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TANTALUM-NIOBIUM
INTERNATIONAL STUDY CENTER
Bulletin N° 175: October 2018

Ytterby: where it all began

(for tantalum, at least, see page 4)

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President's Letter

Dear Fellow Members and Friends,

It is my great privilege to welcome all of you to central Africa this October, a region where I spend much of my time, and from which our members source a large percentage of our industries' supply. I think you will find the conference will be in a very convenient African location, with a first class hotel, in a modern, safe, beautiful and clean country.

Rwanda is known for its regional pro-business environment, capable of attracting foreign investments and business entrepreneurs. In Rwanda, it only takes a few days to incorporate a company, and you will find the government will provide needed assistance along the way. Rwanda is the easiest place in central Africa to set up and manage a business.

Businesses do not exist in a vacuum – they need a supportive political infrastructure to grow and thrive. Rwanda's political system is one that enacts laws, decides priorities and sets regulations using a rational, pro-business approach. Rwanda has a stable and orderly government, whose vision is to develop the nation into a modern industrialized country.

Our annual General Assembly (AGM and conference) has earned an international reputation for being the gold standard in 3Ts networking. Membership of the T.I.C. gives you immediate access to hundreds of business professionals. These members and attendees are all dealing in our minerals, metals, chemicals and end use products representing all market segments from across the world. The T.I.C. is the only international organization of its kind, representing the tantalum and niobium industry.

While business meetings will clearly be an important opportunity for us all, I would most appreciate it, if we can also focus on our organization's efforts in guiding our industries ability to build trust in our two minerals and to promote tantalum and niobium and their unique properties.

In 2018 we have seen recent and sustainable success. Electronics companies have designed in tantalum and niobium products over their competitors. While we are seeing good results in industrial applications, this year will involve significant potential for compliance and supply difficulties.

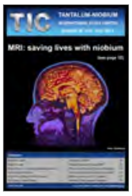
Within the next few months we will see the roll out of compliance programs that incorporate the updated Organization for Economic Cooperation and Development (OECD) recommendations. Companies will begin to enact worldwide due diligence as a result of the upcoming European regulation on conflict minerals. These changes will effectively expand the compliance that our members have become familiar with in central Africa, globally. The interpretation of conflict affected and high risk areas, methods of scrutiny and transportation of concentrates through countries all have the potential to make supply difficult. It is a time when our industry and the T.I.C. need to proactively engage many stakeholders so that we can obtain a workable system for worldwide compliance that is adequate to protect our industries' reputation.

Your executive board values your membership, and commitment to tantalum and niobium. Our staff is here to support and encourage your success and development, and takes great pride in the important role that each of you play in our industries.

Sincerely yours,

John Crawley

President



Join our mailing list to receive the Bulletin directly by email

Our mission with the Bulletin is to provide the global tantalum and niobium community with news, information and updates on our work. We hope you enjoy reading it and you will want to continue receiving it in the future.

Email **info@tanb.org** to join our mailing list and keep up to date with the T.I.C.

Director's Letter

Uppsala, Sweden

Dear T.I.C. Members,

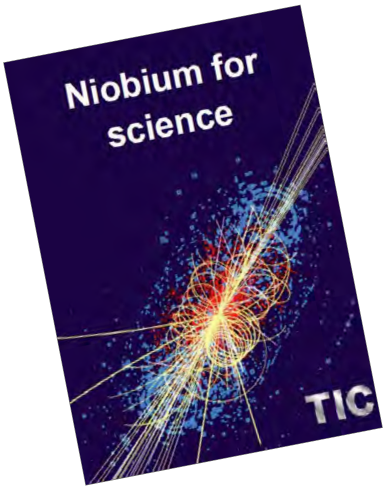
Welcome to an edition of our quarterly newsletter which arguably spans the entire history of one of our two elements, tantalum. The link is Anders Gustaf Ekeberg, the Swedish chemist who first identified tantalum in 1802, and after whom we named our new annual prize for excellence in tantalum.

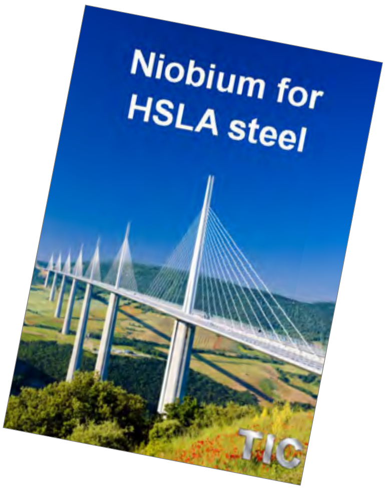
Our story starts by visiting the mine in Ytterby, Sweden, that supplied the mineral samples in which Ekeberg discovered tantalum. From there, we visit his university in Uppsala, Sweden, to understand the context of his discovery and the impact this had on the scientific community at the time.

Of course, the story of tantalum never stops unfolding, but one of the latest chapters is undoubtedly the Anders Gustaf Ekeberg Tantalum Prize. Regular readers of the Bulletin will know how this Association has established the prize, selecting an independent Panel of Experts and boiling down the inaugural shortlist to six publications. Now the time has come to recognise the winner (see page 24), who will receive his prize during the 59th General Assembly which will be held in Kigali, Rwanda, in October 2018.

Niobium news

Whenever my colleagues and I are on the road, meeting stakeholders and promoting the interests of the global tantalum and niobium industry, we often meet people from all walks of life for whom our two elements are something of a mystery. To combat this problem, and as part of the Association's ongoing efforts to promote better understanding and appreciation for niobium and tantalum, we have developed a series of short, introductory guides for a non-technical audience. In Bulletin 174 three guides to tantalum were introduced and now a matching set has been created about niobium:





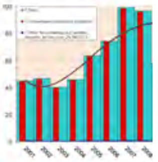
All the guides are available on our website (www.TaNb.org) and paper copies are available on request. We know we have only scratched the surface of the many essential applications of niobium and tantalum and look forward to hearing your feedback on how to improve and expand this initiative in the future.

Best wishes,

Roland Chavasse, Director

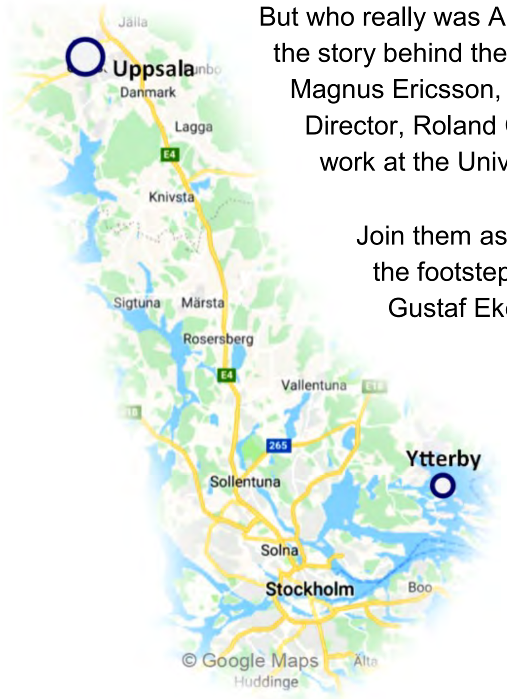
Statistics workshop at the 59th General Assembly: Monday October 15th at 3:30p.m. to 4:30p.m.

During the 59th General Assembly David Knudson, the T.I.C. Technical Officer, will be holding a statistics workshop from 3:30p.m. to 4:30p.m. on Monday at the Marriott Kigali Hotel (room to be confirmed). If you have any questions about the T.I.C. statistics service, how to report your data or what data to report, then please come along and discuss your questions with David.



In the footsteps of Anders Gustaf Ekeberg

It was in 1802 that Anders Gustaf Ekeberg discovered the element tantalum (Ta) through his analysis of two minerals - yttrotantalite from Ytterby, Sweden, and tantalite from Kimito, Finland. In recognition of Ekeberg's pioneering work, in 2017 when the T.I.C. set up an award to recognise excellence in advancing the knowledge and understanding of the element tantalum (Ta), it was named the Anders Gustaf Ekeberg Tantalum Prize ("Ekeberg Prize") in his memory.



But who really was Anders Gustaf Ekeberg? How did he discover tantalum? And what is the story behind the source of his new mineral samples? To learn more, Professor Magnus Ericsson, a member of the Ekeberg Prize panel of experts, and the T.I.C.'s Director, Roland Chavasse recently visited the Ytterby mine and Ekeberg's place of work at the University of Uppsala, both in eastern Sweden.

Join them as they follow the footsteps of Anders Gustaf Ekeberg.

A beautiful morning in eastern Sweden, perfect for a road trip to follow in the footsteps of Anders Gustaf Ekeberg

The mine at Ytterby

It was a sunny morning in early September when we set out in Professor Ericsson's 1970 Jaguar XJ6. The first stop on our trip was Ytterby, a sleepy commuter village on the island of Resarö, part of the Stockholm archipelago. On arrival we were welcomed by Eric Thorslund from the Ytterby Mine Association (http://ytterby.org), an organisation working to preserve the mine's heritage and make it accessible to visitors.

Today most of Ytterby's residents work in Stockholm and their fine timber homes, pleasure-boats and apple trees project an image of comfortable domestic life. However, beneath the surface, buried in the island's granite core, lies a former mine which produced more previously unidentified elements than any other mine in the world.

It is unknown how early mining at the site started, but certainly by the 16th century quartz mining operations were well established here and at several other granite pegmatite outcrops nearby.

An example of 18th century Swedish porcelain, made by Rörstrand, one of the companies supplied with Ytterby feldspar (Photo: Rörstrand)

What made Ytterby mine stand out was the unusually rough crystals it produced, which were relatively easy to separate and enrich, ready for use in the iron and glass industries. By 1790 the mine was also being exploited for feldspar which was used to produce ceramics. Ytterby's feldspar commanded a premium as it had a low iron content that made for an exceptionally white porcelain.

In 1787, an army officer surveying Resarö island as a potential fortress site found a heavy black stone in the mine tailings. He took it away for analysis, hoping that it contained tungsten, but it didn't. Instead the mineral contained large amounts (38%) of a previously unknown oxide. This was identified as yttria by Finnish chemistry professor Johan Gadolin, a result independently confirmed by Ekeberg who had already made a name for himself as an outstanding mineral analyst. Gadolin called the mineral ytterit, but it has since been renamed gadolinite in his honour.

The discovery of yttria heralded the start of a golden age for Swedish chemistry and over the next century no fewer than ten new elements were to be found in Gadolin's yttria. The Ytterby minerals proved to be a rich source of previously unidentified elements, especially the rare earths.

