

T I C

TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

PRESIDENT'S LETTER

As preparations continue for the Forty-fifth General Assembly, I want to address this letter to members and readers of this Bulletin that have never been involved in organizing one of our technical programmes. I'm sure you will agree that our programmes are extremely informative to our highly specialized audience. The success of these programmes is directly related to the individual presenters and the organizers who manage the details. The process solicitation and selection of papers is the most difficult and time consuming of all. Those who have been involved in organizing one of our programmes fully understand this.

We are actively soliciting presentations for the Philadelphia meeting. I call on each member to get involved and take this opportunity to participate by proposing a technical presentation. We also must keep in mind the Symposium proposed in 2005 which will include three full days of technical presentations. Please start your preparations now. Proposals should be directed to the Secretary General or any member of the Executive Committee. Thank you in advance for supporting your organization.

Dave Reynolds
President

FORTY-FIFTH GENERAL ASSEMBLY

The Forty-fifth General Assembly will take place in Philadelphia, in the United States, on Monday October 11th 2004 as part of a meeting from October 10th to 12th.

The registration desk will be open on Sunday October 10th, and in the evening all delegates and guests and their ladies will be welcome at the cocktail reception which traditionally opens T.I.C. meetings. Following the business of the association on Monday morning, the rest of the day will be devoted to a programme of technical presentations – please see the call for papers in the letter from the President of the T.I.C.

On Tuesday October 12th Reading Alloys will very kindly offer a tour of its plant. The company offers more than 50 standard alloy formulations, as well as hundreds of formulations tailored to customers' needs. It has just celebrated the fiftieth anniversary of its foundation and is a global leader in its market. For more information, click on the link from the membership list on the T.I.C. web site, www.tanb.org.

Invitations will be sent to T.I.C. member company nominated delegates three months before the meeting. Others interested in attending should contact the T.I.C. without delay. All participants must pre-register at least one month before the meeting takes place.

NIOBIUM COMPOUNDS FOR CAPACITOR APPLICATIONS

This is taken from the paper prepared for the T.I.C. by Solon Y. Tagusagawa, Masana Imagumbai and Alberto A. Ono, of Companhia Brasileira de Metalurgia e Mineração (CBMM), presented by Mr Tagusagawa at the T.I.C. meeting in Lisbon, October 2003.

ABSTRACT

The first capacitor was invented in 1745 – the Leyden Jar. It was composed of two conductors with an insulator between them. Many developments have been carried out on these three components. At present, the most usual dielectric components are ceramic materials (barium titanate, aluminium oxide and tantalum oxide) and film. Recently research has been carried out on niobium, as a valve metal, as a metal for the manufacture of 'solid' electrolytic capacitors. Several companies have already supplied samples for performance testing, and some industrial production and sales have already taken place. This paper discusses CBMM's recent advances in the manufacture of high quality niobium metal and niobium monoxide powder. Furthermore, the manufacture of niobium

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metal wire for capacitor applications is discussed and presented.

1. NEW DIELECTRIC MATERIALS

Substitution of material and searching for a cheaper solution are a constant in mankind. Since the development of the tantalum capacitor there has been interest in developing niobium as an alternative metal. In fact, niobium as a valve metal presents a theoretical potential of achieving very high capacitance, as the dielectric constant of the oxide is 41, compared with 27 for tantalum. The capacitance per unit of anode surface, Dk/a , is proportional to the dielectric constant but inversely proportional to the thickness of the anodic film, so that Dk/a has a value of 1.71 for niobium and 1.69 for tantalum, almost identical. The density of niobium is half that of tantalum, 8.57g/cc compared with 16.6g/cc, if the same volumetric capacitance can be achieved.

Attempts to manufacture niobium metal capacitors began as soon as the material became available commercially in the 1960's. Niobium exhibits a higher oxygen solubility than tantalum, and it is not so easy to produce a thermally stable oxide film. Furthermore, the chemical purity of niobium powder was not as good as that of the tantalum powder, which contributed to the poor dielectric properties. (1)

Utilisation of niobium as ground metal for solid electrolytic capacitors is determined by the direct current leakage (DCL), which is linked with the degradation during high temperature processing (sintering and pyrolysis) and electrical loading. There are two major processes which are responsible for the increase in DCL:

- The process of oxygen extraction from the Me_2O_5 film by the Me anode. Increase of conductivity due to oxygen deficit, because oxygen vacancies act as donor center
- Crystallisation of Me_2O_5 film originated by thermodynamically non-equilibrium state of the amorphous film (2)

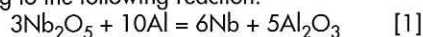
CBMM is the world's largest producer of niobium and operates a mine which has, at the present rate of consumption, reserves sufficient to cover the world's total demand for niobium for more than 400 years. CBMM and the other two major producers of niobium, located in Canada and Brazil, all produce ferro-niobium for the steel industry, but CBMM also has the capacity to produce other niobium products, such as niobates, pentachloride, and oxalates. The major tantalum producers also make niobium units as a by-product of their operations.

