and chemical processes associated with the transformation of the tantalum containing revert into commercially viable product. In conclusion, the authors will trace these commodities downstream until they reach “widget” status, achieve “end of life” and re-enter the cycle.

New EU Regulation on conflict minerals

by Signe Ratso, EU Commission, DG Trade

A new EU Regulation on conflict minerals entered into force on June 8th 2017, under which EU importers in the upstream section of the supply chain for tin, tantalum, tungsten and gold will face mandatory due diligence. To this end, they must ensure that their materials are not indirectly financing conflict, or are not mined with forced labour. The Regulation draws on well-established rules laid out in the Organisation for Economic Co-operation and Development (OECD) Due Diligence Guidance and will apply as of January 1st 2021. This will curtail the opportunities for armed groups and unlawful security forces to trade in these minerals and metals – as has in the past too often happened, in particular, in the Great Lakes region of Africa. The EU is at the forefront of promoting supply chain excellence and responsible sourcing. But, to effect a real change, our leadership needs to be echoed around the world. We are therefore taking this issue forward with our main trade partners, and have already seen some countries moving in the right direction. Work is also ongoing with the governments of the Great Lakes Region itself: their commitment to “responsible sourcing” is as vital as anything we can do. Moreover, the EU is calling upon all OECD members, as well as European and global industry, to actively push forward this agenda.
Tantalum and niobium resources – perspective of North American explorationists
by George Simandl (British Columbia Geological Survey), David Trueman (Consulting Geologist) and Richard Burt (Consulting Metallurgist)

The world’s main Ta resources are in pegmatites (e.g. Wodgina, Australia), rare element-enriched granites (e.g. Abu Dabbab, Egypt), peralkaline complexes (e.g. Nechalacho [REE, Nb, Ta, Zr], Canada), weathered crusts overlying the previously mentioned deposit types, and in placers. Nb resources with the highest economic potential are in weathered crusts that overlay carbonatite complexes (e.g. Catalão I and II, Brazil). Brazil accounts for 90% of the global Nb mine production with another 9% coming from the Niobec Mine, Canada. However, at least 17 undeveloped carbonatite complexes outside Brazil have NI-43-101 compliant Nb resource/reserve estimates. Concentrates from most carbonatites are used to produce ferro niobium, Ta not being recovered. The Ta and Nb content of some carbonatites (e.g. Upper Fir deposit and Crevier dyke, Canada) is of the same order of magnitude as that of pegmatite ores; however, concentrates from carbonatites have a higher Nb/Ta ratio. Historically, 10-12% Ta₂O₅ in Nb concentrates have not been treated in ‘western’ smelters because of the hydrofluoric acid cost. Western countries perceive Ta and Nb supplies to be at risk. Ta market downturns resulted in several mines in Australia and Canada closing, at least temporarily, and a resultant shortfall has been filled by what is now recognised as conflict free ‘coltan’ from Central Africa. The lack of ore will not be a key factor in any future Ta and Nb supply disruption. For example, more than 280 Nb- and 160 Ta-bearing occurrences are known in Canada alone and more resources will be discovered as geophysical and geochemical exploration methods are optimized.

Tantalum, beyond capacitors
by Melanie Stenzel, H.C. Starck Ta & Nb GmbH

Capacitors remain the main application for tantalum. The major share of research efforts in the last 50 years has been devoted to improving capacitor performance by increasing the surface area, improving leakage and ESR. However, the field of applications making use of tantalum is much more manifold due to the special properties that it offers. This paper gives a small insight into some examples of emerging usages of tantalum. Comparable to the small capacitor in the PC or the car, in a wide range of applications tantalum is very often not visible and not directly recognized by the user, although it is essential for the safe function of the device. Tantalum might be used as a dopant or catalyst to speed up chemical reactions or used in the form of tantalum compounds as a thin but important layer or interlayer. In addition to that, the excellent biocompatibility combined with new production methods open new opportunities in the field of challenging applications.

