TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

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Brussels meeting, April 1992

There will be an informal meeting at 40 rue Washington, 1050 Brussels, on the morning of Tuesday April 7th 1992, to be followed by lunch. This will provide an opportunity for an informal gathering of delegates who are able to be in Brussels at this time, and for the Executive Committee to report on its meeting to be held on the previous day.

Invitations are being sent to member company delegates, but anyone from a non-member company who would like to participate should contact the Secretary General of the T.I.C. (fax (02) 649 32 69, telex 65080).

President's letter

From June 21st to 26th 1992, the T.I.C. will take part in the exhibition of the 1992 Powder Metallurgy World Congress at the San Francisco Marriott, San Francisco, California. If you are at the conference, please to come and see the display our Technical Adviser, Rod Tolley, is arranging.

Also I should like to encourage you to attend the informal meeting in Brussels on April 7th. These events have proved over the past few years to provide a useful forum for a general exchange of news and views, and an additional chance for those involved in our industry to get together.

With best wishes,

Yoichiro Takekuro
President
February 21st 1992

Advances in tantalum and niobium technology

Members of the T.I.C. receive each month "Headline News" of advances in processing and application of our two metals as revealed by datasearch of patent and other technical literature. In the past year, each copy of the list has contained on average 110 references, and this indicates the world's level of interest in the two elements, and the progress which is continually being made.

In recent months the following topics have been well represented, and the examples show how versatile tantalum and niobium are.

A. NIOBIUM AND ITS ALLOYS

1. McDonnell Douglas : US Patent 5 015 440 (May 14 1991)
   Niobium aluminide (Al_3Nb) has attractive properties, particularly as a high temperature structural material. It has a low density (similar to that of titanium), a high melting point (above 1600 °C) and is resistant to oxidation. It unfortunately has very low ductility, but this patent claims that parts can be made from it to finished dimensions by reacting the two constituents in an inert atmosphere at a temperature of some 1000 °C in a die. The reaction is strongly exothermic, sufficient to fuse the mass.
2. NKK Corporation : Japanese Patent 3-39426 (Feb 20 1991)
   Ferroniobium can be used as a source of metallic niobium by nitriding the pulverised ferroalloy under 800 Torr nitrogen at 100 °C, extracting the iron by leaching with sulphuric acid (which also removes other impurities such as silicon, sulphur and tin) and then heating the residue to 2000 °C under 0.01 Torr vacuum, when the nitrogen is removed.
3. Japan Metals and Chemical Co. : Japanese Patent 2-221337 (Sep 4 1990)
   The constituent metals of scrap niobium titanium alloy (from superconductor manufacture) can be separated by heating the metal under hydrogen (which makes it brittle), pulverising the product and then vacuum treating it for removal of the hydrogen. The material is then chlorinated and the volatile chlorides are fractionally separated. These are then reacted with sodium and magnesium to produce the two metals.
4. W.A. Spitzig and others : Journal of Materials Science 26 (8) 2000-2006 (1991)
   The composite of copper and 20 % niobium (which Dr Spitzig described to the T.I.C. at the Philadelphia meeting in October 1991) has an unexpected advantage over its constituent metals in that it is not subject to embrittlement by hydrogen. This is normally a problem with niobium, but it would seem that the ductility of the copper restrains the niobium filaments from fracturing.
5. U. Gennari and others : 12th Plansee Seminar
   Pure niobium is potentially an excellent material for prostheses and surgical implants but its strength is inadequate. Fine particles of titanium dioxide dispersed in it by powder metallurgy techniques have the effect of greatly increasing the strength of the metal, while retaining its ductility, so the way would now appear to be open for its use in this important application.
6. R.J. Munz and E.J. Chin : Canadian Met. Quarterly 30 (1) 21-29 (1991)
   Pyrochlore is by far the most common source of niobium, and all the world's ferroniobium is made from it by reaction with aluminium. This paper reports continuing experimentation to effect the reduction with what should be a cheaper reaction with carbon, this time in an argon-arc plasma furnace. Most of the niobium was recovered as carbide.
7. M. Naka and T. Saito : Jnl. of Materials Science Letters 10 339-340 (1991)
   As the authors say "Joining of ceramics to metals expands the practical applications of ceramics". In this paper they reported that a 4 mm layer of niobium could join (under pressure and heat) stainless steel and silicon carbide, with the added benefit that the soft niobium's low heat expansion can relax the thermal stress that arises from the difference between ceramics and metal.
8. IMI Titanium Ltd. : U.K. Patent 2.234 921 (Feb 20 1991)
   Niobium-tin based superconducting wires may be formed by inserting tin cored niobium sleeves into a drilled copper billet. The billet is then pre-cooled (to prevent the tin melting at that stage) and extruded. The wire is then drawn down, and finally heated to react the niobium and tin.
9. Mitsubishi : European Patent 0 365 043 (Apr 25 1990)
   The contact material in a vacuum circuit breaker is subject to severe stresses. Alloys of copper with chromium and tungsten have been used with considerable success but they each have limitations due for instance to a disability to withstand high voltage. In 1984 an alloy of copper, molybdenum and niobium was patented and this has performed well, but suffers from a high chopping current and melt-adhesion. The present patent claims that adding a small amount (0.5 %) of a low melting point metal, such as bismuth or lead, to copper molybdenum niobium or copper molybdenum tantalum (approximately 74:8:18) alloys solves these problems.