2. NIOBIUM POWDER PRODUCTION

CBMM is pursuing two major routes for producing niobium metal powder:

- HDH process
- Reduction of niobium compounds

The starting material for the HDH Process is high purity niobium metal, which is produced by refining niobium-aluminium alloy (Nb-ATR) in an electron beam furnace. This alloy is obtained by aluminothermic reduction of high purity niobium oxide, according to the following reaction:



The charge is a mixture of niobium oxide with aluminium powder and may also include a booster and a flux. The cast Nb-ATR bar has 3 to 5 wt% Al. Practice has shown that material with a higher aluminium content becomes more brittle and may fracture when heated, making control of the electron beam (EB) melting process difficult. On the other hand, low

aluminium content leads to higher residual oxygen content, and as a consequence to a lower yield. The oxygen content of Nb-ATR bar normally ranges from 4000 to 8000 ppm.

Niobium metal refined via EB melting achieves a high level of purity. The great majority of metallic elements present in niobium starting materials are easily volatilised under the melting conditions. The exceptions are those impurities presenting saturation vapour pressures lower than that of niobium, such as tantalum and tungsten – these metals cannot be removed by volatilisation. Thus, if the starting material is properly selected, EB processing is capable of producing niobium metal ingots with contents of most residual impurities as low as a few parts per million (ppm) or even within the parts per billion (ppb) range.

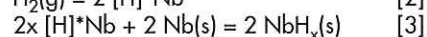
Typical chemical composition of an EB ingot melted three times is presented in Table 1.

Element	Ingot no. 1056301	Ingot no. 1057301	Element	Ingot no. 1056301	Ingot no. 1057301
Li, Be, Sc, Rb,	<0.001	<0.001	P	0.31	0.45
Cr, Co, Ni, Ru,	<0.001	<0.001	Al	0.08	0.39
La, Ce, Pr,	<0.005	<0.005	Si	0.21	0.47
I, Ba, Te, Bi,	<0.005	<0.005	B	0.02	0.02
Mn, Gd, Tb,	<0.005	<0.005	Cu	0.21	0.31
Na, Mg, K, Hf,	<0.01	<0.01	Fe	0.003	0.009
In, Sn, Sb, Zn,	<0.01	<0.01	Zr	0.09	0.14
As, Se, Br, Ir,	<0.01	<0.01	Mo	0.48	0.33
Ag, Cd, Cs,	<0.05	<0.05	V	0.005	0.009
Ta	630	700	Ti	<0.005	0.02
W	0.57	0.51	Cl	0.02	0.03

Table 1: Typical composition of an EB melted ingot after the third melt (ppm)

The carbon content of a third melt niobium ingot made at CBMM is around 2 ppm. This element evolves as carbon monoxide from the molten material and is removed by the vacuum pump.

The hydriding process involves two basic reactions:



The following potential energies should be considered:

- Dissociation energy of the molecule H_2 (2.2 eV/atom H) in the gas phase
- Activation energy of dissociation at the surface
- Activation energy of transfer of atom from surface into bulk
- Enthalpy of exothermic dissolution (-0.3 eV/half molecule for Nb)
- Diffusion activation energy (0.1 eV/atom for Nb)

Reaction [2] appears to be the controlling step. Diffusion of hydrogen in niobium metal is fast even at low temperatures.

For metal hydriding, the two most important operational parameters are the temperature and H_2 pressure in the chamber. The hydriding of niobium is an exothermic process, therefore the solubility of hydrogen decreases with temperature (0.12 wt% at 600°C, and 1.2 wt% at 400°C). At lower temperatures, the permeation rate of hydrogen through the surface decreases drastically. A higher temperature is helpful to start the process, however, although the hydrogen solubility is lower. Temperature cycling might improve the efficiency of this process. Niobium is fully hydrided on slow cooling from 800°C under hydrogen.

Two alternatives are currently being considered in relation to grinding:

- Attrition grinder
- Jet-milling

The first equipment is used for mechanical alloying and has a high input of energy in the milling process. High contamination with iron is observed if tool steel balls and a stainless steel cup are used, but this can be remarkably improved by using a niobium cup and balls.

Jet milling is another alternative for grinding NbH. However, in order to avoid contamination with oxygen, nitrogen gas should be used.

Handling the powder with care, and using vacuum chamber to store the niobium hydride, can help in reducing the oxygen contamination.

Dehydriding is carried out by heating the NbH-powder under high vacuum. It was observed that around 380°C NbH begins to decompose. The hydrogen content of the niobium metal powder after one cycle at 380°C for 4 hours, and 900°C for 1/2 hour, is below 100 ppm.

A typical niobium metal powder made by HDH process is shown in Figure 1.



Figure 1: SEM image of HDH niobium powder

The oxygen content of the powder is controlled by deoxidation with magnesium, either in the intermediate or final steps of processing. Typical properties of powders obtained by the HDH process are presented in Table 2.