Ultra-low profile capacitors
by Chris Stolarski, Siva Lingala, K. Moore and B. Summey, KEMET Electronics Corporation

The trend towards lower profile electronic devices is driving the transition to thinner components. Capacitors in EIA footprint sizes in the range of 3528 to 7343 need component thicknesses less than 1.0 mm in height. Current customer needs are for capacitors in the range of 0.5 to 0.7 mm height while future needs are 0.4 mm and thinner. As the height of the finished capacitor gets smaller, the available volume for capacitance is reduced because of the inefficiency of the packaging. With current design and construction methods for tantalum capacitors, each step reduction in height reduces the possible capacitance by a greater and greater percentage until virtually no volume for the active capacitor element remains. This paper discusses the volumetric efficiencies and construction challenges of ultra-low profile capacitors. It will also compare the trade-offs between competing tantalum polymer and solid aluminum polymer technologies to reach these targets.

The changing face of tantalum
by Patrick Stratton, Jack Anderson and Robert Baylis, Roskill Information Services

The tantalum industry has seen many changes over the years. Prices have displayed a habit of volatility, often not based on reality. The pattern of demand has altered. Relatively low-cost artisanal mining has made much of the conventional mining sector uneconomic and few new pure-play tantalum projects stand much chance of commercialization. Roskill will review the recent history of the tantalum industry and markets, using published information and its own data, which is in the public domain. Roskill will then address what could come in future and what might cause things to happen or not to happen. No specific forecasts on tantalum demand or prices will be provided. The outlook will cover what Roskill considers to be the drivers and will be based on Roskill’s expertise in tantalum, lithium, tin, superalloys and other areas. On the demand side, Roskill will examine possible trends in the field of electronics, such as the bundling of functions into one device, along with assessment of the outlook in superalloys, with reference to the importance of recycling and revert scrap. On prices, Roskill will examine what has happened before, why it happened and what might lead to further movements. Regarding supply, Roskill will review the changes that have taken place in the shift from conventional mining to artisanal mining and how this could change again in the current geo-political climate (including President Trump’s announcements). A key issue will be the future of hard-rock lithium supply and how this might impact on by-product tantalum supply. Also addressed will be the outlook for tin and tin slags. The history of tantalum has seen it go from being a by-product to a main product and it now seems quite possible that it will go back to being a by-product again.
Development of polymer tantalum capacitors with high rated voltage
by Yasuhisa Sugawara, TOKIN Corporation

With the advancements of technology in the fields of IT infrastructure and automotive electronics, the opportunities for high rated voltage capacitors have been expanding. Tantalum capacitors have gained favor from these market opportunities due to their high capacitance per unit volume and stable electrical characteristics. In recent years, ceramic capacitors and aluminum capacitors with high rated voltage have been released, also in response to expanding market needs. However, these capacitors have certain negative aspects in their electrical characteristics which can limit their applicability. Ceramic capacitors present acoustic noise issues when under AC bias. In addition, their capacitance can be reduced depending on applied voltage and ambient temperature conditions. Aluminum capacitors have limitations in their ability to be miniaturised. We will report on our activity and results towards the development of polymer tantalum capacitors with high rated voltage. We have been developing unique technologies and application techniques of tantalum powder and conductive polymer for developing high voltage polymer tantalum capacitors. Key to the development of these high voltage capacitors are 1) the tantalum capacitor powders, and 2) suitable polymer used in the manufacture of the capacitors. In our presentation, we will show our development roadmap for polymer tantalum capacitors with high rated voltage, and make an explanation of the future prospects for these products. We will refer to some of our applied technologies and present our specific requirements to the tantalum capacitor powder manufacturers.

An update on the Maboumine project
by Eric Tizon, Maboumine

The Maboumine project aims to develop the Mabounié ore deposit, a world class polymetallic deposit located in Gabon. Since 2005, this strategic project has been developed by the Maboumine company under the leadership of the French mining and metal group ERAMET and with the strong support of Gabonese authorities and local communities. The extensive development effort carried out so far has enabled the establishment of a sound knowledge of the deposit while developing an innovative metallurgical process able to recover most of the valuable metals embedded in the ore. Although the economic potential of the deposit was confirmed by a recently updated preliminary feasibility study, Maboumine has recently considered an alternative project scenario involving a reduced scope and CAPEX, more adapted to current market conditions. The outcome of this study, which confirms the important economic potential of the Mabounié deposit, is presented in this paper.

Wire + Arc Additive Manufacturing: a new way of producing large-scale refractory metal components
by Stewart Williams, Gianrocco Marinelli, Filomeno Martina, Supriyo Ganguly, Cranfield University.

