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TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

PRESIDENT'S LETTER

Dear Friends,

In spite of ongoing difficult trade negotiations between the United States and Japan and drastic exchange rate fluctuations, which have silenced - at least for a while - experts, chart analysts and fortunetellers, the world-wide business environment remains encouraging. Demand for tantalum and niobium products continues on a high level. New applications are being discussed that could influence positively our industry's future growth.

This is also the theme of this year's major event of our association, the T.I.C. symposium in Goslar: finding new ideas for the application of tantalum and niobium in a dialogue between suppliers and end-users. The organizing committee has done an excellent job. The papers promise to be very interesting and should attract many participants to create new opportunities for our industry - thus helping to improve the financial situation of T.I.C. !

Sincerely,

Peter Kählert,
President

INTERNATIONAL SYMPOSIUM

The International Symposium on Tantalum and Niobium will take place in Goslar, Germany, from September 24th to 28th, 1995. The conference sessions will be held in the Hotel Der Achtermann, where delegates will also stay.

The technical sessions will include industry overviews, up to date information on processing, and authoritative papers on the use of niobium in modern steels. A large section on electronics will cover developments in capacitor technology and prospects for present and future applications in communications, vehicle electronics, ceramics and other fields. In a day's programme on compounds and applications, speakers will present uses as diverse as glass, jet engines and cutting tools, as well as scientific research of both commercial and academic nature.

A complementary social programme will open with a cocktail party to welcome all the participants, and offer entertaining and informative visits for those accompanying the conference delegates. The highlight will be a gala medieval banquet in the Kaiserpfalz, the Imperial Palace of Goslar, to which all will be invited as guests of H.C. Starck GmbH.

Starck is hosting this meeting as part of its 75th Anniversary celebrations, and will round off the conference on Thursday September 28th by offering a tour of its metallurgical plant.

Inquiries : T.I.C., 40 Rue Washington, 1050 Brussels, Belgium. Fax : (32) 2 649 64 47.

SUMMARY

TANTALUM - NEW TECHNOLOGY AND ITS APPLICATION IN JAPAN

by Mr Yasuhiro Higashiguchi, Vacuum Metallurgical Co., Ltd.

Tantalum is a very attractive material because of its excellent mechanical, electrical and chemical properties.

We would like to report on three new applications of tantalum in Japan:

1 - Tantalum sheet with mirror finish surface
2 - Tantalum as active material for ultrahigh vacuum getter pump
3 - Tantalum as electrode material for liquid crystal display (LCD) devices.

1. TANTALUM SHEET WITH MIRROR FINISH SURFACE

Tantalum is a typical refractory metal with a high melting point, similar to tungsten and molybdenum. Tantalum is superior in its workability to W and Mo, but it is likely to be flawed during working such as polishing and grinding, because of its relative softness. This is the reason why it is difficult to attain a mirror finish on tantalum sheet. We have developed a new apparatus to achieve a mirror finish for a tantalum sheet of large size.

The schematic illustration for the grinding apparatus which was developed by VMC is shown in Figure 1. The reference symbol T refers to the grinding wheel, B the abrasive grain, and P the pressing force. The pressing force is variable, depending on the grinding wheel, but the maximum value is 50kg/cm². The axis can be rotated and its speed is also variable up to 1000rpm.