Oxygen/Surface Area	[ppm/m ² /g]	≤ 5,000
Metallic Impurities (except Ta)	[ppm]	≤ 1,000
Bulk Density	[g/cm ³]	1.5 – 2.0
Flowability (Hall)	[sec/50g]	≤ 50
Surface Area (BET)	[m ² /g]	0.5 – 1.0
Specific Capacitance CV/g	[microFV/g]	30,000 – 65,000
Leakage Current Ir/CV	[nA/microFV]	< 10

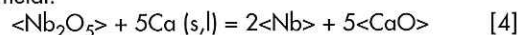
Table 2: Typical properties of niobium powder, made by the HDH process

A much higher specific capacitance can be obtained if the shape of the powder is changed from a massive type to a flake type. This process is well known, and can be carried out by processing the niobium metal powder in a ball mill (3). A capacitance greater than 65 000 CV/g can be obtained with this type of niobium powder.

2.1 Reduction Process

Suitable porosity of niobium powder is essential if an anode of

high capacitance, such as 100 000 CV/g, is to be obtained. This is possible with a sponge type niobium powder, which can be produced by metallothermic reduction of niobium compounds, such as halogen and oxygen compounds, using calcium metal.



This reaction is extremely exothermic and the morphology of the final powder cannot be easily controlled. There are three ways to control this reaction better:

- Reduce the activity of Nb₂O₅ by using a niobate
- Reduce the activity of Ca by mixing its vapour with inert gas
- Media control, by carrying out the reaction in molten salts

Reduction of calcium niobate (Nb₂O₅.CaO) was carried out to evaluate the effect of the temperature and the reducing agent on the properties of powder produced. The experiments were carried out at around 900°C using metallic calcium and magnesium as reducing agents.

After reduction, the reaction products were leached and dried under vacuum. The chemical composition, specific surface area and particle size distribution of the powders were analyzed. Furthermore, the powders were characterised by X-ray diffraction and scanning electron microscopy (SEM) in order to evaluate morphology.

The typical properties of powders obtained by this process are presented in Table 3.

Oxygen/Surface Area	[ppm/m ² /g]	≤ 4000
Metallic Impurities (except Ta)	[ppm]	≤ 1000
Bulk Density	[g/cm ³]	1.5 – 2.0
Flowability (Hall)	[sec/50g]	≤ 50
Surface Area (BET)	[m ² /g]	2.5 – 20.0

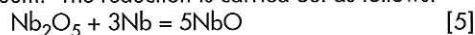
Table 3: Typical properties of powder made by metallothermic reduction of niobate

3. PRODUCTION OF NbO-POWDER

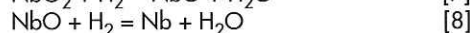
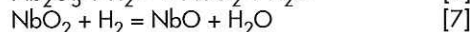
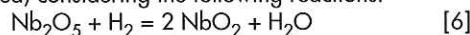
CBMM is pursuing two major routes for producing NbO powder:

- Reduction of Nb₂O₅ by niobium metal at high temperature, under vacuum
- Reduction of Nb₂O₅ by H₂-gas

The first route is the mixing of suitable Nb₂O₅ with fine niobium metal powder, and its heat treatment at high temperature and high vacuum. The reduction is carried out as follows:



According to published papers on the synthesis of NbO, this oxide can also be produced by reduction of Nb₂O₅ under H₂ atmosphere using niobium metal as an oxygen getter (4). In this process a thermodynamic equilibrium between the condensed phase (NbO/Nb) and gas phase (H₂/H₂O) can be established, considering the following reactions:



The reduction of Nb₂O₅ to NbO₂ occurs at relatively low H₂/H₂O ratios, while the reduction from NbO₂ to NbO can be carried out at higher H₂/H₂O ratios. In spite of the possibility of promoting the reduction of NbO₂ to NbO with H₂, the volume of this gas should be extremely high in order to keep the required H₂/H₂O ratio in the field where the NbO is stable.

From the kinetic point of view, the excess of getter and its surface area are important parameters to be controlled. In addition, the temperature and time of the treatment are also

crucial parameters in order to guarantee complete reduction and at the same time to prevent the sintering or even the excessive growth of NbO particles.

A typical NbO powder made by CBMM is shown in Figure 2.

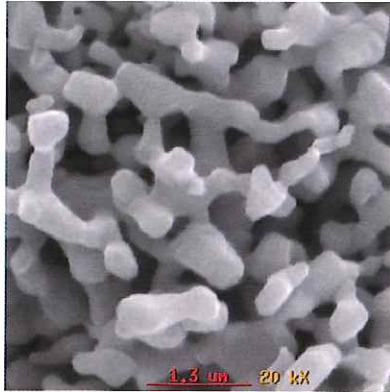


Figure 2: Typical NbO powder

The typical properties of NbO powder obtained by this process are presented in Table 4.