Gadolinite from Ytterby mine (Photo: T.I.C.)

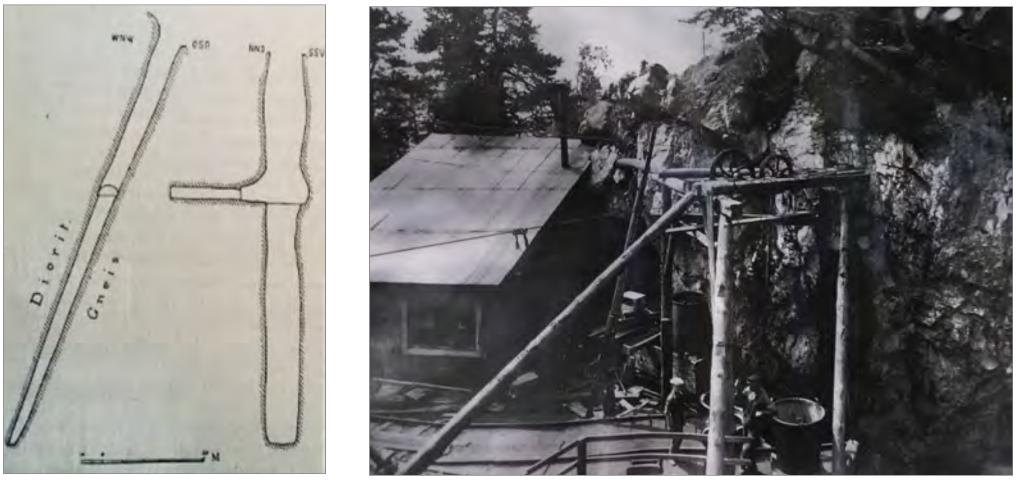
In total, four of the new elements were named after the mine:

- yttrium (Y)
- ytterbium (Yb)
- erbium (Er)
- terbium (Tb)

While four more were named for regional connections:

- gadolinium (Gd), after Johan Gadolin
- scandium (Sc), after Scandinavia
- holmium (Ho), after the Latin name for the city of Stockholm
- thulium (Tm), after the land of Thule, an Ancient Greek place name associated with Scandinavia.

However, while identifying and naming new elements might have been exhilarating for academic chemists, without a market the new elements didn't pay the bills and at Ytterby mine the impact of such chemical discoveries was nothing compared to the impact of dynamite. By the late 19th century the main shaft was 170m deep, leaning at 60 degrees in a westerly direction.



The working mine (pit head) in the 1920s and a diagram of the shaft in 1908
(Photos: Ytterby Mine Association)

The working mine in the 1920s; a trolley ran down to the sea
(Photo: Ytterby Mine Association)

Production at Ytterby peaked around 1900, but, soon after that, several porcelain plants relocated from Stockholm to western Sweden and mining slowed to a halt in 1933.

For twenty years the mine lay abandoned, until in 1953 it was one of several former mines that were converted to become fuel storage facilities for the Swedish military. The shaft was sealed with concrete and filled with up to 53,000 m^3 of aviation fuel, floating on a water pillow that provided depth control. This arrangement didn't last long, though, as it was discovered that rare microbes in the tunnels were poisoning the aviation fuel. Thereafter Ytterby was then used to store diesel fuel for naval vessels until 1995 when it was emptied of fuel and a rehabilitation process was started.

Two views of the mine as it is today; (left) looking down into the pit from the north, (right) looking from the south rim. (Photos: T.I.C)

Roland Chavasse at Tantalvägen, Ytterby (Photo: T.I.C.)

After some twenty years of treatment the mine shaft is considered clean, but it is inaccessible to the public, flooded with water and buried beneath 15 m of concrete.

Today, the visible remains of the Ytterby mine form a surprisingly small and peaceful glen. A few noticeboards and a small plaque erected by ASM International discuss the history of the mine and mention that rare earths were found here, but otherwise there is little indication just how important this site is to the history of chemical discovery.

Perhaps the most lasting reminder of Ytterby's importance to the periodic table comes from the local street names: Terbiumvägen, Gadolinitvägen, Yttriumvägen, and, of course, Tantalvägen.

It was time to travel north to Uppsala for the next stage of our journey.

Ekeberg's early years and the context of Swedish chemical discoveries

Anders Gustaf Ekeberg

Uppsala University is understandably proud of its alumni and our hosts Mikael Norrby and Thomas Fredengren spared no effort in helping us to understand the context of Ekeberg's life and what motivated his work.

Anders Gustaf Ekeberg was born on January 16th 1767 in Stockholm, Sweden. His father was a shipbuilder in the Swedish Royal Navy and as a boy Ekeberg benefited from a broad education. Although he suffered from poor health throughout his life, from an early age Ekeberg excelled at school and displayed an insatiable thirst for knowledge, especially for Greek literature, poetry, natural science and mathematics.

His interest in natural science was undoubtedly encouraged by his uncle, Carl Gustaf Ekeberg, a captain in the Swedish East India Company, who regularly collected botanical and zoological samples for the botanist Carl Linnaeus, on his many journeys to Asia and Africa. Linnaeus, the father of modern taxonomy, repaid the favour by naming a genus of mahogany trees *Ekbergia*.

Given the family connection, it is not surprising that when Anders Ekeberg was old enough to study at Uppsala University he chose to focus on botany, studying under Linnaeus's pupil Carl Peter Thunberg. On graduating in 1788 Ekeberg travelled to Germany, hoping to meet the leading natural scientists of his day.

However, northern Germany in winter offers few opportunities for a budding botanist and Ekeberg's focus soon moved on to a less seasonal subject, the analytical chemistry of minerals. This was to be the start of a life-long fascination and became his core subject on returning to Uppsala in 1790.

In 18th century Sweden, chemistry was highly utilitarian and had very close links with mining. In 1739 the government had established the Royal Swedish Academy of Sciences (Kungliga Vetenskapsakademien) to promote the development of practically useful knowledge in Sweden (publishing for the first time in Swedish, rather than Latin), and by Ekeberg's time 'utility' was the overriding framework for chemistry, mineral analysis and metallurgy. By all accounts Ekeberg was fully committed to the goal of utility and saw his work as a key contributor to the happiness of mankind.

Royal Swedish Academy of Sciences (Kungliga Vetenskapsakademien)

Ekeberg lived during a time of great scientific and social progress (and political change) in Europe, including the dawn of the new science of chemistry as distinct from alchemy. Central to the new chemistry was the quantitative work of Antoine-Laurent de Lavoisier, the French "father of modern chemistry", who identified and named oxygen, nitrogen and hydrogen, helped to construct the metric system and to establish a chemical nomenclature.


Ekeberg's laboratory in the Laboratorium Chemicum, now part of Uppsala University's law library (Photo: T.I.C.)

Lavoisier's work went against centuries of 'phlogistic' chemistry which claimed a fire-like element called phlogiston is released as flame during combustion. Differences between the two schools of chemistry were the subject of heated arguments during this period and many older academics bitterly resisted the new ideas.

To Ekeberg, ever the utilitarian, Lavoisier's new element-based chemistry provided more answers, especially in metallurgy, and he became an early convert, even if it meant he sometimes had to publish anonymously to avoid upsetting his professor, Johan Afzelius.

Ekeberg finds fame

In 1795 Ekeberg published *Om chemiska vetenskapens narvarande skick* (*On the Present State of the Chemical Science*), a proposal for Swedish names for the recently discovered elements hydrogen (väte), nitrogen (kväve), and oxygen (syre). Later that year he and the physician Pehr Afzelius (the brother of his professor, but a committed antiphlogist) jointly published a complete nomenclature, *Forsok till svensk nomenklatur for chemien, liimpad ejter de sednaste upptackterne* (*An Attempt Toward a Swedish Nomenclature for Chemistry*).

Although both documents were published anonymously, they made a great impact and when the identity of the authors became known it confirmed Ekeberg's place in the foremost ranks of Sweden's chemists of the day. He was elected a member of the Royal Swedish Academy of Sciences in 1799. As proof of Ekeberg's ability, he was elected before his professor, Johan Afzelius, was.

Ekeberg discovers tantalum

Throughout his life Ekeberg was never financially successful (including one disastrous attempt at wine-making), even as he gained a Europe-wide reputation as a superb analytical chemist of minerals. He was often invited to confirm new chemical discoveries and this included the mineral ytterit (gadolinite) in 1797 found in samples taken from the Ytterby mine; this was the mineral which later was found to contain over a dozen different "rare earth" elements.

In 1802 while he was analysing new samples from Ytterby and also a mineral labelled as a "tin garnet" taken from Kimito, near Åbo in Finland, Ekeberg noticed a previously unknown element.


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

The mineral sample from Ytterby was yttrotantalite, a rare earth tantalate containing a high concentration of yttrium and tantalum, while the “tin garnet” from Kimito was found to actually be tantalite. Experiments on these minerals resulted in the isolation of a ‘new metal oxide’.

Ekeberg named his discovery tantalum, partly to follow the practice at that time of taking names from Greek mythology, and partly in recognition of the difficulty he found dissolving it in any of the available acids in his laboratory.

While Ekeberg was undoubtedly pleased to have identified tantalum, as a chemist who placed such a high importance on utility, one can only imagine how he viewed an element which had no apparent purpose.

Later years

Among the students taught by Ekeberg was a young man named Jöns Jacob Berzelius who would later bring significant fame to the University of Uppsala and ranks alongside Lavoisier as one of the fathers of modern chemistry. When Berzelius was not discovering new elements (selenium, silicon, thorium, cerium, and zirconium) he tirelessly defended Ekeberg’s discovery of tantalum.

The legend of Tantalus

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

In Greek mythology Tantalus was the king of Phrygia in present-day Turkey, and also a demi-god.

He offended the gods and in a desperate attempt to apologise he killed his own son as a sacrifice, cooked him served him to the gods at a banquet.

However, his crime was discovered and the gods were not amused. As punishment Tantalus was condemned to suffer eternal frustration. He was forced to stand eternally beneath a fruit tree with low branches in water up to his neck, but the water receded whenever he attempted to drink it and wind blew the fruit out of reach whenever he reached up to pick them.

Anders Gustaf Ekeberg was portrayed by all those who knew him as a kind and gentle man. He was very popular in his student body, the Upland Nation, because of his prodigious output of poetry (including one poem that was read in public when the King Gustaf III of Sweden visited Uppsala in 1801), much of which was set as songs by the other students for their regular musical evenings.