B. NON-METALLIC APPLICATIONS

1. F.H. Mok and others : Optics Letters 16 (8) 605 (April 1991)
   Holograms may be stored in lithium niobate crystals. The author describes how a single iron-doped (0.015 % Fe) crystal was made to store 500 distinct high resolution images. The latter were generated by a liquid crystal television : the object beam and a reference plane wave produced the interference pattern to which the crystal was exposed, and the multiple holograms were separated by varying the angle of incidence. Examples of the recovered images given in the article are impressive in their quality.
2. GTE Products : U.S. Patent 4 970 024 (Nov 13 1990)
   Yttrium tantalate, doped with up to 15 % niobium (but typically 0.5 %) is used as a phosphor for X-rays. The patent claims a

T.I.C. statistics

TANTALUM

PRIMARY PRODUCTION

(quoted in lb Ta_2O_5 contained)

	4th quarter 1991
Tin slag (2 % Ta_2O_5 and over)	61 209
Tantalite (all grades)	182 752
Other	3 642
Total	247 603

Note : 14 companies were asked to report, 12 replied. The companies which reported included the following, whose reports are essential before the data may be released :

Datuk Keramat Smelting, Greenbushes, Malaysia Smelting, Mamoré Mineração e Metalurgia, Metallurg group, Pan West Tantalum (Wodgina Mine production), Tantalum Mining Corporation of Canada, Thailand Smelting and Refining

QUARTERLY PRODUCTION ESTIMATES

(quoted in lb Ta_2O_5 contained)

LMB quotation :	*US \$ 30*	*US \$ 40*	*US \$ 50*
1st quarter 1992	248 900	347 100	372 500
2nd quarter 1992	257 900	347 100	372 500
3rd quarter 1992	257 900	347 100	372 500
4th quarter 1992	257 900	347 600	372 500
1st quarter 1993	265 900	347 100	372 500

Note :

The quarterly production estimates are based on information available, and do not necessarily reflect total world production.

PROCESSORS' RECEIPTS

(quoted in lb Ta contained)

	4th quarter 1991
Primary raw materials (e.g. tantalite, columbite, struverite, tin slag, synthetic concentrates)	339 828
Secondary materials (e.g. Ta_2O_5, K_2TaF_7, scrap)	136 895
Total	476 723

Note : 17 companies were asked to report, 17 replied.

PROCESSORS' SHIPMENTS

(quoted in lb Ta contained)

Product category	*4th quarter 1991*
Ta_2O_5, K_2TaF_7	56 384
Carbides	76 963
Powder/anodes	230 592
Mill products	115 710
Ingot, unworked metal, other, scrap, alloy additive	49 066
Total	528 715

equivalent to 713 765 lb Ta_2O_5.

Notes :

In accordance with the rules of confidentiality "alloy additive" was combined with "ingot, unworked metal, scrap and other".

17 companies were asked to report, 17 replied. For both receipts and shipments by processors, reports by the following companies are essential before the data may be released :

Cabot Performance Materials, W.C. Heraeus, Kennametal, Metallurg Group, Mitsui Mining and Smelting, NRC Inc., Showa Cabot Supermetals, Hermann C. Starck Berlin, Thai Tantalum, Treibacher Chemische Werke, Vacuum Metallurgical Company, V Tech

NIOBIUM

PRIMARY PRODUCTION

(quoted in lb Nb_2O_5 contained)

	4th quarter 1991
Concentrates : columbite, pyrochlore	15 264 719
Occurring with tantalum : tin slag (over 2 % Ta_2O_5), tantalite, other	86 002
Total	15 350 721

Note :

16 companies were asked to report, 14 replied. The companies which reported included the following, whose reports are essential before the data may be released : Cambior, Mineração Catalao de Goiás, Niobium Products Co. (CBMM)

PROCESSORS' SHIPMENTS

(quoted in lb Nb contained)

	4th quarter 1991
Compounds and alloy additive : chemical and unwrought forms (e.g. $NbCl_5$, Nb_2O_5, NiNb, FeNb [excluding HSLA grades])	676 107
Wrought niobium and its alloys in the form of mill products, powder, ingot and scrap	
(i) Pure niobium	115 638
(ii) Niobium alloys (such as NbZr, NbTi and NbCu)	101 950
HSLA grade FeNb	7 284 119
Total	8 177 814

Note : 18 companies were asked to report, 18 replied. Reports by the following companies are essential before the data may be released : Cabot Performance Materials, W.C. Heraeus, Kennametal, Metallurg Group, Mitsui Mining and Smelting, Niobium Products Co. (CBMM), NRC Inc., Hermann C. Starck Berlin, Teledyne Wah Chang Albany, Thai Tantalum, Treibacher Chemische Werke, Vacuum Metallurgical Company

Capacitor statistics

TANTALUM CAPACITORS IN THE U.S.

The basis for statistics for U.S. capacitor shipments has been changed, and backdated to the beginning of 1991. We consider the most useful figure is U.S. consumption, which is local manufacture for domestic consumption plus imports. Data are also given for an additional quantity of tantalum capacitors of all types produced in the U.S. for export, to give total worldwide U.S. sales.

U.S. CONSUMPTION OF TANTALUM CAPACITORS

(thousands of units)

	1st quarter 1991	2nd quarter 1991	3rd quarter 1991
Metal-cased (incl. wets & foil)	30 065	27 494	22 705
Dipped (radial)	109 960	107 229	112 261
Chips	143 045	159 174	177 576
Other (molded axial & radial)	94 903	99 955	105 646
Total U.S. consumption	377 973	393 852	418 188
Add U.S. production for export (all types)	85 290	116 223	104 807
Total worldwide U.S. sales	463 263	510 075	522 995

(Data from EIA)

EUROPEAN TANTALUM CAPACITOR SHIPMENTS

(thousands of units)

3rd quarter 1991	178 820

(Data from ECTSP)

JAPANESE TANTALUM CAPACITOR PRODUCTION AND EXPORTS

(thousands of units)

3rd quarter 1991

Production	1 262 241
of which exports	255 303

(Data from JEIDA)

significant (up to 22 %) improvement in the brightness of the image by incorporating a halide of, for example, strontium or rubidium, and optionally an oxide of gallium or aluminium.

3. Energy, Mines and Resources : U.S. Patent 4 973 776 (Nov 27 1990)
Gasoline-range hydrocarbons (such as iso-butene) can be produced from natural gas by reacting the contained methane and acetylene in the presence of solid superacid halides. Those preferred include tantalum, niobium and antimony pentafluorides.

4. P.G. Pries de Oliveira et al : J. Catalysis 130, 293-305 (1991)
Aluminium niobate is shown to be a valuable support for vanadium as a catalyst in the dehydration of isopropanol.