Bulk Density	[g/cm ³]	1.2
Flowability (Hall)	[sec/50g]	≤ 50
Surface Area (BET)	[m ² /g]	1.1 to 1.9
Specific Capacitance CV/g (BIAS 2.5V)	[microFV/g]	75,000 to 100,000
Leakage Current Ir/CV	[nA/microFV]	0.2 to 0.4

Table 4: Typical properties of NbO powder

4. NIOBIUM WIRE PRODUCTION

CBMM supplies niobium wire for capacitor applications. CBMM's niobium wire production starts from ingot, and the process flow is shown in Figure 3. Ingot size is normally 250 mm diameter, which is finished by triple EB remelting. The ingot is forged to 50 to 100 mm diameter bars by cold- or warm-forging, and then cold-rolled to 10 mm diameter rods. The materials are annealed in high vacuum twice between these processes. The first half of the further wire-making process is called Cassette Roller-Dies Rolling, and the final processing is drawing. As for the final drawing process, one of two methods is selected according to the customer's preference – smooth

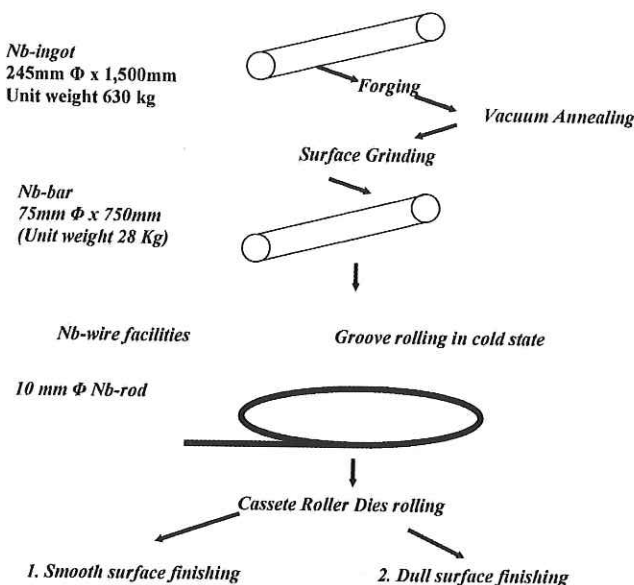


Figure 3: Process flow of CBMM's niobium wire for capacitors

surface or dull surface finishing.

The sizes available in CBMM's niobium wire menu range from 0.15 to 0.3 mm diameter. In addition to pure niobium wire, CBMM is ready to supply Nb-1%Zr wire.

5. CONCLUSIONS

As an alternative to tantalum for capacitors, the first option has been niobium, which has quite abundant resources around the world, and is considered the twin sister of tantalum. Attempts to manufacture niobium metal capacitors began as soon as the material became available commercially in the 1960's. However, niobium exhibits higher oxygen solubility than tantalum, and it is not so easy to produce a thermally stable oxide film. Furthermore, the chemical purity of niobium powder at that time was not as good as that of tantalum powder, which contributed to poor dielectric properties.

In recent years, new manufacturing techniques both for niobium metal powder production and for niobium capacitor production have completely changed this scenario. Several capacitor manufacturers have already announced that they are offering niobium capacitors (with niobium metal or NbO as the anode material) with almost the same quality as tantalum capacitors for some applications.

The major advantages of niobium metal and NbO capacitors over tantalum capacitors are stable supply, lower price (half the density), and potentially equal quality. The advantages over aluminium capacitors are higher volumetric efficiency (smaller case size), and better temperature stability. Niobium and NbO capacitors with tantalum quality may be used as a lower price drop-in replacement of tantalum capacitors, and small size-high performance replacement of aluminium capacitors.

The stable supply of niobium products is guaranteed by the huge resources of niobium available all over the world. There is a mine located in Brazil which can supply world demand, at its present rate, for niobium products for several centuries.

References:

- (1) "The use of niobium in capacitor applications", D.F. Persico, B.J. Melody, T. Kinard, L. Mann, J.J. Beeson, J. Nance, Niobium 2001
- (2) "Solid niobium capacitors with equivalent performance to tantalum capacitors", Y. P-Freeman, CARTS 2002, 22nd Capacitor and Resistor Technology Symposium, March 2002
- (3) "Making niobium and other metal powders by milling", PCT, WO 00/56486
- (4) "Electrochemical Measurement of the Standard Free Energies of Formation of Niobium Oxides", Transactions ISIJ – Iron and Steel Institute of Japan, Vol. 11, pages 102-106, published in 1971

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TANTALUM CAPACITORS – CHALLENGES AND DEVELOPMENTS

This is taken from the paper prepared for the T.I.C. by John Moore and John Prymak, KEMET Electronics Corp., and presented by Mr Moore at the T.I.C. meeting in Lisbon, October 2003

ABSTRACT

The past five years have seen an erosion of tantalum capacitor market share, beyond overall market decline. Challenges facing this device as the market recovers include perceptions of limited supplies or future restrictions impacting cost and availability, as well as concerns over failure modes and performance at higher frequencies. Additionally, the growth of niobium-based capacitors increases these concerns, as this alternative emphasizes that it holds solutions to all of these problems at reduced pricing.

Developments for tantalum capacitors must emphasize better performance, reliability, and a more benign failure mode to address the niobium challenge. The manufacturers and ore suppliers must show that the supply issues of the past have been addressed, and that these can be flexible to meet the market demands in the future.