Refractory metals have intrinsic low-temperature brittleness, poor weldability and a high susceptibility to oxidation over a large temperature range. These properties result in limitations in various steps of the manufacturing process. An innovative way of producing refractory metals parts has been developed by using Wire + Arc Additive Manufacturing (WAAM). Fully-dense 200-mm-long structures in pure tungsten and tantalum have been deposited using an arc power of around 6 kW and a relatively low travel speed ranging between 2 and 4 mm/s. Despite substrates suffering from high deformation or even cracking, the as-deposited structures are free from internal cracks, and the layer’s geometry is stable during the process. In particular, tantalum structures can be deposited with high integrity and excellent mechanical properties, superior to those of commercially available tantalum. For example, an ultimate tensile strength of 200 MPa was achieved for the WAAM deposited material compared to the 180 MPa for commercial tantalum, even though the grains in the WAAM material were large and had a high aspect ratio. Interestingly, these grains were refined into an equiaxed microstructure when additional cold-working was implemented, obtaining an average grain size of 650 μm. Furthermore, a functionally graded structure between molybdenum and tungsten has been successfully deposited with a linear gradient across 4 mm of thickness. WAAM has shown the potential to produce refractory-metals components with relatively low cost, exploiting the freedom of 3D printing and the opportunity of obtaining engineered properties, offering a solid alternative manufacture route to powder metallurgy.

Preparation of high nitrogen content capacitance grade tantalum powder
by Yang Guo-qi1,2, Li Zhong-xiang1,2, Li Hui1,2, Ma Hai-yan1, Luo Guo-qing1,2, Zhao Chun-xia1

1. Ningxia Orient Tantalum Industry Co., Ltd; 2. National Engineering Research Center of Tantalum and Niobium

This paper describes an improved method of adding nitrogen to capacitor grade powders with better control and increased saturation of nitrogen within the tantalum crystals. This method improves performance properties of the Ta anode used for manufacture of the capacitor in a way which improves capacitance, leakage current and dissipation. Also, there is an improvement in the acceptance rate of the finished capacitors. The new method introduces solid tantalum nitride into the process of sodium reduction of potassium heptafluorotantalate (K2TaF7) which diffuses the nitrogen from the seed material into the newly formed tantalum crystals creating a homogeneous distribution of nitrogen in the finished powder. This method is very precise and nitrogen content is highly controllable.
Tantalum supply chains today: how responsible are they?

Paper written and presented by Sophia Pickles, Global Witness, on October 18th 2016, as part of the Fifty-seventh General Assembly in Toulouse, France. A full version of the presentation is available from Global Witness’s website: https://www.globalwitness.org/ru/campaigns/conflict-minerals/taking-look-tantalum-supply-chains-how-responsible-are-they/. All views and opinions in this article are those of Global Witness and not the T.I.C.

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Introduction

For decades the trade in minerals, precious stones, and other commodities has played a central role in funding and fuelling some of the world’s most brutal conflicts and weakening already fragile States.

The links between natural resources and conflict are not always simple and not always the same. There are undoubtedly cases in which violence is aimed directly at control of natural resources. More often, however, the root causes of a conflict go much deeper. In such cases, ready access to the cash supplied by the trade in minerals can intensify violence and prolong conflict, creating economic incentives that favour continued chaos over peace or longer term stability.

This illicit trade has flourished because there has often been an undiscerning and ready market for these resources. Global supply chains - many of which lead to major markets like the EU, US or China - are often opaque and poorly regulated.

It doesn’t have to be this way. When companies and sectors work together to make their supply chains more transparent they can ask better questions and identify warning signs that warrant further investigation and action, building more responsible and resilient supply chains in the process.

Tantalum and conflict - what has already happened?

The question of tantalum’s links to instability and human rights abuses probably prompts most to think of the Democratic Republic of Congo, where links between artisanal tantalum mining and conflict have been well-documented for well over a decade. The following examples (using ‘coltan’ interchangeably with ‘tantalum’1), provide a flavour of over a decade’s worth of reporting:

In the early 2000s, consecutive UN Panel of Experts reports described how tantalum financed armed conflict in the country’s east via the Congo Desk, a pseudo-ministry run by the Rwanda Patriotic Army, that “served to link the commercial and military activities of the economic wing of the RPA.” The Rwandan government rejected the UN Panel’s findings2.