His contemporary, the Swedish writer Carl Christoffer Gjörwell described Ekeberg as being a “philosopher, naturalist and poet, young, beautiful, free, open to the soul, [and] precious to the heart”. However, he suffered from poor health, including tuberculosis, deafness, and blindness in one eye, the latter caused by a laboratory explosion in 1801, and in later years his activity was greatly reduced due to his frail health. Ekeberg never married or had children.

He died on February 11th 1813 at the age of just 46. He is buried in Uppsala University’s cemetery.

Paying our respects at the grave stone of Anders Gustaf Ekeberg: (L-R) Roland Chavasse, Magnus Ericsson, Mikael Norrby and Thomas Fredengren (Photo: T.I.C.)

Postscript: controversy about tantalum and columbium

Controversy about tantalum erupted almost as soon as the element had been identified. A year before Ekeberg's discovery of tantalum Charles Hatchett, working in England, had identified columbium (as he named it) from some American mineral samples. Since chemical analysis was still in its infancy and test samples of columbium- and tantalum-bearing minerals were rare, the challenge of separately identifying the two similar elements was too difficult for most chemists.

One such was William Hyde Wollaston who published a paper in 1809 claiming that columbium and tantalum were the same element. His paper may have been soon forgotten, had it not influenced Thomas Thomson, the editor of a highly popular series of books on chemistry. Soon after Ekeberg's death, Thomson published an English translation of a memoir about Ekeberg that had been written by Berzelius. However, what could have clarified the matter only made things worse when Thomson took the editorial decision to change the word "tantalum" to "columbium" throughout the document.

Jöns Jacob Berzelius, Uppsala's most famous chemist and an ardent admirer of Ekeberg, his former tutor.

Berzelius came out in defence of his former tutor, since although Berzelius believed that the discoveries made by Hatchett and Ekeberg were of the same element, he argued that "tantalum" was a better name and Ekeberg's claim was stronger. Berzelius wrote that 'Without wishing to depreciate the merits of the celebrated Hatchett, it is nevertheless necessary to observe that tantalum and its properties in the metallic as well as in its oxidized condition were not known at all before Mr Ekeberg'. And he continues 'The reason for the name tantalum (derived from the story of Tantalus) is still more valid if one adds that metallic tantalum, reduced to the finest powder, is not attacked by any acid, not even by aqua regia, concentrated and boiling'.

Professor Ericsson with his beautiful 1970 Jaguar XJ6, ready to follow in Jean Charles Galissard de Marignac's footsteps? (Photo: T.I.C.)

The debate raged until 1865, over half a century after Ekeberg's death, when the Swiss chemist Jean Charles Galissard de Marignac used spectroscopic analyses to confirm that tantalum and columbium/niobium were in fact two different elements, but that is a different story for another road trip.

Acknowledgements

This article is indebted to Magnus Ericsson, Eric Thorslund from the Ytterby Mine Association, and Mikael Norrby and Thomas Fredengren from Uppsala University for their generous advice, guidance and research assistance with this project.

Notes:

In a few contemporary sources Ekeberg's middle name is recorded as "Gustav". We use the form "Gustaf" that is used by the Svenskt Biografiskt Lexikon, the Swedish national biographical record. https://sok.riksarkivet.se/Sbl/Presentation.aspx?id=16798

This article was inspired by a series of articles written by C. Edward Mosheim, T.I.C. Technical Promotion Officer from 1999 to 2003.

A study of the map of Finland suggests that the sample of tantalite from Kimito was from the same general area as Kemiö Island, Finland, the site of the Rosendal Project of Tertiary Minerals.

Further reading:

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Ytterby Mine Association (http://ytterby.org)

Temperature stability assessment of GaN power amplifiers with matching tantalum capacitors

This is a summary of a recent paper by T. Zednicek at the European Passive Components Institute, Lanskroun, Czech Republic (www.passive-components.eu), R. Demcko, M. Weaver, and D. West at AVX Corporation, Fountain Inn, SC, USA, and T. Blecha, F. Steiner, J. Svarny, and R. Linhart at RICE, University of West Bohemia, Pilsen, Czech Republic. The full report can be downloaded at https://lnkd.in/dQns22u.

Introduction

In coming years wide band gap gallium nitride (GaN) and silicon carbide (SiC) power amplifiers are expected to experience high levels of growth in applications ranging from power conversion to radio frequency (RF) transistors and monolithic microwave integrated circuits (MMIC, a type of integrated circuit device that operates at microwave frequencies). End users recognise that GaN technology has the advantageous ability to operate under higher currents and voltages than its competitors. The popularity of GaN systems for RF is increasing rapidly and the RF GaN market is expected to grow at 22.9% CAGR through 2017-2023, boosted by the implementation of fifth generation (5G) mobile phone networks.

Nevertheless, the GaN "revolution" is not only about the high RF frequencies. During the past recent years, the wide band semiconductors have reported achievement of over a 1000 V breakdown voltage that opens new challenges for high power industrial applications such as electric traction systems in trams, trolley buses or high-speed trains.

Decoupling and BIAS matching tantalum capacitors are used due to their stability of capacitance value over a wide temperature range, stable capacitance with BIAS, no piezo noise sensitivity at small, low profile case sizes. They are not prone to wear out associated with aluminium electrolytic capacitors and exhibit high reliability and stability across temperature, voltage and time.

GaN RF Power Amplifiers

Telecom and defence markets are and are expected to remain key markets for the GaN industry. Due to the increasing pace of development of 5G networks, the telecom market will bring a huge opportunity for GaN devices. Compared with existing technologies (silicon LDMOS and gallium arsenide (GaAs)), GaN devices can deliver the power and efficiency required for next-generation high-frequency telecom networks.

Also, the broadband capability of GaN power amplifiers is a key factor for enabling important new technologies, such as multi-band carrier aggregation (a way to maximise the capacity of telecom networks that includes exploiting fragmented spectrum allocations between different phone companies).

At the same time, market volumes will increase faster because higher frequencies reduce the coverage of each base station, hence more transistors will be implemented.

An example of a RF GaN power amplifier (Photo: Cree)

Linearity is one of the key power amplifier design parameters. Requirements for the best linearity of RF GaN power amplifiers can be achieved by two ways: 1) use of optimum output impedance of the optimum linearity, this could however limit the output power and decrease efficiency. Or, 2) use optimum output impedance for maximum power output and define the working linearity region by the proper BIAS point setting and optimization. This way requires a proper design of BIASing circuits and their stability in wide operating conditions. The same consideration is valid for a proper design of the gate BIAS level.

Tantalum capacitors have become the favourite choice for BIAS decoupling capacitors in GaN power amplifiers, ensuring stability of their electrical parameters at various conditions and keeping the GaN transistor working point within the high linearity region.

RF GaN reference designs with tantalum capacitors include units by Nitronex (part of MACOM), Qorvo and Wolfspeed (part of Cree Inc.):

◊ Nitronex NPTB00004 GaN 28V, 5W RF Power Amplifier for CW, pulsed, WiMAX, W-CDMA, LTE, DC to 6 GHz. 10μF 16V gate decoupling capacitors.

◊ Qorvo QPD1008 125W, 50V, DC – 3.2 GHz, GaN RF 10μF 16V gate BIAS decoupling capacitors.

The other Qorvo designs:

- QPD1008L DC - 3.2 GHz, 125 Watt, 50V GaN RF Power Transistor
- QPD1009 DC - 4 GHz, 15 Watt, 50V GaN RF Transistor
- QPD1010 DC - 4 GHz, 10 Watt, 50V GaN RF Transistor
- QPD1015L DC - 3.7 GHz, 65 Watt, 50V GaN RF Power Transistor

A TIDA 00961 GaN board by Texas Instruments, designed for telecom, servers and industrial power supplies refers to tantalum capacitors (photo: Texas Instruments)

◊ Cree / Wolfspeed CGHV50200F 200W, 4400 - 5000 MHz, 50-Ohm Input/Output Matched, GaN HEMT with 10μF 16V capacitors

The other Cree references:

- CGH40006P 6 W, RF Power GaN HEMT
- CGH40010 10 W, DC - 6 GHz, RF Power GaN HEMT
- CGH40025 25 W, RF Power GaN HEMT
- CGH40045 45 W RF Power GaN HEMT
- CGH55030F1 / CGH55030P1 30W, 5500-5800 MHz, 28V, GaN HEMT for WiMAX

Conclusions

The authors of this paper undertook a board temperature assessment using a GaN test circuit using tantalum capacitors and results displayed a very good stability. The reference measurement on the test GaN RF power amplifier Qorvo QPD 1008 with a tantalum 10 μF 16 V decoupling capacitor confirmed its very good stability through the temperature range -30 °C to +70 °C. This supports the widely held belief that tantalum capacitors provide high capacitance efficiency in small dimensions with stable electrical parameters over their long lifetime.

The rate of improvements of conventional metal-oxide semiconductor field-effect transistors (MOSFETs) has levered off, as their performance is now close to its theoretical limits as determined by the underlying fundamental physics of these materials and processes.

GaN is featuring a higher critical electric field strength than silicon that is resulting in a smaller size for a given on-resistance and breakdown voltage than a silicon semiconductor. GaN also offers extremely fast switching speed and excellent reverse-recovery performance, critical for low-loss, high-efficiency performance. This feature supports GaN as an ideal choice for RF systems and the upcoming fast growing 5G networks development as well as the growing market of high power ~1 kV industrial applications such as renewable energy, electric and hybrid-electric vehicles, power traction systems, servers and similar applications. GaN advantages can bring also new applications that have not been possible to make within such small a size and simplified architecture so far such as the 48-V to 1-V single-stage hard-switched converter.

Stability in a wide temperature range and harsh conditions is one of the design challenges for a number of industrial applications. Linearity, efficiency, stability and high-power outputs are mostly driven by the desire for good impedance matching and stable gate BIAS working point setting. Tantalum capacitors have been the favourite solution for BIAS decoupling circuits in the latest GaN power amplifiers and this situation is expected to continue for the foreseeable future.

For a list of references and further information on this subject please visit www.passive-components.eu.

Ultra-low profile tantalum capacitors

Paper written by Chris Stolarski, Brandon Summey, Keith Moore, and Siva Lingala, KEMET Electronics Corp., and presented by Chris Stolarski on October 16th 2017, as part of the Fifty-eighth General Assembly in Vancouver, Canada. All views and opinions in this article are those of the authors and not the T.I.C.

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Introduction

KEMET Electronics has been producing surface mount solid electrolytic capacitors since the late 1980s. As time and customer needs have evolved, the product lines have expanded from Tantalum Manganese Dioxide to Tantalum Polymer and Aluminum Polymer. This evolution of counter electrode and dielectric types has opened significant markets for new uses of tantalum, but there is still one key capability that drives the industry: improved capacitance and voltage per unit volume (CV/cc), see Figure 1 for the history of CV/cc.