5. Union Carbide : U.S. Patent 4 994 498 (Feb 19 1991)
Mixtures of carbon monoxide and hydrogen are converted to lower alkanols over a catalyst of molybdenum sulphide with an alkali metal (e.g. potassium) salt but performance is enhanced by 0.7-5 mole % tantalum (added as oxalate and then calcined).

C. ELECTRONICS

1. Composite Materials Technology : U.S. Patent 5 034 857 (Jul 23 1991)
Porous tantalum or niobium electrodes may be made by inserting filaments of the metal into holes drilled in a copper billet (compare A8, above). This is then extruded for a 6:1 reduction, and the wire drawn down. This may be further reduced by cutting and stacking, and again extruding and drawing. The copper is then leached out, and the resultant porous tantalum (or niobium with a tantalum coating) is then anodised.

2. Sumitomo Electric Ind. : Japanese Patent 2-221125 (Sep 4 1990)
A lanthanum strontium niobate made by mixing the respective oxides or carbonates and heating in a weak reducing atmosphere at 800-1200 °C, shows adequate superconductivity at 4.2 °K, and can be readily fabricated into wire or film.

3. N.E.C. Corp. : Japanese Patent 2-98836 (Apr 11 1990)
A gold film is used as the reflecting layer in optical memory bodies, but good adhesion to its substrate is difficult to obtain. Tantalum, applied by high frequency magnetron sputtering, ion plating, etc. acts as an effective adhesive layer between the substrate and the gold, and also gives corrosion resistance to improve the reliability of the device.

R.J. Tolley
Technical Adviser

New opportunities for growth in tantalum capacitors

[Recent improvements in tantalum capacitors were the subject of a presentation by Mr William A. Millman, AVX Ltd., to the meeting held in Philadelphia in October 1991.]

INTRODUCTION

Solid tantalum capacitors would not have reached their present level of world-wide sales of over 7 billion units per year in the face of competition from cheaper forms of capacitors unless they had proven themselves to be highly reliable components.

The revolution in circuit board component connection technology Surface Mounted Technology (SMT) and its inherent severe demands upon component performance is today's driving force behind the tantalum market displacing less compatible component technologies which today enjoy major shares of the capacitor market.

They are used in the most demanding of circuit applications because of their combinations of SMT compatibility, small size, performance and high reliability. However, as the use of tantalum has extended into a wider range of applications, the standardization embodied in the international IEC specifications, so vital in the acceptance of the molded SMD style, is no longer adequate.

Circuit designers are demanding new requirements and conditions of use, such as switching speeds, higher frequency, lower voltage/higher capacitance, lower leakage current and lower ESR, as well as fused capacitors which fail benignly under fault conditions.

New circuit requirements and advances in tantalum technology have brought about a need to understand the latest improvements in tantalum technology and the flexibility available to the circuit designer.

TRENDS IN FIELD OF USE

Since capacitance values are already standardized, standard case sizes, footprints and taping have created a world wide market of multiple sources to serve our increasingly internationalized customers. Moving away from single country standards has not only developed a world-wide market but also removed the first major brake on the growth of tantalum chip capacitors into a much wider field of use. The growth in unit terms of multi-layer ceramic capacitors (MLC) and tantalum can be seen to follow the demand for semiconductor devices, which themselves have undergone conversion to surface mountable forms of ever increasing capability. Along with the miniaturization of circuit board assemblies have come demands for reduced power consumption and faster switching speeds. The impact of higher switching speeds is to reduce the total amount of capacitance required.

Other factors also play a role here, one being the increasing demand for portable battery powered equipment and its implied demands on size, weight and ability to operate over wide temperature spectrums. The solid tantalum and MLC chip capacitors complement each other perfectly over the capacitance range needed for surface mount assemblies. There is, however, an overlap between the top range of MLC's and the bottom end of the range of tantalum capacitors. The cost of manufacture of an MLC is inherently less than that of a tantalum and major advances in MLC and tantalum material process technology are constantly moving that cost cross-over point.

The circuit designer's choice, however, is driven by more than just cost. Consideration of size, performance, weight, availability and maturity all play a role. Comparing the performance of MLC's and tantalum at high frequencies we can see the distinct advantage of MLC's hold over the comparable tantalum. But for applications requiring a wide range of operational temperatures, such as in automotive electronics, the stability of capacitance of tantalum dominates.

Customer driven demand has spawned the development of tantalum chips with lower levels of ESR, greater volumetric efficiency and reliability over wider environmental conditions of humidity and temperature; devices that will fail in an opencircuit condition, safe-guarding our customers' circuit board and equipment functions, in a standardized machine-friendly "fit and forget" chip capacitor.

VOLUMETRIC EFFICIENCY : GENERAL DOWNSIZING

In size we have the ability to exploit the latest technology high surface area tantalum powders allowing a general downsizing of all the range. Not all the voltage ranges can use the very highest surface area powders but the trend to lower operational voltages will help here.

As a result there has been an across the board movement to allow a decrease in size. In particular cases customer demand has driven existing capacitance/voltage combinations down two footprint sizes from the original EIA standard, so allowing increased PCB packing density plus an additional cost saving for the component itself.

The emphasis on putting more capacitance into case sizes A and B will reflect the range of competition from MLC's, and the larger C and D case sizes will compete to replace aluminium types.

This reflects the historical trend of maximum capacitance available per case size doubling every two years (Fig. 1).