An artisanal miner interviewed during that period by the Pole Institute, a Goma-based think-tank, reflected that, “[c]oltan mining is hard work. There is also the problem of armed groups who steal our produce, not to forget what we already said: landslides and collapsing pits.”3

In 2009 Global Witness4 reported on the links between tantalum mines and armed men in the country’s east during 2007 and 2008 when, according to official government statistics from North and South Kivu, 428.4 tonnes of coltan were exported in 2007 and at least 270.79 tonnes in the first half of 2008.

In May 2012 two Chinese companies, one of which exported coltan according to official government statistics from North Kivu, were suspended by the Congolese government for failing to carry out due diligence in line with DRC law, and on suspicion that they were sourcing minerals from areas under the control of armed groups5. In the same year, two members of the Congolese army were reportedly caught while attempting to smuggle minerals, including coltan6.
The good news: a global approach to a global problem

This isn’t just about Congo and central Africa, nor is it just about tantalum. In the Central African Republic (CAR) armed groups have taxed and extorted gold and diamond miners7. In Myanmar, the multi-billion dollar jade industry provides figures and companies associated with the army, and ethnic armed groups, with incentives and financing to continue the country’s intractable civil conflict8. This pattern is repeated in many countries troubled by conflict and instability, be it diamonds in Zimbabwe9, or lapis lazuli in Afghanistan10.

The good news for companies is that international frameworks have been developed to help them to ensure that their mineral purchases are not contributing to conflict or human rights abuses. The United Nations Guiding Principles (UNGP) make it clear that companies have a responsibility to take pro-active steps to ensure that they do not cause or contribute to human rights abuses in their global operations.

As the international standard for mineral supply chains, the Organisation for Economic Cooperation and Development (OECD) Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (the Guidance) translates this second pillar of the UNGP into an operational guide for the minerals sector. The Guidance applies to all mineral resources, is global in its scope, and is designed to engage the whole supply chain - from mine to end-product - through carefully differentiated obligations placed on companies at different points in the supply chain.

Some countries have gone further, and adopted law that requires companies to undertake specific supply chain checks. Section 1502 of the 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act requires U.S.-listed companies to undertake due diligence to check if certain minerals in their products – including tantalum – are funding armed groups or fuelling human rights abuses in Congo and its neighbouring countries.

The European Union (EU) recently passed its own law designed to make sure that ores and metals entering the EU have been sourced responsibly and without funding conflict and human rights abuses.

Domestic due diligence laws were similarly introduced in the Congo in 2012, requiring all companies operating in the country’s tin, tantalum, tungsten and gold sectors to undertake supply chain checks in line with the OECD Guidance. In December 2015, the China Chamber of Commerce of Metals, Minerals & Chemicals Importers & Exporters (CCCME) published Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains11.

The bad news: limited implementation by companies and States

While there has been a lot of welcome progress over the last few years, especially on paper, much of this is yet to translate into meaningful change along supply chains. With a few notable exceptions the majority of companies along mineral supply chains are still falling well short of their responsibility to respect, and as such, the States in which they operate are also failing in their responsibility to protect. It is worth reflecting here on some of the central principles that guide risk-based supply chain due diligence, but which are often misunderstood.

The first is that, properly implemented, supply chain due diligence as it is laid out by the OECD Guidance aims to encourage responsible and transparent sourcing in high-risk areas. It targets only harmful parts of the minerals trade, thus protecting and indeed making space for legitimate business in high-risk areas. It is not a ban or trade restriction.

Second, many companies are still unfamiliar with the concept that supply chain due diligence is not a once a year compliance exercise. Rather, it is an ongoing and proactive process, and one that should develop and improve over time. Companies undertaking supply chain checks to the OECD standard are therefore not required to provide 100 per cent guarantees. What is important is that a company has good processes in place to identify and then address risks as they arise.
Finally, it is critical to recognise that supply chain due diligence will not stop wars and conflict on its own. Better regulating trade might be central to breaking the links between conflict and natural resources in many cases, but must be complemented by diplomatic, development, governance and other initiatives.