Electronic Components KEMET CHARGED.
Electronic Components TOKIN A KEMET Company

ULTRA-LOW PROFILE CAPACITORS

T.I.C. Conference, October 16, 2017

Chris Stolarski
Sr. Director,
Advanced Platform & Tantalum Powder Development

From the market perspective, there is a strong demand to continue improving capacitive technology that will provide higher packaging efficiencies or CV/cc. As an example, IoT and connectivity have been two key drivers for the broad adoption of small electronic products - wearables, mobile device, smart phones, laptops, displays, cameras, and sensors - across market segments, notably consumer, industrial, automotive, and medical. According to IC Insights, between 2015 and 2019 worldwide systems revenues for applications connecting to the IoT will nearly double reaching $124.4 billion in 2020. During that same time-frame, new connections to the IoT will grow from about 1.7 billion in 2015 to nearly 3.1 billion in 2019. Further miniaturization of these products will require smaller discrete, integrated, and/or modular components. Therefore, the large physical space on circuit boards that passives (i.e. capacitors, resistors, and inductors) use today must be reduced. KEMET/TOKIN's response to this need has been the development of more efficient packages such as face down, F/PS and G/PS designs. See Figure 2 for images of these designs. Most recently, there is interest in ultra-low profile capacitors less than 1.0 mm in case height. Designing capacitors below 1.0 mm is increasingly more difficult compared to previous height reductions requiring capability improvements in the anode, cathode layer and packaging as well as the variation of each. Customers further desire surface mount capacitors less than 0.5 mm which will challenge the suitability of tantalum from a cost and CV/cc perspective.

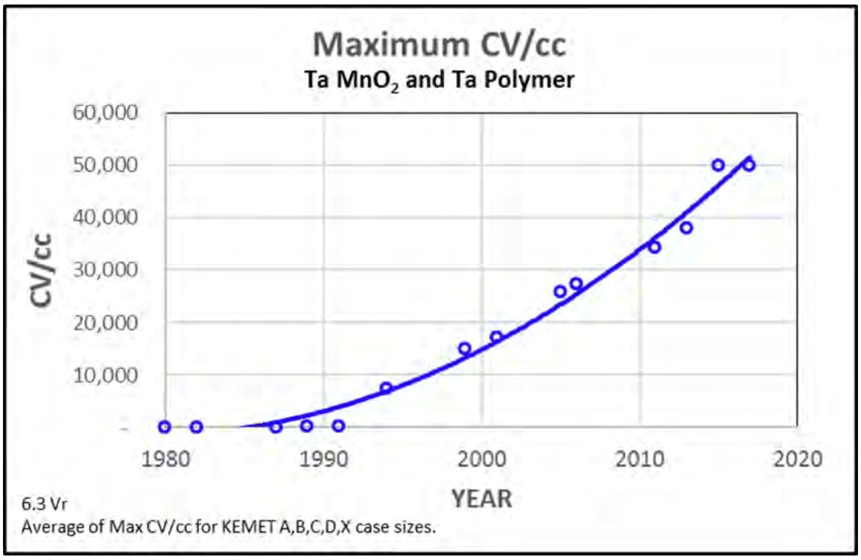


Figure 1: CV/cc timeline by major case sizes

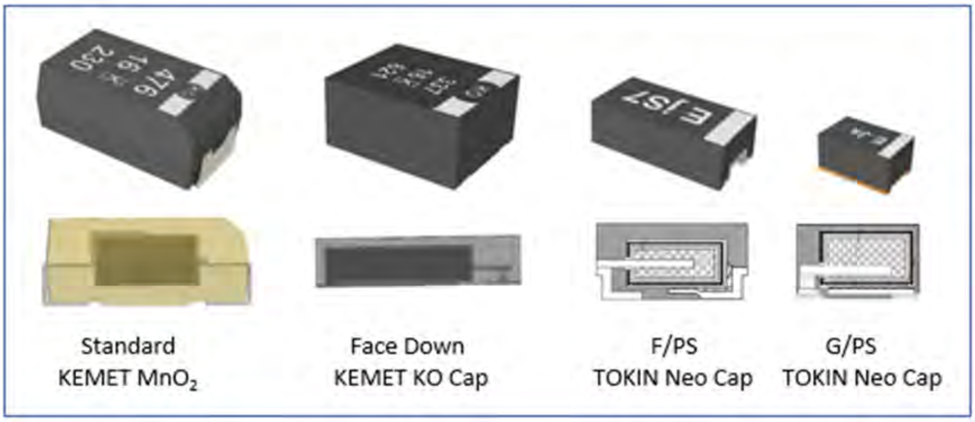


Figure 2: KEMET / TOKIN Tantalum Polymer Package designs

Process of tantalum solid electrolytic capacitors

Manufacturing of tantalum capacitors is a relatively complex process comprising more than 200 steps. An outline of this process is shown in Figure 3. The manufacturing process of polymer tantalum capacitors begins with the pressing and sintering of micrometer-size tantalum powder to form porous pellets which are electrochemically anodized to produce tantalum pentoxide (Ta_2O_5) dielectric. Conductive material as the first layer of cathode is deposited onto the surface of the dielectric via pyrolysis of $Mn(NO_3)_2$ into MnO_2, in situ chemical polymerization, electrochemical polymerization, or coating by pre-polymerized conductive polymer dispersion. Washing and reformation may be used as necessary to remove contaminates and by-products. Carbon and silver coatings are applied to connect the cathode layer to the lead-frame which, after encapsulation, provides the electric connection from the capacitor to the application circuit. The moulded case typically consists of an epoxy moulding compound containing glass fillers. It protects the capacitor from moisture, oxygen, chemical or mechanical stress. The moulded semi-finished products undergo laser marking, inline burn-in or aging, and 100% electrical testing, before final packaging into embossed carrier tape.

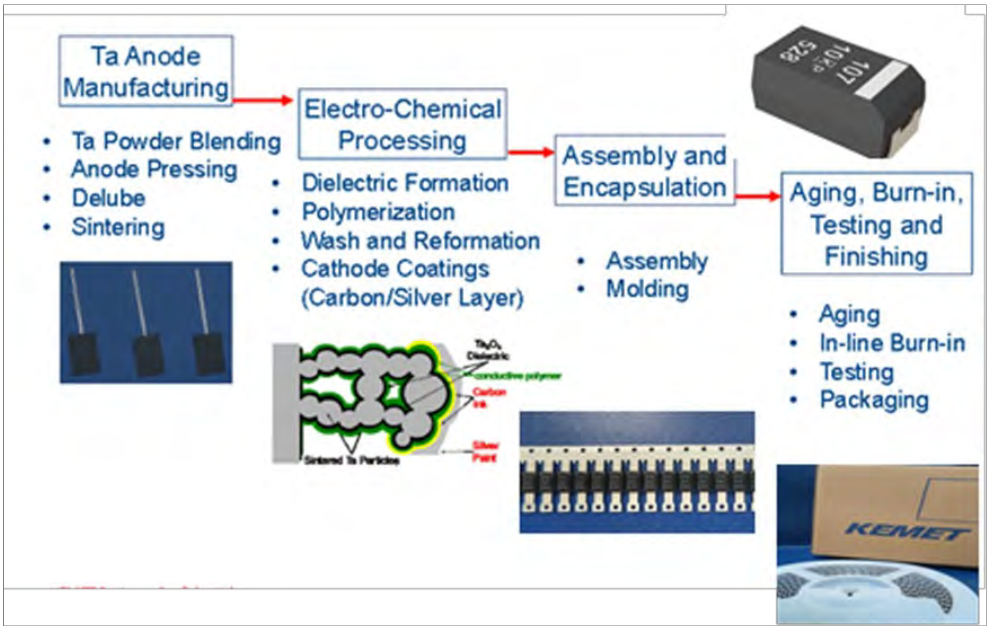


Figure 3: Manufacturing process of KEMET tantalum capacitors

Construction of tantalum solid electrolytic

The basic construction of a tantalum surface mount capacitor is shown in Figure 4. The components contributing to the height of the capacitor are the anode, cathode layers, lead frame and encapsulating materials.

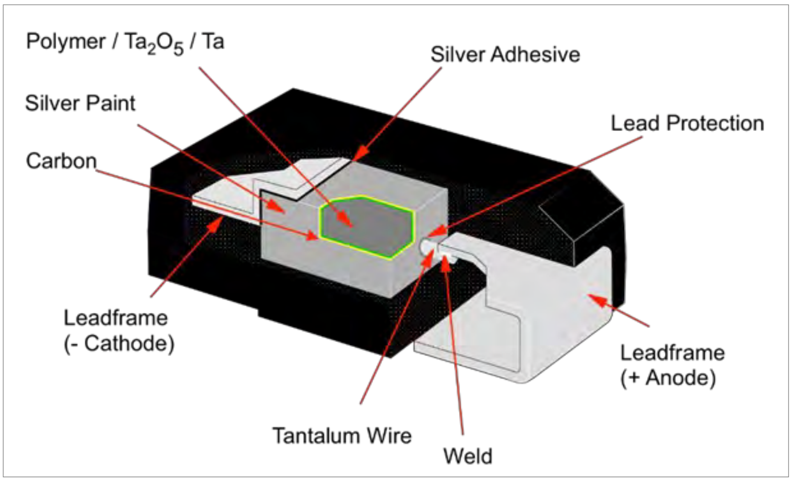


Figure 4: Basic construction of tantalum capacitor

Face down package construction was introduced at KEMET for tantalum polymer capacitors in May 2006. The advantage of face down, see Figure 5, was to increase the volumetric efficiency or CV/cc of the package given the same anode and cathode layer materials and processes. The face down construction also effectively removed the height equivalent of one layer of lead-frame, one layer of mould epoxy and the lead forming tolerance from the capacitor thickness. Figure 5 shows the comparison between the standard and the face down constructions. This gives a clear advantage over the standard construction for an ultra-low profile capacitor.