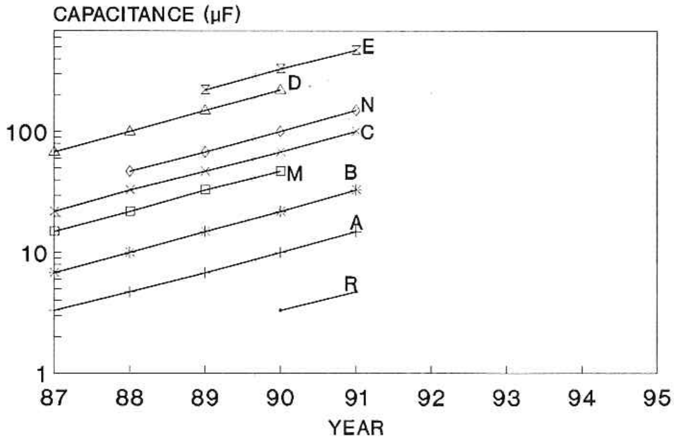


Fig. 1 : Maximum capacitance range for each case size

RANGE EXTENSION

As the EIA standard sizes are, to a large extent, governed by the tape dimensions in which they are supplied, the thrust of extended range development is to increase further the CV available while maintaining constant package size.

There is one exception to this, namely the introduction of an E case design, to meet an increasing number of power supply applications requiring higher ratings without consuming more board space.

For this reason, the E case part has the same footprint (L and W dimensions and termination configuration) as the existing D case, but having a higher profile.

The advantages of this configuration, apart from the extended ratings available, are the lower intrinsic ESR giving greater power handling and enhanced ripple performance with no significant increase in inductance over the D case. The actual dimensions and ratings are shown in Table Ia/b : note that the E case will be accommodated by existing D case pad layouts on IR or VPR soldering.

CODE	L ±0.2	W +0.2 -0.1	H +0.2 -0.1	W1 ±0.1	A +0.3 -0.2	S Min.
D	7.3	4.3	2.9	2.4	1.3	4.4
E	7.3	4.3	4.1	2.4	1.3	4.4

Table Ia

Capacitance Range (letter denotes case code)								
	Capacitance/Rated voltage d.c.							
μF	4V	6.3V	10V	16V	20V	25V	35V	50V
3.3								D
4.7							D	D
6.8						D	D	
10						D	D	E
15					D	D	D	
22				D	D	D	E	
33			D	D	D	E		
47	D	D	D	D	E			
68	D	D	D	E				
100	D	D	E					
150	D	E						
220	E	E						

Table Ib

For the top case size the C/V range has been further extended to incorporate values up to 220 μF 10 V.

Table II shows the original EIA molded chip ratings and the extended values now available.

ORIGINAL EIA-J STD RANGE vs AVX EXTENDED RANGE SMD TANTALUM CHIP

VOLTS / CAP (uF)	4	6.3	10	16	20	25	35	50
0.10								a/A
0.15								
0.22								
0.33							a	b/B
0.47						a		
0.68					a		A	
1				a		A	b/B	c
1.5			a		A	b	B	
2.2		a		A	b		c/B	d/C
3.3	a		A	b/A		c/A		
4.7		A	b/A		c/B		d/C	
6.8	A	b/A		c/B				D
10	b/A		c/B	B		d/C		E
15	B	c/B			d/C		D	
22				d/C		D	E	
33	c/B		d/C		D	E		
47		d						
68	d/C	C		D	E			
100			D	E				
150	D	D						
220	D		E					
330	E	E						

NOTE Only maximum cap*volts per case size diplayed

Lower Case - Original EIA-J Range
Upper Case - Latest AVX Extended Range

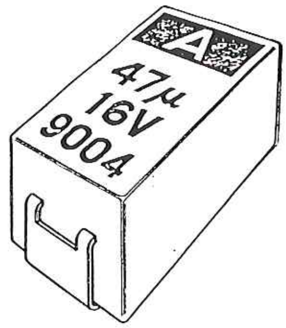
Table II

MINIATURIZATION

Miniaturization has been a major influence in the continuing evolution of capacitors. In recent years the spread of SMT has brought in new shape, size and stress conditions all of which alter the preferences which decide the choice of dielectric. The other main driving force for evolution is tightening specifications. Performance stability, reliability and environmental considerations have always been of prime importance but now mounting conditions have become as important for SMT applications. The body of the component now has to withstand complete immersion in molten solder or infrared heating up to temperatures which can sometimes exceed 300 °C. Also the mounted component is subjected to mechanical stresses during high speed placement and when on the circuit board.

The 0805 case size

Although some SMT tantalum capacitors have been available in an 0805 size the new AVX version is a big advance in that it is fully encapsulated within a regularly shaped body with compliant terminations which absorb the stress at mounting and during temperature cycling. The external configuration and physical sizes are shown in Fig. 2 and Table III respectively.



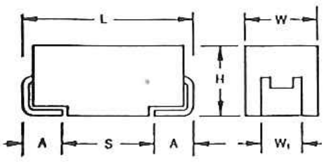


Fig. 2 : 0805 size capacitor

CASE	L	W	Hmax	W1	A	S
R	2.05	1.3	1.2	1.2	0.5	0.85
S	3.20	1.6	1.2	1.2	0.8	1.10
T	3.50	2.8	1.2	2.2	0.8	1.40

Table III

The designation 0805 is in line with the ceramic multilayer capacitor sizes where the length is nominal 0.08 inches and width is 0.05 inches. This compares with the previously smallest molded tantalum in the same range, the EIA A size, which is similar to the 1206 footprint. The height of the 0805 package is 1.2 mm which equates to that of a standard integrated circuit package after mounting. To keep the case size description in line with the other products in the AVX TAJ range this case is designated as the R case.

The range of capacitance and voltage values for the R size extends to 4.7 μF at 2 V and 0.1 μF at 20 V and is shown in detail alongside the other products in Table IV.

Applications will include many where the existing A size is at present used but will also extend further into fields where miniaturization of package volume and weight is a major design objective. Typical applications will be medical aids such as hearing aids and pacemakers, portable telephones, mobile fax machines, wrist watch pagers, etc.

To achieve this small size all the internal features have been re-evaluated in order to reduce dimensions to take off a few tens of microns wherever possible. The basic size of the tantalum anode has been reduced through the development by the material suppliers of special tantalum powders. These powders not only achieve a very high surface area per unit weight but also, more importantly, a very high surface area per unit volume. When tantalum capacitors were first developed the best powders had a figure of merit of 1500 μFV/g. This equates to a surface area of about 120 square cm per gram. Today powders are available up to 45000 μFV/g, a 30 fold increase (see Fig. 3).