[Mr Moore summarized the situation in the early 2000s. The shortage of tantalum capacitors slowed the burgeoning electronics growth, but the understanding that the devices would become truly scarce was unjust. Unnecessary stockpiling caused a real shortage, exacerbated by over-zealous customer forecasts. Ore, processing and capacitor manufacture were all blamed in turn. Designers of electronic circuits decided to protect themselves by eliminating tantalum capacitors from their products.]

He then addressed the recent improvements in tantalum capacitors and their relations with competing capacitor types.]

SUBSTITUTES FOR TANTALUM

Niobium is an alternative that offers a more abundant supply, less density, and higher dielectric constant, that when combined create a less expensive and less restrictive solution. The problem with this alternative is that it requires a thicker dielectric to match the base reliability of tantalum, and the dielectric advantage disappears. It also must be refined from ore, and the same refiners dealing with tantalum are required to refine the niobium. At this point the price advantages disappear.

Aluminum offers another alternative, but the wet electrolytes used in many of these are not appropriate for surface-mount solder processes. With the solid electrolyte, the disadvantage is in its volumetric efficiency - it cannot achieve the capacitance per unit volume that tantalum can.

TANTALUM CAPACITOR CHANGES – MnO₂

Offerings from this industry have targeted their improvements to improve efficiencies in power filtering and decoupling applications. The inherent problems in using manganese dioxide, MnO₂, as a cathode contact are relegated to two major categories: first, the high resistance of this semiconductive material creates high effective series resistance (ESR) and an accompanying capacitance roll-off; and secondly, the material is classified as an oxidizing element and contributes to the

occurrence of catastrophic ignition failures.

The high ESR multiplied by the discharge current creates a step voltage that robs the allowable voltage change required in a decoupling application, demanding higher capacitance to compensate for this theft. The structure of the pellet in this solid device also defines an RC-Ladder that prevents the device from acting at its capacitance value, and instead acts at a much lower capacitance value initially (Figure 1). Both of these faults require higher capacitance to be used than theoretically required.

Electrolytic RC-Ladder Structure

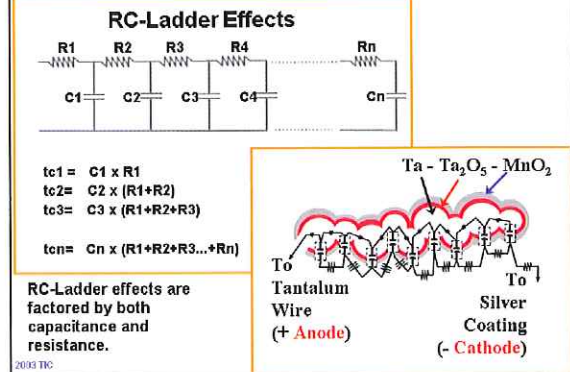


Figure 1: Electrolytic RC-ladder structure

Improvements in the processing methods and materials showed dramatic improvements with a 'Low-ESR' family of products released by KEMET (T495). Manipulation of the anode pellet's geometry created multiple anode devices (T510) which lowered ESR further still (Figure 2).

ESR Reduction in Tantalum ...

Lower Capacitance Loss with Frequency

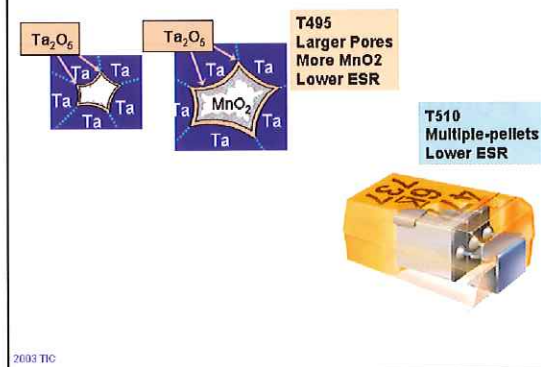


Figure 2: Lower capacitance loss

The ignition failure mode for these devices is an exothermic reaction of pure tantalum combining with free oxygen that is driven out of the MnO₂ as the device goes into a failure mode. The failure is always triggered by voltage stress that collapses the dielectric at a weak point. Current flowing into this flaw generates heat to convert the dielectric from an insulative, amorphous structure into a crystalline, conductive structure. Heat generated in this reaction creates a release of oxygen in the MnO₂ adjacent to the site, as well as heating the pure tantalum on the other side of the dielectric. Free oxygen in the presence of heated tantalum combines to form crystalline Ta₂O₅, and releases large amounts of energy as heat - hence, ignition takes place.

Replacing this highly resistive material has always been a goal, to impact its dominant effect on ESR, but the material to replace it must allow some type of healing mechanism to occur.

TANTALUM - POLYMER

The first commercial application of the conductive polymers was in 'anti-static' sprays for clothing. In this dispersed particulate, the polymer created a conductive film that prevented the isolation of charge into small areas.

As a substitute for MnO_2 , it had to have a self-healing characteristic because it is theoretically impossible to produce angstrom thick film of Ta_2O_5 without imperfection. There are two theories as to how these materials create the healing effect.