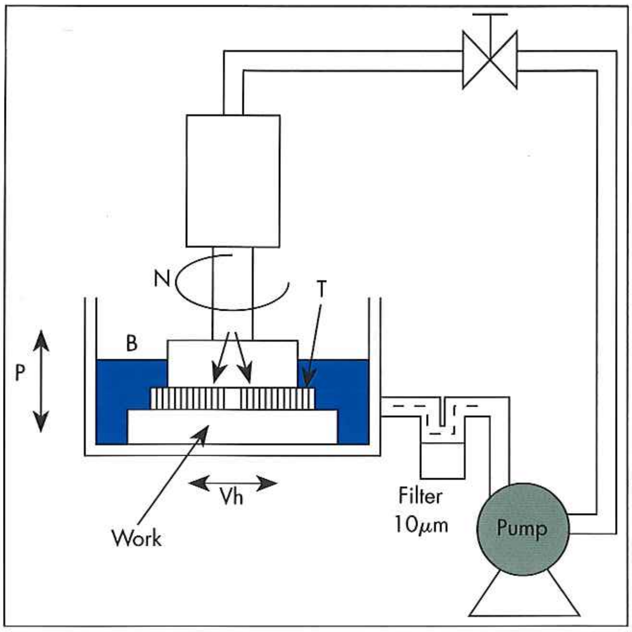

Figure 1 : Grinding apparatus

The size of the work piece is 1600mm in width, and the length of the work piece is variable within a wide range. White Al_2O_3 (WA) is used as the grinding medium for tantalum. Using this apparatus, the relation between the grinding wheel number and the surface roughness is obtained as shown in Figure 2. The

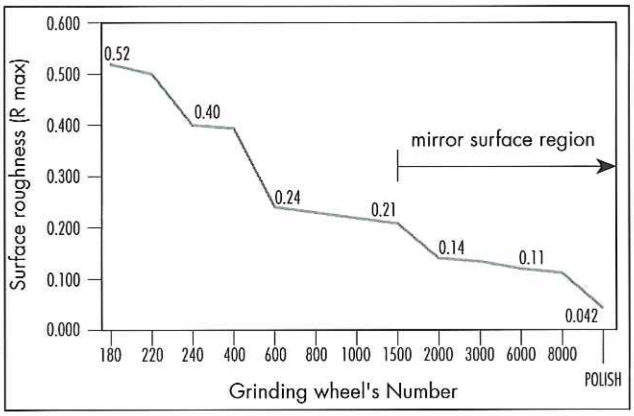

Figure 2 : Relation of surface roughness to grinding wheel number

horizontal axis is the grinding wheel number and the vertical axis the surface roughness. The surface roughness is reduced stepwise with the increase in the grinding wheel number. At a wheel number of 180, the surface roughness is about 0.52, while at the wheel number of 240 the maximum surface roughness (R_{max}) becomes about 0.40. In the range of wheel number 600 to 1500 the R_{max} is about 0.21. In a similar manner, the wheels from 1500 to 8000 were used, and beyond this buff finishing was applied. Mirror surface appeared from a wheel number of around 1500. The surface topographies are shown in Figure 3 for as-rolled material and mirror finished material. The surface roughness data were obtained by a three dimensional measurement. The principle of the measurement is to determine the irregularity of the surface using a reflection of a laser beam. Figure 3(a) shows the data of as-rolled material, and Figure 3(b) shows finished material. In both figures the measured area is 237 x 229μm^2. The scale of the vertical axis represents the magnitude of surface irregularity. Figure 3(a) gives a surface irregularity of about 30 times that of Figure 3(b). For the as-rolled material, Rmax was 48.6nm and RA was 39.5nm. On the other hand, for the finished material, Rmax and RA were 2.35 and 1.86nm, respectively, i.e. these values were reduced to about 1/20.