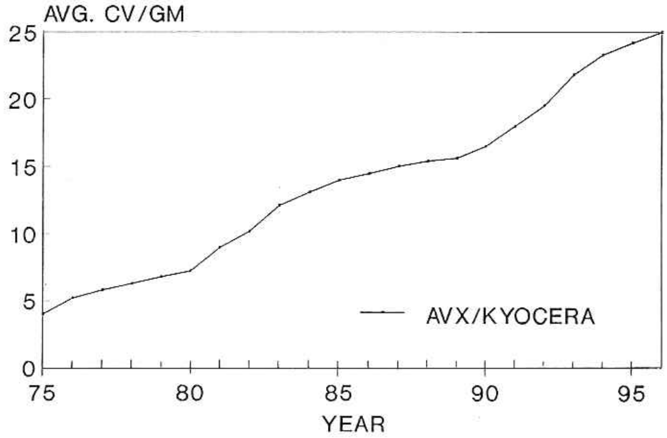


Fig. 3 : Tantalum powder : average CV/g

This major improvement obviously leads to a similar reduction in material usage and hence cost saving.

LOW PROFILE

The 1.2 mm height of the R size is also a feature of two additional sizes; these are of the same footprint as the existing A and B ranges. In line with EIA terminology these are designated S and T respectively. At the present time these are produced in the 6.8 μF 4 V to 0.1 μF 20 V ratings, (for full range see Table IV). There are obvious advantages in having the height the same as that of other major components on circuit boards, in particular it allows mixed technology (SMT and leaded components) to be applied to the primary surface of a pcb and only low profile SMD's on the secondary side. The double sided pcb will have an overall reduction in board height ideal for thin profle equipments such as pocket telephones, remote controllers, note book computer, etc.

CAP µF	2	4	6.3	10	16	20	25	35
0.1						R/S		
0.15						R/S		
0.22						R/S		
0.33						R/S		
0.47						R/S		
0.68					R/S	T		A
1				R/S		T	A	
1.5			R/S			A/T		
2.2		R/S	R		A/T			
3.3		R/S		A/T	A			
4.7	R		A/T	A				
6.8		A/T	A					
10		A						

Table IV : Capacitance and voltage range (rated voltage d.c.). Letter denotes case code

High frequency performance

High frequency performance (in the MHz region) is adversely affected by inductance within the component. The inductance is related to the area traced out by the current path and so downsizing and height reduction reduce this undesirable aspect (see Fig. 4). Typically the inductance of a B case size capacitor is 0.9 nH. The lower profile S and T sizes are about 0.1 nH less than the corresponding A and B. The R size is in the region of 0.4 nH. Although these values are all very low they can influence performance at the high MHz frequencies and so any reduction is useful.

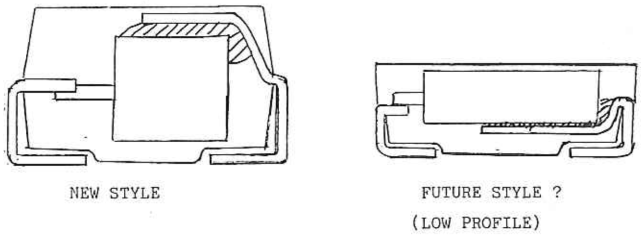


Fig. 4 : Capacitor profile

Low ESR

With the trend to continued downsizing and ever denser board packaging comes the problem of thermal management. In high ripple applications any rise above ambient by the capacitor must be taken into account. It is possible in forced air assemblies to achieve better than free-air ratings for power dissipation, but in general such thermal management is costly.

If ambient cannot be reduced and the application does generate high ripple, then the thermal size can be limited by using a low ESR part. Until recently, there has been little flexibility possible in component choice to address the above points. This has led to the generation of new tantalum products designed to address some or all of these conditions.

A typical relationship between ESR and frequency is shown in Fig. 5. The resistive effects represented by the ESR can affect performance in several ways. First, heat is generated in the capacitor due to I^2R losses. The temperature that the component reaches depends on the balance between this power loss and the rate of heat dissipated from the external surface. By setting a maximum temperature difference between the capacitor and its environment, the ripple rating can be defined.

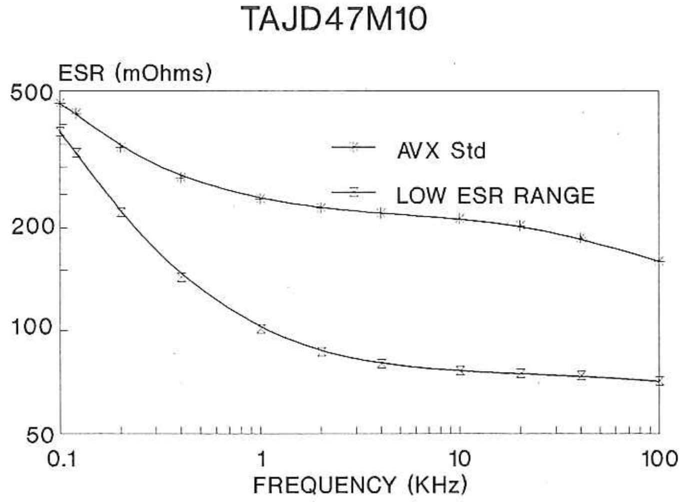


Fig. 5 : ESR and frequency

Secondly, the resistive element increases the impedance above the calculated capacitance reactance. This reduces the effectiveness of the capacitor for filtering and decoupling applications.

Thirdly, a phase shift occurs so that the voltage waveform lags the current waveform by less than 90 degrees. This can cause distortion in waveform shaping circuits. Finally, the rate at which charge can be stored in or taken out from a capacitor is controlled by the product of C and ESR, the "time constant".