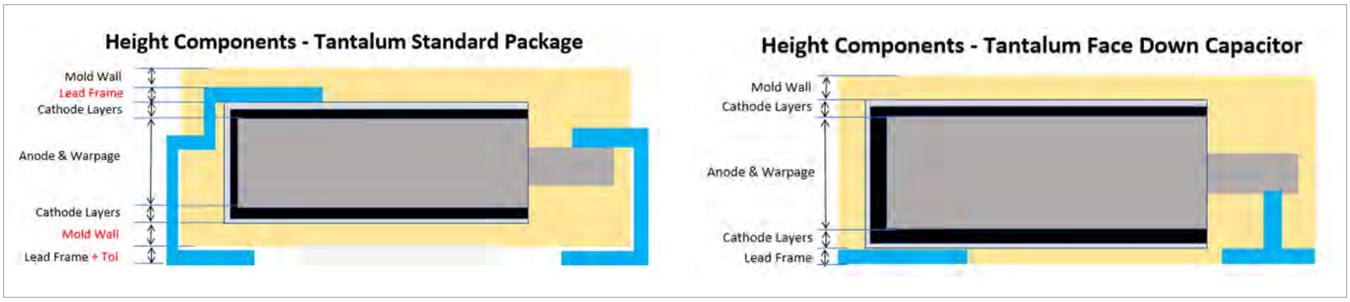


Figure 5: Standard vs face down components to case height.

A “Height Efficiency” can be defined as the % of the available case height occupied by the sintered anode. Current tantalum anode heights and height efficiency versus case heights are shown in Figure 6. In addition, the projected ultra-low profile anode heights are included. This projection demonstrates how the height efficiency decreases rapidly below 1.0 mm.

% Height Efficiency = 100% x Ta anode thickness (mm) / Max Case Height (mm)

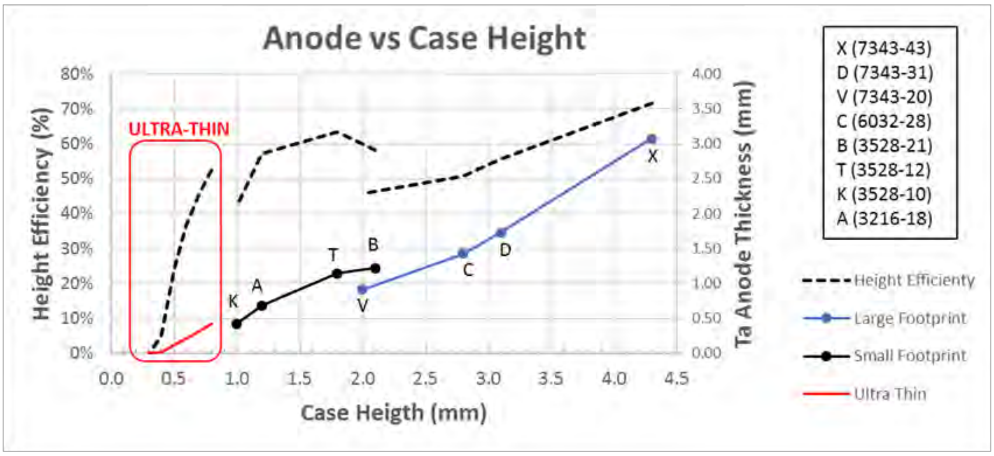


Figure 6: Anode vs case height

Pursuing less than 1.0mm case height

As development commenced on the less than 1.0 mm height capacitor it became readily apparent that the previous methods of removing thickness from the anode to achieve a thinner package would rapidly result in no anode remaining. Table 1 demonstrates the anode thickness calculation using current capabilities for the face down construction for the case sizes based on 7343 footprint. The table illustrates that there is 39% reduction in height and capacitance of the anode from 1.2 mm to 1.0 mm. Going to 0.7 mm, the anode thickness is reduced to 0.02 mm and almost all the capacitance is lost. In addition, at this anode thickness foil technology is better suited than pressing an anode with an embedded tantalum wire.

7343 Footprint (7.3 mm L x 4.3 mm W)	Standard	Face Down			
	1.2 mm	1.2 mm	1.0 mm	0.7 mm	0.5 mm
Molded Case Tolerance	0.03 mm	0.03 mm	0.03 mm	0.03 mm	0.03 mm
Cathode layers	0.20 mm	0.20 mm	0.20 mm	0.20 mm	0.20 mm
Encapsulant (bottom)	0.15 mm	Same plane as Lead frame			
Encapsulant (top)	0.15 mm	0.15 mm	0.15 mm	0.15 mm	0.15 mm
Lead Frame	0.11 mm	0.15 mm	0.15 mm	0.15 mm	0.15 mm
Lead Frame Under Part	0.15 mm	-----------	-----------	-----------	----------
Anode warpage	0.10 mm	0.10 mm	0.12 mm	0.15 mm	----------
Anode	0.31 mm (0.012”)	0.57 mm (0.022”)	0.35 mm (0.014”)	0.02 mm* (0.001”)	< Zero!!!
% Reduction in Case Height from 1.2 mm			-17%	-33%	-58%
% Reduction in Cap			-39%	-96%	-100%

*Cannot press anode 0.02 mm thick.

Table 1: Ultra-Low Profile anode thickness - current capabilities

To develop further capacitor heights less than 1.0 mm, other capabilities need to be improved:

1. Anode warpage
2. Cathode layer thickness (polymer, carbon and silver coating)
3. Lead frame thickness
4. Encapsulant or wall thickness

1. Anode warpage

Anode warpage is of particular importance since this is height space that has no value added and can contribute significantly to limiting the cap of the capacitor as the finished height decreases. Anode warpage is observed after sintering (Figure 7).

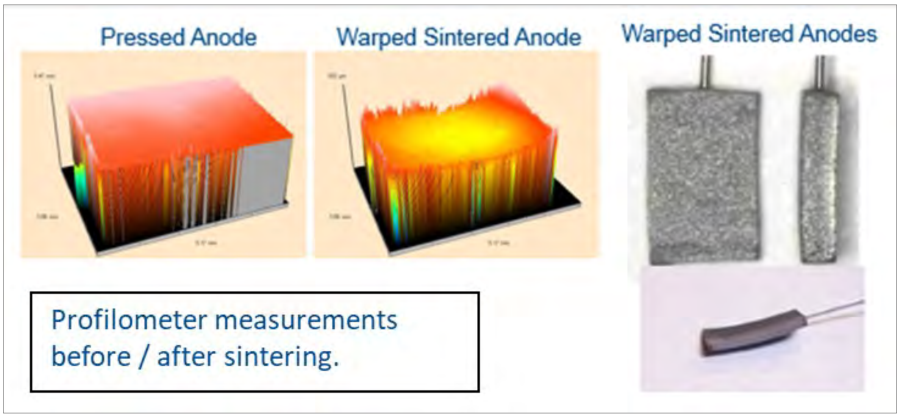
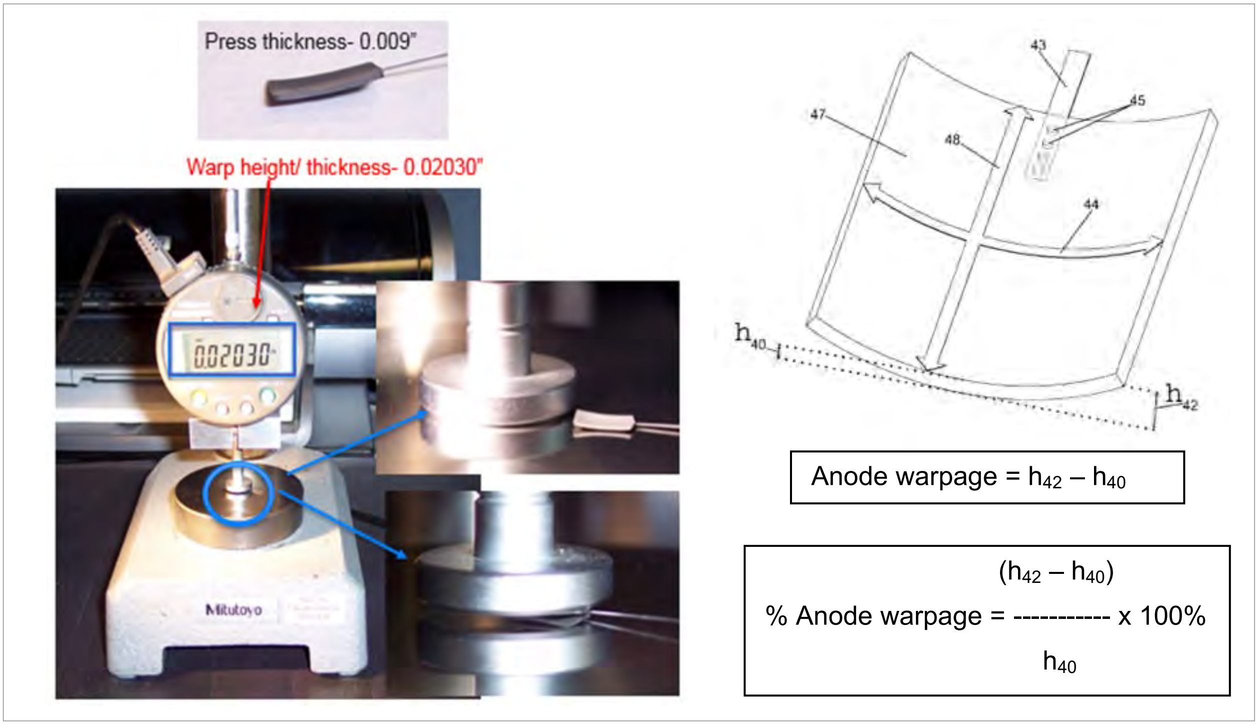


Figure 7: Observed anode warpage.

The method used for anode warpage measurement utilizes a spring micrometer to measure the overall warped anode height and anode thickness, see Figure 8. The warpage can be calculated by subtracting the anode thickness at a corner from the overall sintered (warped) height. The % anode warpage can be calculated by dividing this difference by the anode thickness.