Companies: what more should be done

Company reporting - the public-facing part of a company’s supply chain due diligence - remains particularly limited. Companies have been especially reluctant to report in detail on risks in their supply chains (Step 5 of the OECD Guidance), opting instead for generic commitments and policies. But reporting on detailed and proactive information gathering, and the mitigation that may follow, is an important part of making sure that greater scrutiny and awareness translates into impact and change. Public reporting of this kind is also critical to substantiating company claims that they are showing “improvement over time,” as permitted by the OECD Guidance. Practically speaking, public reporting should be as detailed as possible, and there are several ways in which companies operating in the tantalum sector can improve their reporting.

First, information provided by independent monitors, such as civil society and the United Nations, or the media, is too often ignored. It should be proactively sought out and then carefully and seriously considered to improve supply chain integrity and transparency.

Second, information generated by industry programmes or supply chain schemes should be identified and carefully examined - especially by companies downstream. Downstream companies should include publicly available information generated by these programmes in their annual due diligence reports. This is not current common practise. Instead, there appears to be a growing trend in which companies are increasingly looking to wholly outsource their supply chain due diligence responsibilities to industry schemes and private third party initiatives. That allows them to demonstrate a commitment to responsible sourcing while keeping actual risks at an arm’s length.

Public reporting by many downstream companies in particular simply states their membership of a particular scheme or programme, without providing any detail on what the company has subsequently learned about its own supply chains through information provided by these schemes. Bagging and tagging, labelling or scanning – these outsourced tools for supply chains may bring an extra level of comfort, but firms should be clear that industry programmes cannot eliminate risk from the supply chain.

A similar note of caution should be applied to in-region supply chain due diligence schemes in producer countries. The principle applies here too; although the tin industry’s iTSCI traceability and due diligence system, or private initiatives such as the Better Sourcing Programme, can support individual companies’ supply chain due diligence efforts, they must not and cannot wholly replace them.

The original vision of the OECD Guidance was for supply chains to grow increasingly resilient to risk as every company takes individual responsibility, using industry schemes as a helpful tool where appropriate as part of their own due diligence efforts. Third, companies should consider other publicly available information sources available to them when assessing supply chain risk, beyond supply chain information generated by industry schemes and civil society reporting.

For example, responsible companies working to international responsible sourcing standards that use or trade tantalum from Rwanda or surrounding countries, where illegal cross-border mineral smuggling between Congo and its neighbour has been a persistent problem, could review publicly available export information published by the National Bank of Rwanda year-on-year, or compare this to other available export data.
There are also some ways in which the CFSP scheme could improve, so that its members are better aligned with the OECD Guidance.

CFSP members should be required to publish detailed reporting of their internal management systems, risk assessment, and risks identified, as well as steps taken to mitigate risks as appropriate. This to ensure that they are in line with international standards, but also to facilitate information flow and ensure that the upstream and downstream sections of tantalum supply chains are joined up towards aligned responsibility sourcing. Smelter and refiner supply chain due diligence reports should also be made publicly available on the processor’s website. Otherwise, there is a lack of transparency around smelter and refiner’s own efforts to meet international due diligence standards that threaten the credibility of the entire scheme. The current CFSP protocol revisions are an opportunity to strengthen the scheme’s audit protocols so that they fully embody the aims and objectives of the OECD Guidance across all supplements. This would be advantageous for T.I.C. members and non-members whose supply chains are linked to companies within the CFSP.

Stuck in the mud, or improving over time?

Many of these recommendations share a common theme. The supply chain is a modern marvel. A renewed commitment to individual company responsibility, more and better public reporting, and more information about specific risks all help better harness the combined resources of a supply chain towards more effectively addressing the harms and risks to which it connects each of its members. One swallow does not make spring, nor one bee honey, nor one company a responsible supply chain.

Notes:

1. Particularly in an African context, tantalocolumbite or columbotantalite are often referred to as ‘coltan’, a term which is then usually carried into public reporting on the mineral.


8. The National Bank of Rwanda publishes information on national commodity exports, including tantalum, on at least a national basis, see http://www.bnr.rw/index.php?id=123. The iTSCi Programme also produces and export data based on its members’ activities, see for example https://www.itri.co.uk/index.php?option=com_mtree&task=att_download&link_id=55375&cf_id=24.
Changes in member contact details

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

- Conghua Tantalum & Niobium Smeltery has changed its name to **Guangdong Rising Rare Metals-EO Materials Ltd**. The delegate is still Mr Zeng Guozhong and contact details have not changed.