To achieve a low level of ESR for the solid tantalum capacitor, the tantalum pellet or anode and aspect ratio and procedure for depositing the manganese dioxide counter electrode must be matched with each other and then carefully controlled. The use of super high surface area powders for volumetric efficiency can make the achievement of low ESR extremely difficult if the correct mixture of coarse and fine pores is not controlled. The range of low ESR capacitors available is shown in Table V.

TAJ MATRIX (LOW ESR)

VOLTS / CAP (µF)	4	6.3	10	16	20	25	35	50
0.1								
0.15								
0.22								
0.33								
0.47								
0.68								
1								
1.5								
2.2								
3.3								
4.7								
6.8								
10							D	
15					D	D		
22				D			E	
33					E	E		
47			D	E				
68		E						
100	D		E					
150		E						
220	E							
330								

Table V

RELIABILITY

Concurrent with the surface area improvements, there has been a parallel enhancement of the metal purity. This has resulted in a reduction of leakage currents and ever greater stability on life tests. The levels of reliability that have now been achieved for tantalum capacitors, along with their small size and high stability, are promoting their use in many applications that are electrically and environmentally more aggressive than in the past. To meet these changing demands the industry has expanded the SMD ranges to include "extended CV" and "fused devices".

Failure mode

The main catastrophic failure mode for tantalum capacitors is short-circuit although some open circuits can also occur. Open circuits result in degradation in circuit performance but, unlike the shorts, do not cause high current leading to secondary damage. Life test data show that although the failure rate is low (typically 0.067 % per 1000 component hours), shorts contribute the greater share of the total. With the introduction of the extended CV capacitors, the design engineer now has more room to manœuvre in the case of existing circuits, by using derating (which in general produces a tenfold increase in reliability for a 30 % derating) to solve any field failure problems caused by underestimating the rigors of the operational environment.

Derating is perhaps the only recourse open to enable an existing design problem to be cured and, in most cases, it will achieve the required reliability. The further aspect of preventing secondary failures of electrically adjacent components, including pcb tracks, will now be addressed.

Fused tantalum capacitors

Overheating is related to the power dissipation rather than the current itself. If the capacitor resistance drops to zero when it becomes short circuited no power is developed in the device and so it does not heat up. The maximum heating is generated when the resistance equals the circuit impedance. Therefore the risk of overheating depends on the coexistence of a number of critical factors; firstly the circuit must be capable of supplying a high power level, secondly the resistance of the short circuit must approach that of the impedance of the associated circuitry and thirdly the power dissipation must exceed that which can be safely dispersed from the capacitor into the local environment. As a guide to the latter, the level of power dissipation which can be tolerated without serious overheating is in the order of 0.5 — 5 W depending upon case size.

Given the combination of requirements to be present before there is any risk, coupled with the generally low failure rate, the total risk of serious overheating is very small. However it is not zero. There are many circumstances where the consequences of a failure of this sort are unacceptable, hence the need for a fuse to disconnect the device.

Fused tantalum capacitors are available from a number of manufacturers, but because of the additional volume required for the incorporation of a fuse, the full capacitance voltage range within a case size is not always available.

Current developments have permitted downsizing the fused chip to the EIA standard sizes, while retaining the advantages of electrical fusing. Another advance has been the development of novel fuse wire materials. These systems act as both an electrical and a thermal fuse.

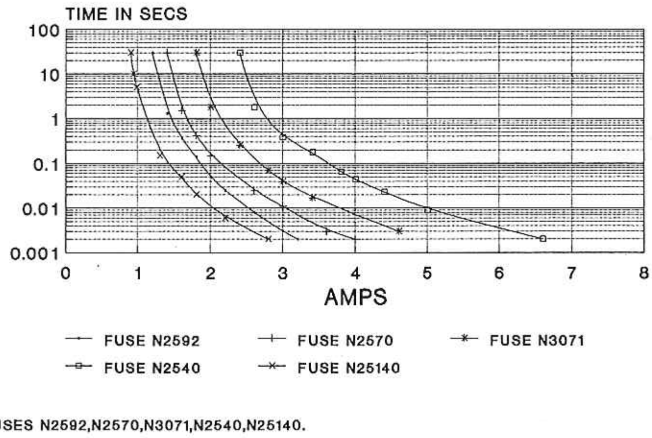


Fig. 6 : Binary fuse types (blow times against amps)

Fuses of this construction can be tailored to suit different design requirements as can be seen in Fig. 6.

CONCLUSION

Capacitors account for an appreciable proportion of the component count of an electronic circuit and so their performance is an important factor. The design engineers have been given the flexibility they need through tantalum SMD product developments to address application specific problems and further improve reliability and circuit performance.

The major advances in the preparation of tantalum powders have resulted in a new generation of SMD capacitors. The volumetric efficiency has been more than doubled from that of the early devices leading to a general movement down within the existing case sizes. In addition advances in internal assembly techniques and encapsulation methods have allowed new, smaller, case sizes to be added to the range. This downsizing has, in itself, reduced parasitic inductance.

Other improvements in the purity of the tantalum powder have lead to lower leakage currents and even greater stability on life tests. The use of the higher CV powders reduces the total amount of tantalum employed so minimizing the effects of material price movements. The risk of serious overheating in failed components, although very low, is addressed by the provision of fused devices, capable of beng tailored to specific customer requirements, to disconnect the device.

All of these aspects are not only good news for the user and designer but allow a wider application of tantalum capacitors to real advantage.

ACKNOWLEDGEMENTS

The author would like to express his appreciation for the assistance provided in the preparation of this paper by R. Franklin, I. Salisbury, C. Reynolds and M. Stovin, all of AVX Ltd.

Innovation in tantalum capacitor powder

[This is an abridged version of a paper by Hongju Chang, James A. Fife and Roger W. Steele of Cabot Corporation, and given by Dr Chang to the October 1991 meeting of the T.I.C. in Philadelphia.]

BACKGROUND

Tantalum powder is the basis of the tantalum capacitor and the last thirty years have seen a dramatic increase in the capacitance per gram of the powder available to industry (and so a proportional decline in size per capacitor, and cost per unit).