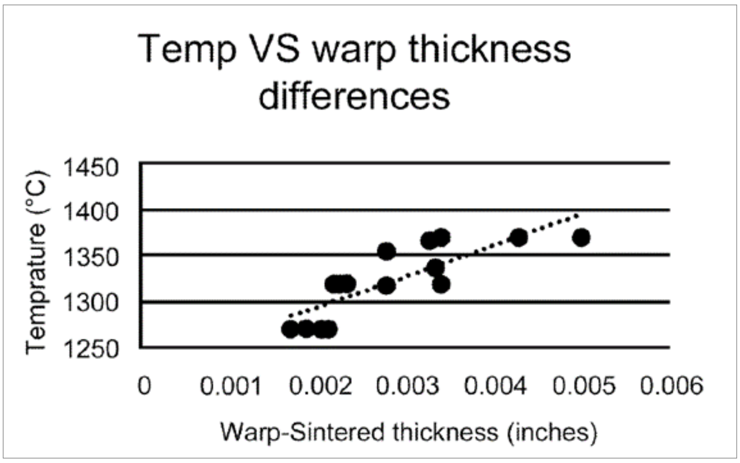


$$\text{Anode warpage} = h_{42} - h_{40}$$

$$\%\ \text{Anode warpage} = \frac{(h_{42} - h_{40})}{h_{40}} \times 100\%$$

Figure 8: Anode warpage measurement

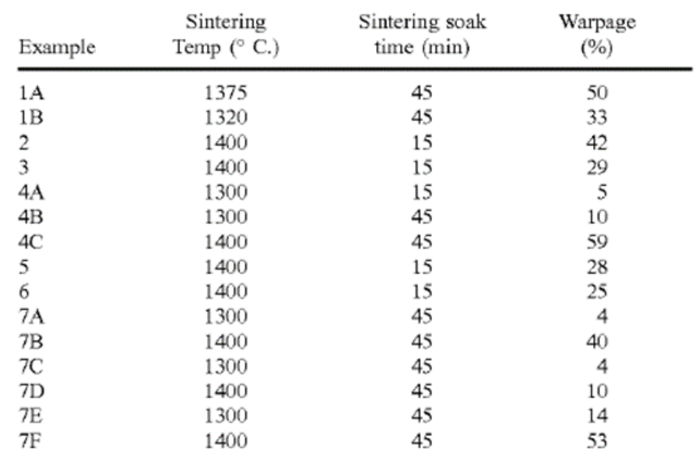
As the anode height is reduced the warpage tends to increase. Even more so for larger capacitor footprints such as 7343. Through careful selection of sintering parameters and other methods anode warpage can be held to a minimum value of 0.05 mm (0.002"). The relationship between warpage and sinter temperature for a large, flat anode can be seen in Figure 9.



Anode = 0.133" x 0.190" x 0.009", 5.5-6.5 PD, 80K CV/g powder

Figure 9: Warpage vs sinter temperature

Further experimentation has shown sinter time and physical arrangement during sintering have effects on warpage as presented in Table 2. Practically, anode warpage can be controlled to 0.075 mm for the 7343 footprint and 0.05 mm for the 3528 footprint.



Example	Sintering Temp (° C.)	Sintering soak time (min)	Warpage (%)
1A	1375	45	50
1B	1320	45	33
2	1400	15	42
3	1400	15	29
4A	1300	15	5
4B	1300	45	10
4C	1400	45	59
5	1400	15	28
6	1400	15	25
7A	1300	45	4
7B	1400	45	40
7C	1300	45	4
7D	1400	45	10
7E	1300	45	14
7F	1400	45	53

Ex	Description
1	Piled 0.23mm anodes
2	Sandwiched (Ta plates) 0.34mm anodes
3	Sandwiched (TaN Plates) 0.34mm anodes
4	Single layer anodes – on Ta plate.
5	Single layer anodes – on TaN plate.
6	Single layer anodes – on dusted Ta plate.
7AB	Sandwich, no wire.
7CD	Single layer, no Ta wire
7EF	Single layer, w/ Ta wire

Anode = 0.133" x 0.190" x 0.010", 6.0 PD, 0.0059" wire, 80K CV/g powder

Table 2: Warpage experiments, US 2017/0084397 A17

2. Cathode Layers

Current cathode layer thicknesses are typically ~100 µm per side. In the SEM photo, Figure 10, the Polymer / Carbon is 86 µm, the Silver coating is 32 µm and total thickness is 118 µm.

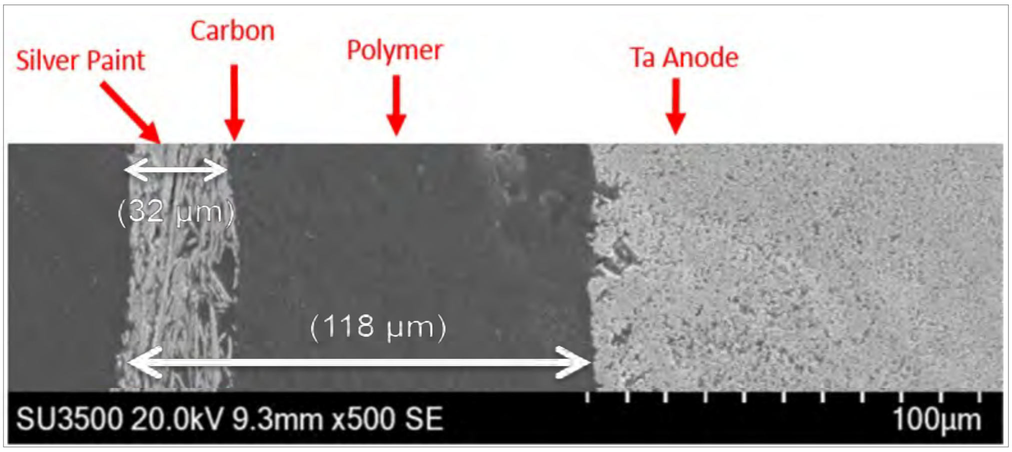


Figure 10: SEM of current cathode layers

As the capacitor height decreases the same cathode layer thickness consumes a larger and larger percent of the available volume in the case. As can be seen in Figure 11 below, the cathode layers % of height approaches 70% of available height in the case as capacitor thickness goes below 0.4 mm.

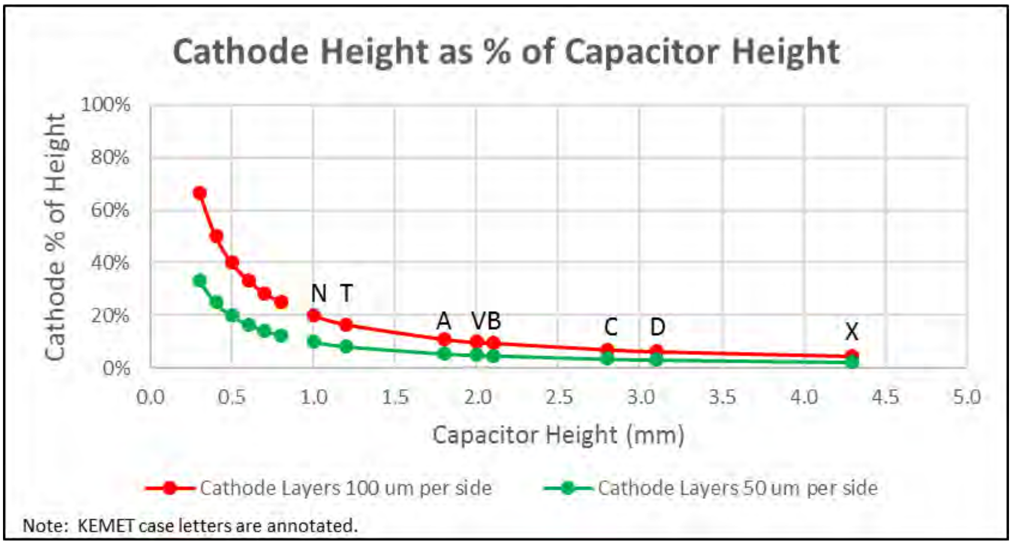


Figure 11: Cathode height as % of finished capacitor height.

Cathode layer thickness can be reduced by use of pre-polymerized polymer, especially on low voltage product that typically utilized the thicker in situ polymer process. In addition, optimizing the silver paint layer, which composes up to one third of the cathode layer, is needed. Current trials have reduced the cathode layer from 100 µm per side to less than 50 µm per side, Figure 12, with little effect on Equivalent Series Resistance (ESR) or DC Leakage.

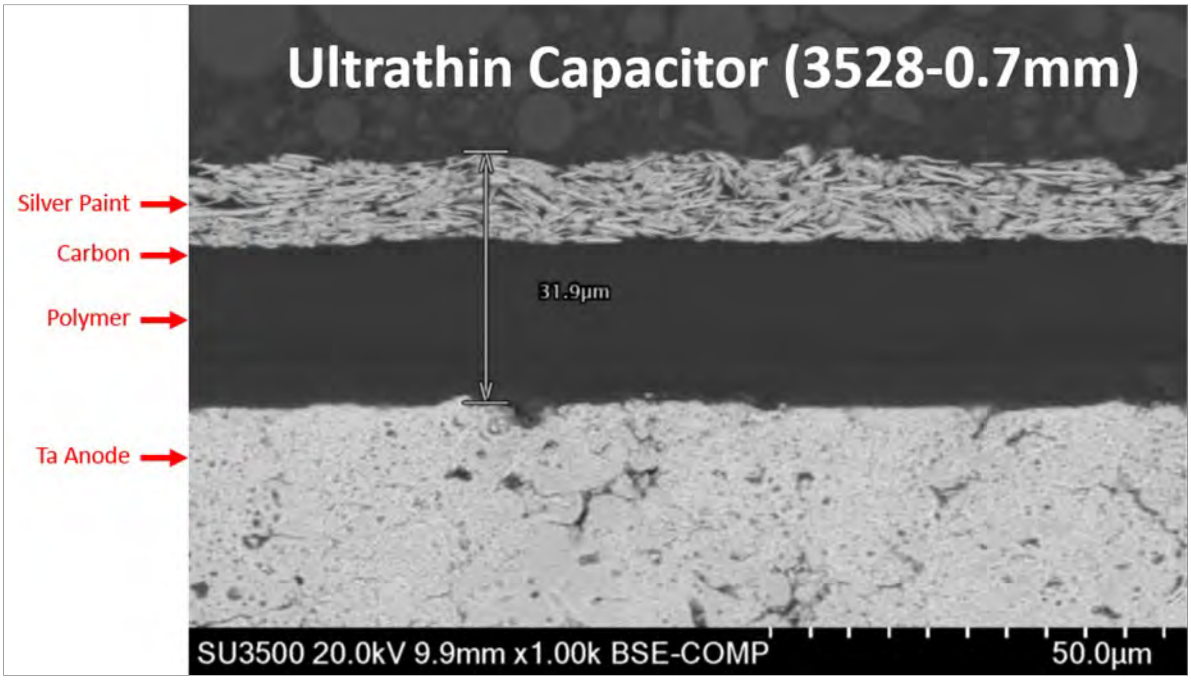


Figure 12: Ultra-Low Profile Capacitor cathode layers

3. Lead frame thickness

Further, the lead frame thickness can be reduced, but attention needs to be given to capability needed to anchor the leads of the capacitor in the face down design. Methods currently used to anchor the lead to the capacitor in addition to attachment to the capacitor itself are lead frame coining, beveling, bent up tab etc. The effectiveness of the coining / beveling will be reduced as the LF thickness is reduced for two reasons: the tooling features are much smaller and the encapsulant material providing the anchoring is thinner. Trials have shown acceptable performance at 0.100 mm lead frame thickness.