- The delegate for **Niobras Mineracao Ltda** has changed from Dr Frank Jackel to Mr David Elliott, who can be reached at delliot@c mocin ternational.com. Niobras Mineracao Ltda is currently in the process of receiving the membership transferred from Anglo American Nióbio Brasil Ltda.

- **NEC TOKIN Corporation** has changed its name to **TOKIN Corporation** following its full acquisition by KEMET Electronics Corporation. The delegate is still Mr Shinji Arai but his email is now s-arai- sx@tokin.com (please note all TOKIN employees now have new emails with the “@tokin” suffix). The company website has also changed to http://www.tokin.com.

- **Metal Do Co. Ltd** has moved office to ONTEX Namba Bld. 11F, 2-2-45, Minatomachi, Naniwa-ku, Osaka 556-0017, Japan. The telephone number is now +81 6 6635 5166 but all other details are unchanged.

Changes in T.I.C. staff contact details

The T.I.C. staff emails have been expanded and in the future there will be two working email addresses for each person. The historic emails will continue indefinitely. Also, to avoid spam-filter issues, the T.I.C. mass-mail database will use tic@tanb.org. Please add all seven email addresses to the safe list for your organisation.

**Roland Chavasse**, Director: director@tanb.org and roland.chavasse@tanb.org

**Emma Wickens**, Secretary General: info@tanb.org and emma.wickens@tanb.org

**David Knudson**, Technical Officer: tech@tanb.org and david.knudson@tanb.org

A new look to the online statistics database

The T.I.C.’s statistics collection website, hosted and run by Miller Roskell Ltd, has undergone a small face-lift. Functionality of the new website and forms for data entry will have the same feel as the original. As always, the confidentiality and security of your data is of core importance and the website remains highly secure and encrypted. If you have any questions at all about statistics, how your data is handled, or the independence of Miller Roskell, then please email T.I.C.’s Technical Officer, David Knudson, david.knudson@tanb.org.

The main changes are:

- The colour scheme has been changed to match Miller Roskell’s new website (www.millerroskell.co.uk).
- Page formatting has been changed to automatically re-size to fit screen proportions, making it easier to enter your data from a phone, tablet or other mobile device.
- The website is now compliant with the EU General Data Protection Regulation (GDPR) which comes into force on May 25th 2018.

**The original design**

**The new design**
This year's event, generously sponsored by KEMET Electronics Corp., will take the form of a Technical Symposium, with extended presentations. Among the highlights will be the Gala Dinner, held at the Vancouver Convention Center, with stunning views of the harbour and the mountains behind. The Gala Dinner is generously sponsored by Exotech, Inc. and A&R Merchants Inc., while the Welcome Cocktail is generously sponsored by Krome Commodities Ltd.

The booking form and further information are available at https://www.tanb.org/event-view/58th-general-assembly. We look forward to seeing you there!

Members of the Executive Committee of the T.I.C. 2016-2017

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 named here was approved by the T.I.C. members at the Fifty-seventh General Assembly and consists of (alphabetical by surname):

Conor Broughton       conor@amgroup.uk.com
John Crawley          jcrawley@mrcmc.com.hk
David Gussack        david@exotech.com
David Henderson (President) dhenderson@rittenhouseir.com
Marc Hüppeler        marc.hueppeler@hcsarck.com
Jiang Bin            jiangb_nniec@otive.com.cn
Kokoro Katayama      kokoro@raremetal.co.jp
Raveentiran Krishnan raveentiran@msmel.com
David O'Brock        david.obrock@gmail.com
Candida Owens        candida.owens@btinternet.com
Daniel Persico       danielpersico-rc@tokin.com
Alexey Tсораyev      tsorayevaa@ulba.kz

Of these twelve, Mr David Henderson was re-elected as President of the T.I.C. until October 2017. The next elections will take place on Monday October 16th 2017 in Vancouver, Canada.

To stand for election in October 2017 please email emma.wickens@tanb.org before September 16th 2017.

The T.I.C. currently has the following subteams (chaired by): Marketing (Daniel Persico), Meetings (David Gussack), Statistics (Alexey Tсораyev) 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.