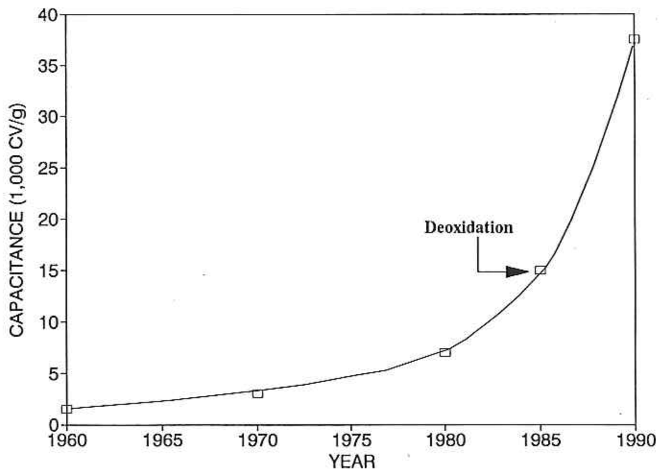


Fig. 1 : Progress in capacitance increase

As the graph indicates, the development of technology for a reduction in oxygen content certainly assisted, as did a decline in impurities in the powder.

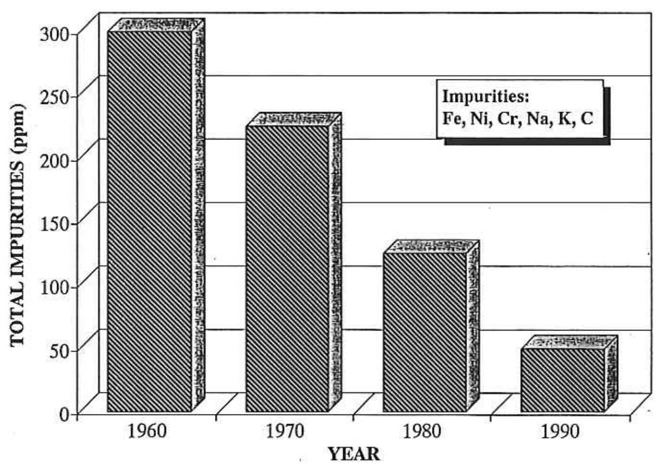


Fig. 2 : Progress in impurity reduction

But in addition, the following interrelated properties are critical : (a) surface area per gram, (b) morphology, and (c) consistency. All five of these factors are influenced by the manufacturing process for the powder (see Fig. 3).

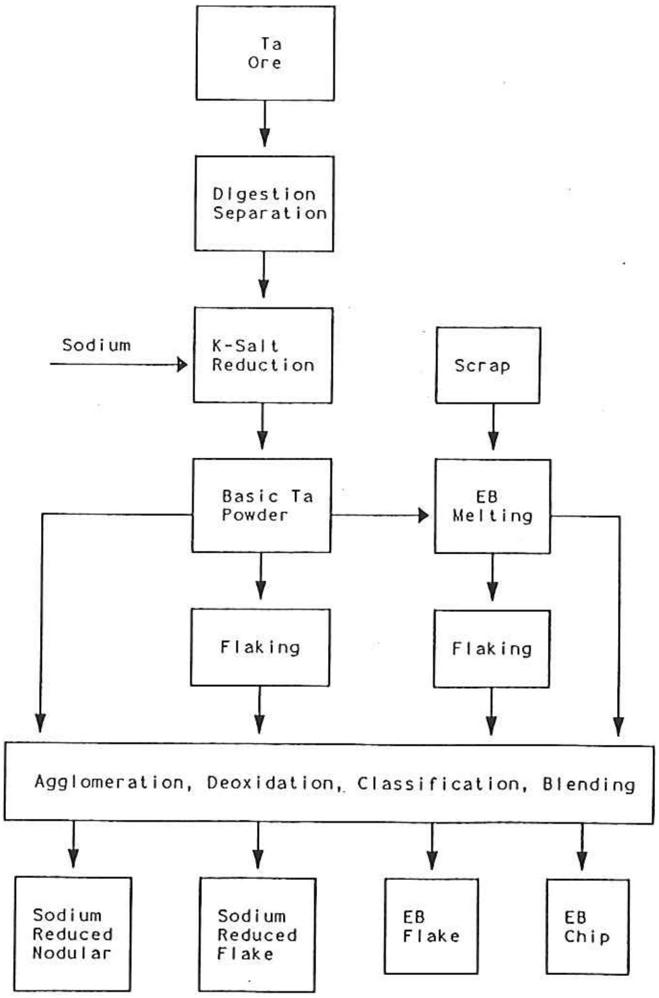
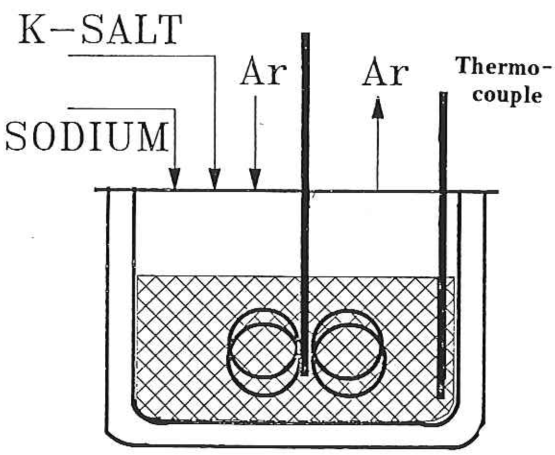


Fig. 3 : Tantalum powder manufacturing process

The first significant step is the reduction of K-salt by sodium, shown diagrammatically in Fig. 4, together with its process steps.



Process Steps:

- Diluent salt charging
- Heating up
- Reduction reaction
- Cooling
- Neutralization of excess sodium
- Water/acid leaching

Reaction:

$$K_2TaF_7 + 5Na \rightarrow Ta + 5NaF + 2KF + Heat$$

Fig. 4 : Reduction

The three controlled properties of particle size, purity and morphology are all more or less influenced by the controllable variables of temperature, concentration of reactants and their feed rate, the diluent salt chemistry, the reactant stoichiometric ratio as well as the size of the batch and the intensity of mixing. For instance, the nucleation of the tantalum particles is related to the surface tension of the molten salt, which itself depends on its composition and temperature. Similarly the rate of particle growth is a complex function of temperature and concentration (which itself changes with time). The purity of the resulting powder is influenced by temperature, particularly with regard to the alkali metals, (see Fig. 5) and by the materials of construction of the reactor with particular reference to iron, nickel and chromium.