One theory details that this material has almost no oxygen in its most conductive state. The absorption of oxygen in its chain structure creates an increase in resistivity in much the same manner as oxygen depletion from MnO_2 creates an increase in resistivity for that material. The healing is activated when the polymer, in contact with the isolated fault site, is heated as electrical current flows through it and absorbs oxygen from the free space within the pellet structure. As this absorption increases in time, the resistivity increases and the fault current is 'blocked' off.

The other theory relies on the low boiling-vaporization temperature as the mechanism of healing. As the heat from the current increases in this material, it evaporates the polymer over time, leaving an open connection to the fault site. This mechanism creates a fusing effect whereby the fault site is disconnected from the circuit.

Besides the higher conductivity of this polymer material, it is almost entirely devoid of oxygen. This is in sharp contrast to the MnO_2 that is being replaced since it is an oxidizing agent. As such, the ignition or exothermic reaction of the heated tantalum in a shorted tantalum polymer capacitor must rely on the free, random oxygen in the package to become active. The results are that these devices fail short, but their propensity for ignition failure is dramatically reduced. (Figure 3)

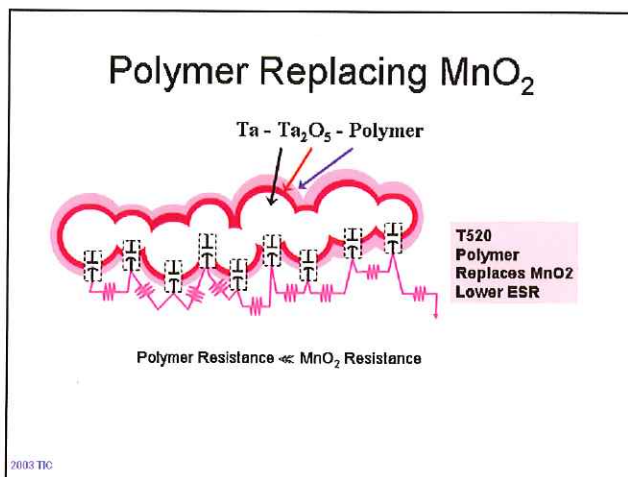


Figure 3: Polymer replaces MnO_2 in capacitors

The improvement in ESR in a tantalum polymer capacitor is in the range of 30% to 50% of those tantalum capacitors using the MnO_2 system. (Figure 4)

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Improvements in Tantalum - Polymer

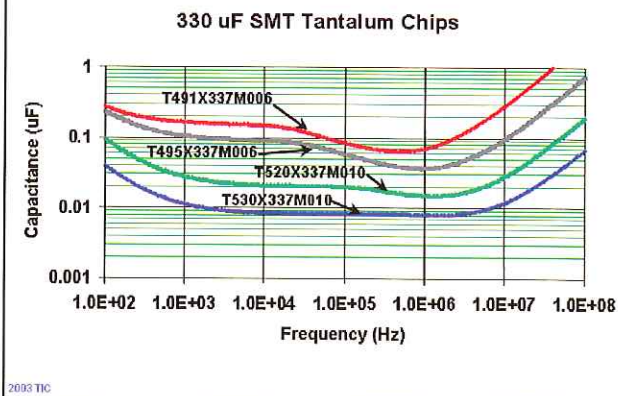


Figure 4: Improvements made in tantalum chip capacitors by using polymer

ALUMINUM - POLYMER

Using the same conductive polymers as in the tantalum system, an anode structure using aluminum plates as the anode element and aluminum oxide as the dielectric can be created. Unlike previous capacitors with this structure, the conductive polymer is substituted for the wet electrolyte as the first cathode contact.

It is built using etched aluminum foils, and the dielectric is electrochemically created on the surface of the foil in contact with the electrolyte (Figure 5). The polymer is applied (polymerization) to the dielectric surface, followed by a thin film of carbon, then silver paint. This silver layer is the outermost cathode contact. When the capacitor is built using multiple plates, a conductive adhesive is used to bind these contacts together with the lead frame.

Aluminum Polymer



- Solid state polymer cathode system
- Low ESR, small capacitance roll-off
- Surface mount

2003 TIC

Figure 5: Structure of aluminum polymer capacitor

The anode contact is made by welding the other end of these plates to the lead frame, allowing electrical connection to the aluminum base metal.

The change in basis structure from pellet to plate has an enormous impact on ESR for these devices (Figure 6).

With a 47 μF capacitor (A700 series) it is possible to achieve ESRs below 20 milliohms, a level that could previously be achieved only by using 680 μF tantalum capacitors. These devices are approaching ESR levels more like those of ceramic capacitors, with capacitance capability much higher than the ceramic. In addition, these devices have unmeasurable loss of capacitance with applied voltage, whereas ceramics can lose a considerable amount of their capacitance.