4. Encapsulant or wall thickness

The encapsulant, a thermal set epoxy moulding compound, is the final material where reductions in height can have a significant improvement. For the bottom of the capacitor, the wall thickness is determined by the lead frame thickness for the face down design. The top wall thickness can be reduced from 150 µm to 100 µm with little effect on the package integrity as the variation in other layers is reduced as their thickness is reduced. Wall thickness targets below 0.10 mm present difficulties maintaining a robust case for environmental testing.

Applying these improvements, the anode thicknesses are re-calculated in Table 3. As can be seen in the table, the face down design using a pressed anode will likely be limited to 0.5 mm capacitor height. Below this thickness, developing capacitors with meaningful CV will be challenging.

7343 Footprint (7.3 mm L x 4.3 mm W)	Face Down				
	1.2 mm	1.0 mm	0.7 mm	0.5 mm	0.4 mm
Molded Case Tolerance	0.03 mm	0.03 mm	0.03 mm	0.03 mm	0.03 mm
Cathode layers	0.20 mm	0.20 mm	0.10 mm	0.10 mm	0.10 mm
Encapsulant (bottom)	Same plane as Lead frame				
Encapsulant (top)	0.15 mm	0.15 mm	0.10 mm	0.10 mm	0.10 mm
Lead Frame	0.15 mm	0.15 mm	0.10 mm	0.10 mm	0.10 mm
Lead Frame Under Part	-----------	-----------	-----------	----------	----------
Anode warpage	0.03 mm	0.05 mm	0.05 mm	0.05 mm	0.05 mm
Anode	0.64 mm (0.025")	0.42 mm (0.017")	0.32 mm (0.012")	0.12 mm (0.005")*	0.02 mm (0.001")**
% Reduction in Case Height from 1.2 mm		-17%	-33%	-58%	-67%
% Reduction in Cap		-34%	-50%	-81%	-97%

*Difficulty pressing anodes at this thickness.
**Cannot press anode 0.02mm thick.

Table 3: Ultra-Low Profile anode thickness - improved capabilities

Other anode and cathode solutions

The electronics market will continue to move towards components even thinner than 0.5 mm. Other technologies have the potential to reach finished capacitor thicknesses less than 0.5 mm:

Tantalum Paste Technology introduced by H.C. Starck has a stated capability to reach 0.2 mm finished capacitor height and anode thicknesses from 0.062 to 0.185 mm. These are clearly more capable than current tantalum pressing technology, but case thicknesses greater than 0.4 mm will require multiple anode layers contributing to cost, which is in addition to the higher cost of using tantalum foil compared to tantalum wire.

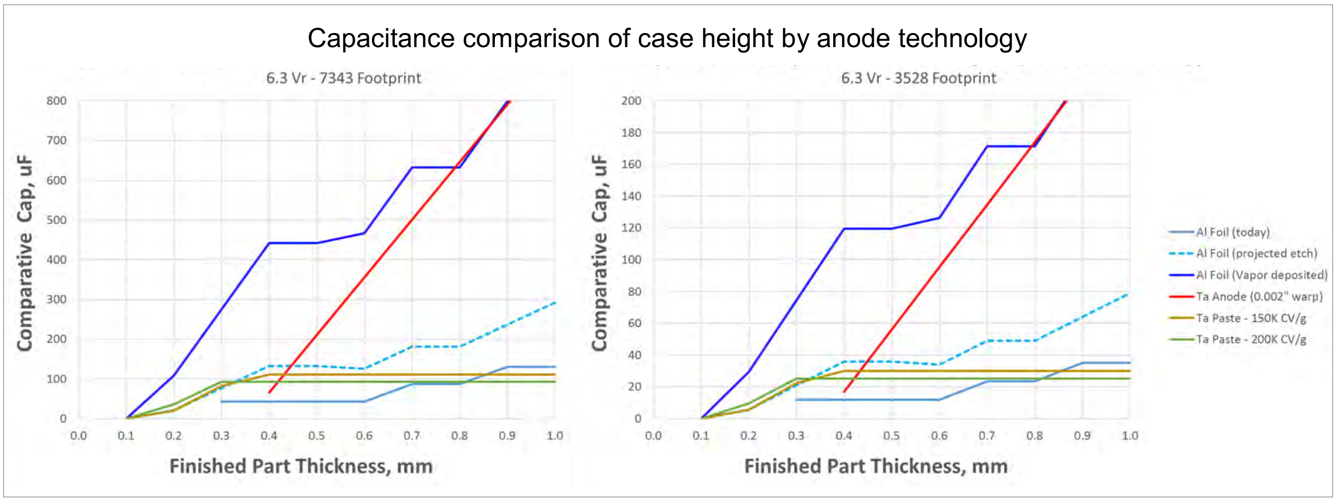
Once capacitor case sizes are reduced below 0.5 mm, attention will be needed for cathode layers, lead frame and encapsulant wall thickness since they will compose 60% of the usable height in the case. It is anticipated that these items will be approximately reduced by 50% as Ulta-Thin Capacitor development continues.

Experiments with single sided cathode on a tantalum pressed anode have shown a 18-20% gain in capacitance with the same overall anode /cathode thickness. However, the equivalent series resistance (ESR) doubles versus the control. The processing of a single sided tantalum pressed anode would be inherently more difficult. Processing single sided aluminium foil or tantalum paste would be much easier to achieve.

Aluminium polymer, with its inherently thin thickness and lower formation to rated voltage ratios, may be also suitable for ultra-low profile capacitors. Manufacturing techniques today allow varying thicknesses of foils from 75 to 300 µm. Some manufacturing methods such as tantalum paste and Al vapor deposition technology lend themselves very well to single sided foils.

Comparison of competing technological solutions:

Figures 13 and 14 are graphical comparisons of the competing technologies for the ultra-low profile capacitors for 7343 and 3528 footprints. For capacitor thicknesses above 0.5 mm, the pressed tantalum anode will be the best choice for CV/cc since it yields much higher capacitance over others while being a mature process. A rival for this space from 0.5 to 1.0 mm would be the vapor deposited aluminium foil technology, but this technology is generally still in its infancy. Below 0.5 mm, tantalum paste and aluminium polymer capacitors begin to close the gap and will outperform the pressed tantalum since pressing a tantalum anode with an embedded tantalum wire less than 0.100 mm will be difficult.



Figures 13 and 14: Capacitance comparison – 7343 footprint and 3528 footprint

Finally, other issues that will present themselves for ultra-low profile capacitor development are listed below. As development proceeds, these issues will need to be addressed:

- Pressing thin anodes, cracking / warping,
- Pressing thinner and thinner tantalum wire (less than 0.15 mm),
- Brittle leads with thin wire and high charge tantalum powders,
- Lead anchoring as lead frame thickness decreases,
- Case integrity as features significantly decrease,
- Positive connection attachment method / lead-frame design,
- Imbalances during moulding flow as case wall thickness decreases, and
- Tolerance stack up much more significant for less than 0.5 mm case height.

Conclusion:

Ultra-low profile capacitor development will continue to be a priority for many capacitor manufacturers. The need for higher packaging efficiency and thinner passive components will increase as new technology and products are developed. The tantalum pressed anode design can be competitive down to the 0.5 mm height. Tantalum paste is suited well for less than 0.5 mm case heights, but it will require significant investment and have higher material cost which will continue to be a challenge. Aluminium polymer solutions have similar or better (in case of vapor deposited aluminium foil) capacitance for less than 0.5 mm case heights, lower costs and a mature process / material stream.

Acknowledgement:

The authors acknowledge the great contribution and cooperation of KEMET R&D and Technical Marketing team members across multiple locations.

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Tantalum and niobium intellectual property update

Historically the T.I.C. reported those patents and papers that were relevant to the tantalum and niobium industries (2000-2007, available in the members' area at www.TaNb.org). Information here is taken from the European Patent Office (www.epo.org) and similar institutions. Patents listed here were chosen because they mention "tantalum" and/or "niobium". Some may be more relevant than others due to the practice by those filing patents of listing potential substitute materials. Note that European patent applications that are published with a search report are 'A1', while those without a search report are 'A2'. When a patent is granted, it is published as a B document. Disclaimer: This document is for general information only and no liability whatsoever is accepted. The T.I.C. makes no claim as to the accuracy or completeness of the information contained here.

Publication #	Applicant(s)	Publication date

TANTALUM

Method of obtaining wire from titan-niobium-tantal-zirconium alloys with the form memory effect

RU2656626 (C1)	FEDERAL INSTITUTE OF METALLURGY AND MATERIALS SCIENCE A.A. BAIKOV [RU]	2018-06-06

Method for obtaining the agglomerated tantal powder

RU2657257 (C1)	KOLA SCIENCE CENTRE OF THE RUSSIAN ACADEMY OF SCIENCES [RU]	2018-06-09

Processes for extracting and recovering tantalum present in an acid aqueous phase by means of an ionic liquid, and use of such an ionic liquid for extracting the tantalum from an acid aqueous phase

EP3334846 (A1)	CENTRE NAT RECH SCIENT [FR], UNIV MONTPELLIER [FR], UNIV DE CHAMBERY [FR], ENSCM [FR], TND [FR]	2018-06-20

Materials and coatings for a showerhead in a processing system

US2018171479 (A1)	APPLIED MATERIALS INC [US]	2018-06-21

Advanced metal insulator metal capacitor

US10008558 (B1)	IBM [US]	2018-06-26

Bulk acoustic wave resonator and filter including the same

US2018183407 (A1)	SAMSUNG ELECTRO MECH [KR]	2018-06-28

Processes for producing tantalum alloys and niobium alloys

AU2017221276 (A1)	ATI PROPERTIES LLC [US]	2018-08-30

Process for extracting and recovering tantalum present in an acid aqueous phase by means of an ionic liquid, and use of such an ionic liquid for extracting the tantalum from an acid aqueous phase

US2018230572 (A1)	CENTRE NAT RECH SCIENT [FR], UNIV MONTPELLIER [FR], UNIV DE CHAMBERY [FR], ENSCM [FR], TND [FR]	2018-08-16

Mask blank, method for manufacturing transfer mask, and method for manufacturing semiconductor device

WO2018155047 (A1)	HOYA CORP [JP]	2018-08-30

Electrophotographic photosensitive member, process cartridge, and electrophotographic apparatus

US2018246441 (A1)	CANON KK [JP]	2018-08-30

Iron-based alloy

RU2663951 (C1)	SHCHEPOCHKINA YULIYA ALEKSEEVNA [RU]	2018-08-13

Semiconductor device and method of manufacturing the same

US2018240700 (A1)	RENESAS ELECTRONICS CORP [JP]	2018-08-23

Paste method to reduce defects in dielectric sputtering

WO2018148091 (A1)	APPLIED MATERIALS INC [US]	2018-08-16

Dental implant for a jaw with reduced bone volume and improved osseointegration features