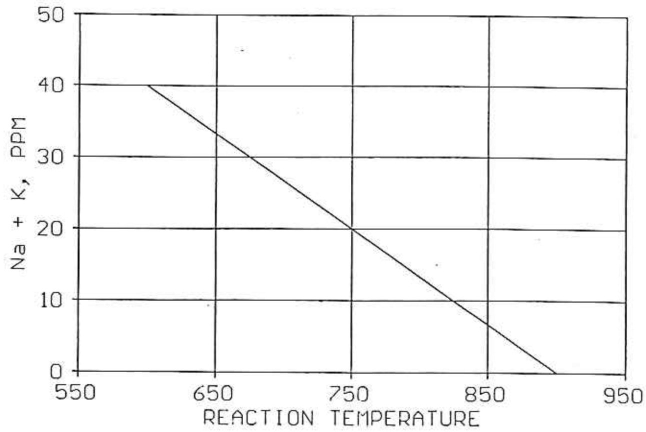


Fig. 5 : Purity control : effect of temperature on alkali metal content in powder

RECENT DEVELOPMENTS IN CABOT

The effect of this analytical approach to quality control is well shown in figures 6 and 7. Particle size has declined dramatically,

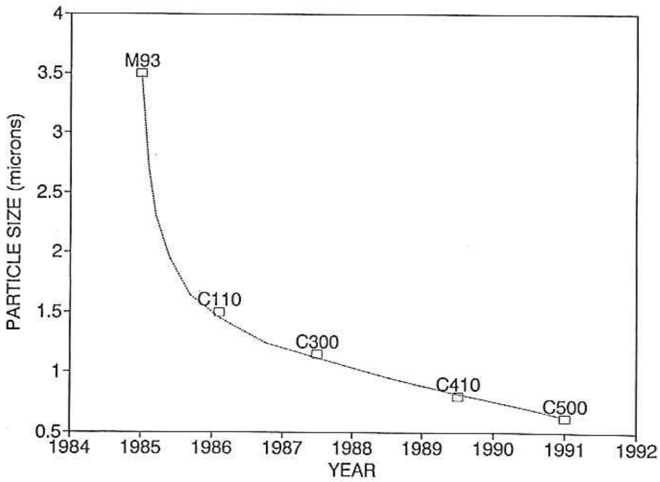


Fig. 6 : Results of particle size-control technology

and the reduction in impurities, particularly with the C110 HP powder, has strongly reduced DC leakage currents.

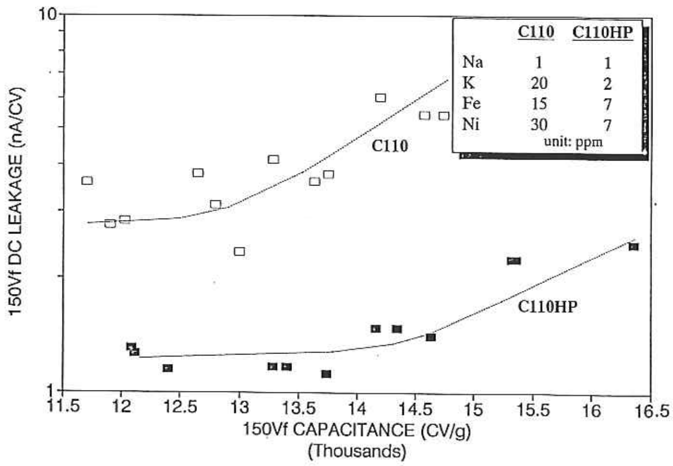


Fig. 7 : Improved properties as the result of improved powder purity

As a result, tantalum capacitors are made from modern powders (following the flow diagram in figure 8) to a consistency and with electrical capability barely dreamed of twenty years ago.

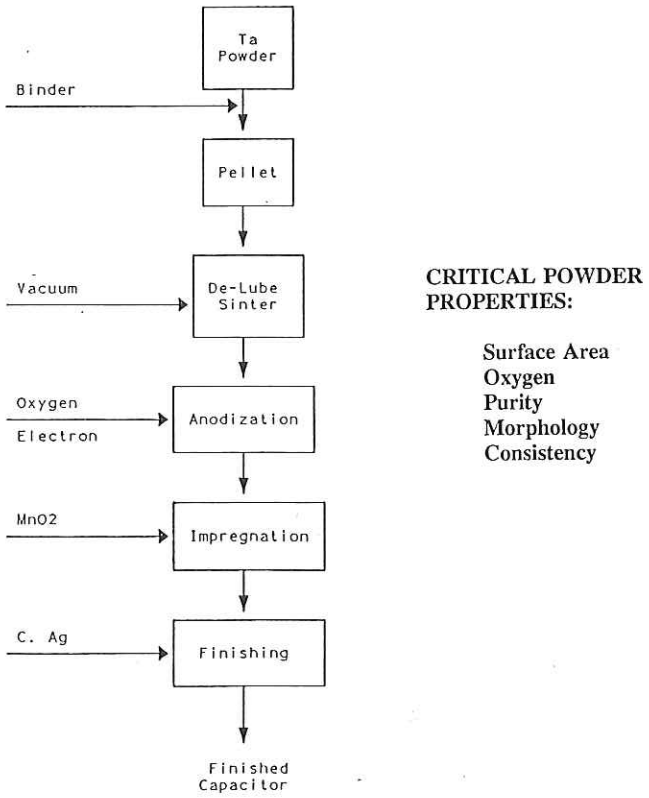


Fig. 8 : Use of tantalum powder and critical properties

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SYMPOSIUM PROCEEDINGS

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