Improvements in Aluminum - ESR

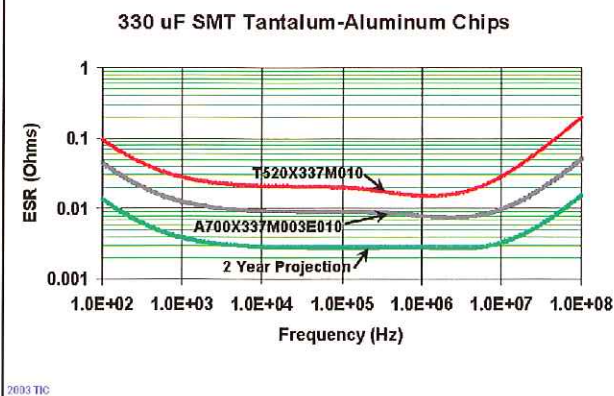


Figure 6: Improvements made in aluminum capacitors

NIOBIUM SUBSTITUTE FOR TANTALUM

Niobium is close to tantalum in the periodic chart and is a viable valve metal. There is no impetus to push niobium from a reliability and performance standpoint. The clear advantage that makes niobium a valid substitute for tantalum is pricing. As the disparity between the refined material costs of the two metals becomes greater (niobium being of lower cost), the penetration of niobium into tantalum markets will rise.

Arguments discounting this material as poorer quality will be overcome by increasing the piece counts and still demonstrating a cost advantage. Present offerings of niobium include nitrogen-doped and oxygen-doped materials, both offering higher stability over pure niobium (Figure 7). The key for this product's growth (as with all others) will be cost.



Figure 7: Niobium capacitor development

CERAMIC SUBSTITUTE FOR TANTALUM

Most of the applications that used tantalum capacitors before the shortage are being changed over to ceramic capacitors. Consider a filter circuit at 100 kHz, with a desired capacitance impedance of 100 milliohms. A perfect capacitor with no ESR and frequency-independent capacitance would require a unit of 16 μ F, using 22 μ F as a standard EIA value. A standard tantalum chip (T491B226M006) would have an impedance of 582 milliohms at 100 kHz, because at this point the impedance is dominated by the ESR of the device. A ceramic chip offering of 22 μ F in a 1206 chip size (X5R) would offer an impedance of 76 milliohms at this frequency – a viable solution for the filter. If the tantalum was previously used in this design, it would have

required a larger chip with lower ESR and higher capacitance to offer a viable solution – T495D157M010 has an impedance of 92 milliohms at 100 kHz. Now with the mandate to design out where possible, this 150 μ F capacitor can be replaced with a 1206 ceramic that is one-eighth of the capacitance and only 20% of the volume. When designers were forced to look at new capacitor solutions due to the tantalum shortage, they discovered that not only could they successfully substitute ceramic for tantalum in most applications, but they saved board space and component cost as well.

CUSTOMER RESPONSE

Since the electronics economic recovery is still at a very early stage, it is difficult to correlate our customers' plans to a point in time where demand will increase and have a positive impact on both pricing and volume. Early indications from many electronics manufacturers are that they are 'designing tantalum out'. Substitutions available include aluminum (both polymer and new 'wet' electrolytics) and ceramics. As the capacitance available in ceramic chips increases, the substitution will increase even further. The difference in ESRs between tantalum and ceramics is still so vast that the substitutions are one for five or one for eight (capacitance ratios).

TANTALUM CAPACITOR FUTURE

The most volumetric of the electrostatic capacitors is the tantalum capacitor. Used under proper conditions, the useful life of this product will far exceed any circuit's life expectancy. Defining these 'proper conditions' for our customers will gain them the capability of using these capacitors with no failures. Powder developments are necessary to maintain or extend the volumetric efficiency of tantalum capacitors (Figure 8). Extending the polymer technology into more products will also be necessary both to improve performance and to reduce risk.

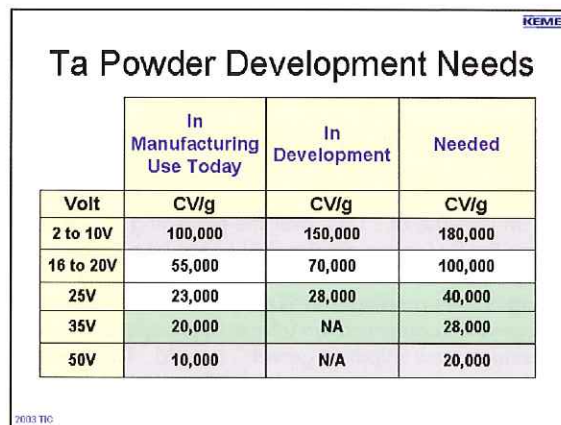


Figure 8: Tantalum powder development needs



Figure 9: Competitive needs for tantalum and KO

The immediate future will reveal how much market share will be lost to alternative types of design, but it is important to recognize that there is a definite goal of elimination where possible. The driving factor in any design change will not be revenge or mistrust; it will be cost balanced by performance. As tantalum capacitor manufacturers, we must resist the temptations to compromise the design margins in our products to gain volumetric efficiencies, because the result would be poor performance. What needs to be done to impact positively the use of tantalum capacitors as we move into the future is to maintain and improve the reliability of these products as we achieve volumetric and performance improvements. Just as important, and what must go hand in hand with these gains, is improvement in cost.