EP3366259 (A1)	ZIMMER DENTAL INC [US]	2018-08-29

A titanium-based alloy

WO2018138502 (A1)	UNIVERSITY OF OXFORD INNOVATION LTD [GB]	2018-08-02

NIOBIUM

Ferritic stainless steel and method of manufacturing the same

US2018179607 (A1)	POSCO [KR]	2018-06-28

Titanium nickel niobium alloy barrier for low-emissivity coatings

PL2969994 (T3)	GUARDIAN GLASS LLC [US]	2018-08-31

Processes for producing tantalum alloys and niobium alloys

AU2017221276 (A1)	ATI PROPERTIES LLC [US]	2018-08-30

NIOBIUM *(continued)*

Titanium alloy having good oxidation resistance and high strength at elevated temperatures		
US2018245478 (A1)	RTI INT METALS INC [US]	2018-08-30
Piezoelectric element, actuator, and liquid droplet ejection head		
WO2018150844 (A1)	PANASONIC IP MAN CO LTD [JP]	2018-08-23
Systems, methods and devices for hot forming of steel alloy parts		
US2018237878 (A1)	GM GLOBAL TECH OPERATIONS LLC [US]	2018-08-23
Titanium aluminide alloys and turbine components		
US2018230576 (A1)	GEN ELECTRIC [US]	2018-08-16
Piezoelectric element and piezoelectric element applied device		
US2018233656 (A1)	SEIKO EPSON CORP [JP]	2018-08-16
Amorphous thin metal film coated substrates		
WO2018143951 (A1)	HEWLETT PACKARD DEVELOPMENT CO [US]	2018-08-09
Hypoeutectoid bearing steel		
US2018223402 (A1)	AB SKF [SE]	2018-08-09
Method for producing steel sheets, steel sheet and use thereof		
WO2018149967 (A1)	VOESTALPINE STAHL GMBH [AT]	2018-08-23

T.I.C. meets Mr Joseph Ikoli, General Secretary of Mines, DRC

(photo: T.I.C.)

In August the T.I.C. President, Mr John Crawley, met with Mr Joseph Ikoli, General Secretary of Mines at the Ministry of Mines, Democratic Republic of Congo (DRC). Secretary Ikoli expressed his displeasure about the T.I.C. holding its 59th General Assembly in neighbouring Rwanda in October 2018, since he felt it was an act that showed support of a regional rival, one which many people in the DRC accuse of impropriety in the mineral supply chain.

Mr Crawley explained that the Association works to help raise the profile of the entire region for the betterment of the global tantalum industry and does not favour any one country (or company) over another. Giving examples from the considerable improvements in mineral supply chain due diligence processes, which the T.I.C. and DRC government have been at the forefront of developing, Mr Crawley explained that over the last decade the supply of tantalum-bearing minerals from Africa has risen enormously, from approximately 30% to 90% of global mineral supply, with the DRC mining sector playing a vital role in this growth.

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

- **T.I.C.’s 59th General Assembly and AGM in Kigali, Rwanda, October 14th to 17th**
- CRU-Ryan’s Notes, Orlando, FL, USA, October 21st to 23rd 2018
- RMI’s Annual Conference in Santa Clara, CA, USA, October 31st to November 1st 2018
- Raw Materials Week, Brussels, Belgium, November 12th to 16th 2018
- Formnext, Frankfurt, Germany, November 13th to 16th 2018
- IAEA’s 37th TRANSSC meeting in Vienna, Austria, November 26th to 30th 2018
- Mining Indaba, Cape Town, South Africa, February 4th to 6th 2019
- OECD’s 13th Forum on Responsible Mineral Supply Chains, Paris, France, April 23rd to 26th 2019
- **T.I.C.’s 60th General Assembly and AGM in Hong Kong, China, October 13th to 16th 2019**

* correct at time of print

Member company and T.I.C. updates

Changes in member contact details

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

- **Alliance Mineral Assets Limited**: The delegate has changed from Ms Simone Suen to Ms Pauline Gately. She can be contacted on pauline.gately@alliancemineralassets.com.au. All other details remain the same.
- **AS International Corporation Ltd**: The delegate has changed from Mr Alex Stewart to Ms Carol Shirley. She can be contacted on secretary@alexstewartinternational.com. All other details remain the same.
- **Avon Specialty Metals Ltd**: The email for the delegate, Mr Steven Munnoch, has changed to steven.munnoch@avonspecialtymetals.com. All other details remain the same.
- **Global Advanced Metals** has a new office address: 100 Worcester Street, Wellesley Hills, MA 02482, United States.
- **Guangdong Zhiyuan New Material Co., Ltd**: The delegate Mr Wu Lijue has a new email address: betty@zhiyuanm.com.
- **Jiujiang Jinxin Non-ferrous Metals Co. Ltd** has a new address: No.3 Industrial Zone, Xunyang District, Jiujiang City, Jiangxi Province, China.
- **KEMET Electronics Corporation** has a new office address: KEMET Tower, 1 East Broward Blvd., 2nd Floor, Fort Lauderdale, FL 33301, United States.
- **Mineração Taboca S.A.**: The delegate has changed from Ms Luciana Pagnoncelli to Mr Ronaldo Lasmar. He can be contacted on ronaldo.lasmar@mtaboca.com.br. All other details remain the same.
- **NPM Silmet AS** has changed its name to **NPM Silmet OÜ**.
- **Pilbara Minerals Limited**: The email for the delegate, Mr Ken Brinsden, has changed to agray@pilbaraminerals.com.au.

Members of the Executive Committee of the T.I.C. 2017-2018

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 current Executive Committee was approved by the T.I.C. members at the Fifty-eighth General Assembly and consists of (alphabetical by surname):

Conor Broughton	conor@amgroup.uk.com
John Crawley (President)	jcrawley@rmmc.com.hk
David Gussack	david@exotech.com
Jiang Bin	jiangb_nniec@otic.com.cn
Janny Jiang	jiujiang_jx@yahoo.com
Kokoro Katayama	kokoro@raremetal.co.jp
Raveentiran Krishnan	raveentiran@msmelt.com
Ben Mwangachuchu	bmwangaceo@smb-sarl.com
Candida Owens	owens.candida@cronimet.ch
Daniel Persico	danielpersico@kemet.com
Alexey Tsorayev	tsorayevaa@ulba.kz

Of these eleven, Mr John Crawley was elected President of the T.I.C. until October 2018.

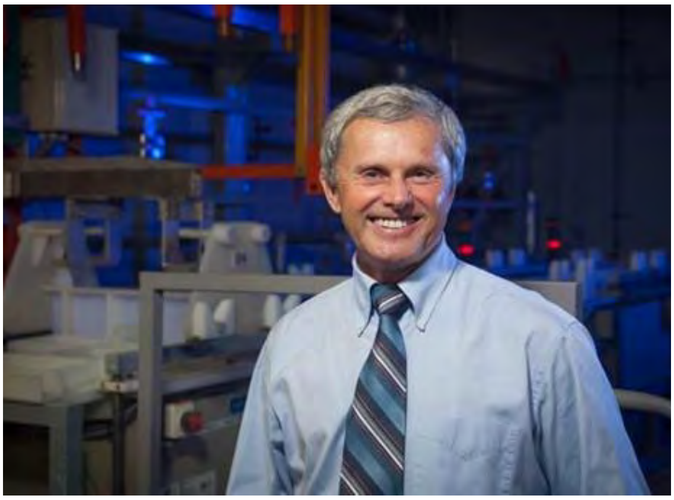
The T.I.C. currently has the following subteams (chaired by): Marketing (Daniel Persico), Meetings (Candida Owens), Statistics (Alexey Tsorayev) and Supply Chain (John Crawley).

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

The Anders Gustaf Ekeberg Tantalum Prize

Winner 2018

The Anders Gustaf Ekeberg Tantalum Prize ('Ekeberg Prize'), awarded annually for outstanding contribution to the advancement of the knowledge and understanding of the metallic element tantalum (Ta), has been awarded to Dr Yuri Freeman of KEMET Electronics, for his 2018 book 'Tantalum and Niobium-Based Capacitors' .



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

Dr Freeman is the Director of Advanced Research in the Tantalum (Ta) business unit and a member of the Advanced Technology Group at KEMET Electronics.

Dr Freeman received his PhD in Solid State Physics from Kharkov Technical University in Ukraine. Prior to KEMET, he worked as principal scientist at Elitan, the largest producer in the Soviet Union of Ta and Niobium (Nb) capacitors, and at Vishay Sprague in the USA. He has published more than 30 papers and received 26 patents in the field of physics and technology of Ta and Nb-based capacitors.

The judges' verdict

Announcing the 2018 winner, the independent judging panel stated that they had chosen Dr Yuri Freeman because his book, which has made up for the lack of basic books about tantalum and tantalum capacitors in education, was a very good scientific overview, providing basic insight into the manufacturing process of Ta-based electrolytic capacitors.

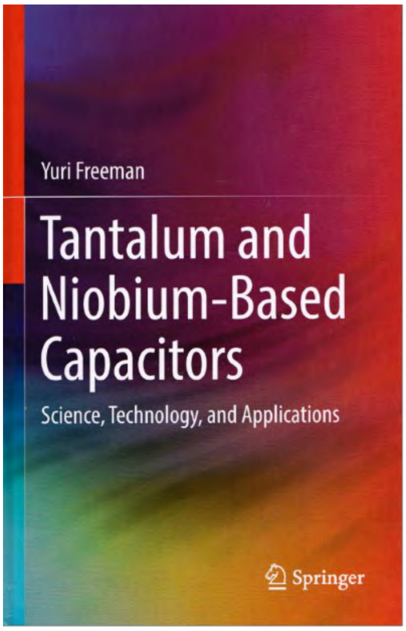
Furthermore, Dr Freeman has devoted most of his career to the development of Ta-based capacitors and made significant contributions, technological breakthroughs and performance improvements in these devices.

The panel of experts added that they wished to congratulate all the authors of publications on the shortlist whose work is challenging the boundaries of current knowledge of tantalum.

The prize and award ceremony

The medal for the Ekeberg Prize is currently being manufactured from 100% pure tantalum metal by the Kazakhstan Mint and will be awarded at the T.I.C.'s annual conference, the 59th General Assembly, which will be held in Kigali, Rwanda, in October 2018.

For details of how to submit a publication for the 2019 Ekeberg Prize please visit the website www.TaNb.org. TIC



Dr Freeman's book, 'Tantalum and Niobium-Based Capacitors' © Springer 2018