DLA/DNSC

Sales in November 2003 were announced on December 5th: 24 000lbs of vacuum grade tantalum metal were awarded to Sovereign Recycling. The sale of approximately 240 000lbs Ta₂O₅ contained in concentrates to DM Chemi-Met for about \$6 million was announced on December 18th 2003. No awards were made in December under the Basic Ordering Agreement (BOA).

In January 2004 Cabot Corporation and H.C. Starck were awarded 24 000lbs capacitor grade tantalum metal and 36 000lbs of tantalum concentrates, between them, for \$2 million. A further award of 3000lbs capacitor grade tantalum metal was made to H.C. Starck in February under the BOA, it was announced on March 5th.

About 150 000lbs Ta₂O₅ contained in concentrates were offered in March by solicitation, not BOA, with bids due by 10a.m. on Monday March 22nd. The posting day for BOA offers is Thursday, and information is available on <https://www.dnsc.dla.mil>.

MEMBER COMPANY NEWS

AVX

On January 27th 2004, AVX reported a net loss for the December 2003 quarter of \$8.5 million, compared with \$0.7 million in 2002 for the same quarter. Sales were \$296.8 million, an increase of 11.1% over the preceding quarter and 5.0% over the December quarter 2002. Mr John Gilbertson, CEO and President, stated that there were positive signs of improving market conditions in 2004. 'Increases in information technology and communication infrastructure spending will drive continued unit shipment growth', he said. The Asia region showed strong growth and sales there for the December 2003 quarter represented 43% of total sales.

Cabot Corporation

The earnings of Cabot Corporation for the December quarter 2003 were reported as \$29 million. Mr Kennett Burnes, Chairman and CEO, said he was pleased with the financial results for the quarter 'which reflect improved performance in our Chemical Business due to our cost reduction efforts, offset by an anticipated decline in Cabot Supermetals' income'. The latter had been 'adversely affected by the expiration of contracted intermediate product sales'. The company saw encouraging development in demand in the electronics market, said Mr Burnes.

Furisa

The company address has been changed to:
Spinnakers No.2,
Fore Jay Road No.2,
Milnerton/Cape Town 7441, South Africa.

F&X Electro-Materials

This member company now has a web site, at www.fxelectro.com.

Sons of Gwalia

Reporting on the December quarter 2003 on January 20th 2004, the company announced sales of 500 240lbs (Ta₂O₅ contained) in the quarter, in line with its contractual arrangements, so that sales for the full year were anticipated to be about 2.1 million lbs. 560 641lbs Ta₂O₅ contained were produced, 261 641lbs at Greenbushes and 299 000lbs at Wodgina. Reopening the Greenbushes underground mine in January 2005 was the subject of a feasibility study, and drilling adjacent to the existing Wodgina open pit had encountered significant high grade tantalum mineralisation.

The company had acquired the Aracuai tantalum project in Brazil, with the option to assess 'what appears to be a potentially large tantalum resource', consistent with the company's objective to remain the world's largest tantalum producer.

Mr Peter Lalor, Executive Chairman, is due to retire in April 2004. Mr John Leivers was appointed Managing Director with effect from January 27th 2004, and Mr Neil Hamilton will assume the role of Non-Executive Chairman on the retirement of Mr Lalor.

Kemet

On February 18th 2004 Kemet announced the grand opening of its newest production facility in Suzhou, China. Production began in October 2003 and the facility has already shipped 1.5 billion capacitors. A second production facility in China is expected to be operational in 2004, and Kemet's Asian headquarters has moved to Shanghai. By March 2005 virtually all commodity production will be in low cost regions.

The company reported its results for the December 2003 quarter on January 19th 2004, with a net loss before special charges of \$7.3 million. This compared with a loss of \$13.3 million in the September quarter, and a loss of \$3.6 million in the December 2002 quarter. Net sales for the quarter were \$111.3 million, up from \$100.1 million in the September quarter and \$103.7 in the equivalent quarter of 2002. Dr Jeffrey Graves, Chief Executive Officer, stated that 'Kemet is beginning to benefit from a sustained recovery in the electronics industry. For the first time since December 2000 quarterly revenue increased over revenue from the same quarter in the prior year.' Capacity utilisation reached approximately 75%. Significant unit growth in North America and Europe reflected the early stages of improvement in information technology infrastructure spending, combined with continued strength in the industrial, military and automotive sectors, added Dr Graves.

Metallurg/CIF

The membership of Metallurg has been transferred to Cia Industrial Fluminense,
Rodovia BR, Km 94 - CP 91,
Colônia de Marçal,
São João del Rei - MG, Brazil.

The delegate is Mr Itamar Resende.

Treibacher

Treibacher Industrie has opened a sales office in Toronto, Canada, as it believes that this presence will 'secure and extend its position on the North American market'. It hopes the new office will enable it to increase the North American part of its exports, which were around 7% in 2003.

Vishay

Mr Richard Mager has succeeded Mr Peter Maden as delegate of Vishay. His address is
63 Lincoln Highway,
Malvern, PA 19355, U.S.A.