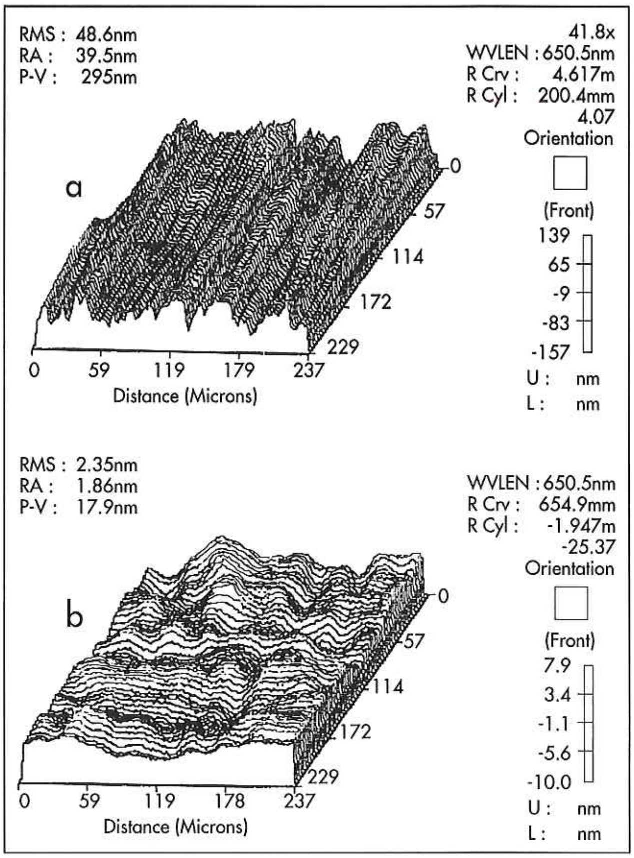

Figure 3 : Surface topography (a) as-rolled (b) mirror-finished

Figure 4 shows an example of mirror-finished tantalum sheet obtained by the polishing technology. The work size is about 1m x 1m. Top and bottom sheets are of tantalum. A beautiful surface, free from flaws, is observed. Even large sheets can be mirror-finished, e.g. from a width of 1600mm and a length of about 10m. Some examples of applications of mirror-finished tantalum sheet are summarized as follows:

1) Parts of vessel and piping for Chemical Vapour Deposition (CVD) for ULSI
2) Vibrating board of ultrasonic cleaner for LCD, HDD, quartz, etc.
3) Substrate for ULSI
4) Tantalum wafer

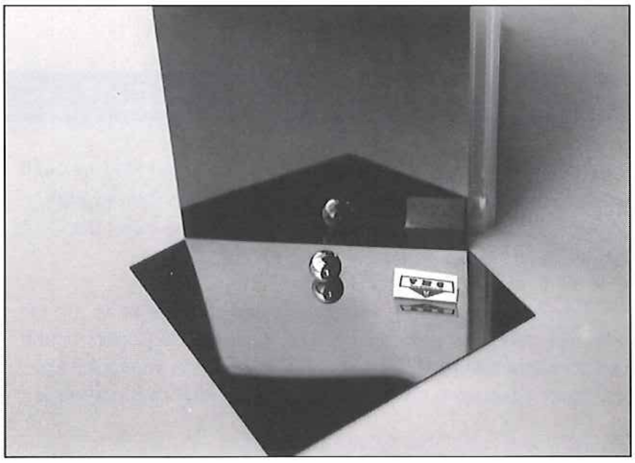

Figure 4 : Mirror-finished Ta sheet

2. TANTALUM AS ACTIVE MATERIAL FOR ULTRAHIGH VACUUM GETTER PUMP

The relation between vacuum level and pressure is shown in Figure 5. Vacuum from atmospheric pressure to 10Pa is called

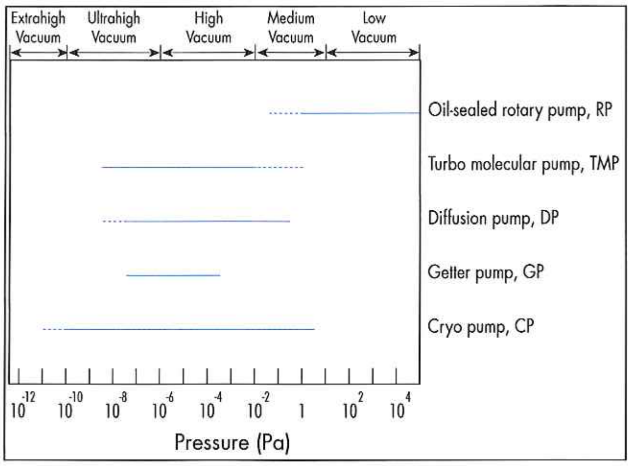

Figure 5 : Operating regions of vacuum pumps

"low vacuum". That from 10Pa to 10^{-2}Pa is "medium vacuum". From 10^{-2} to 10^{-6}Pa is "high vacuum", and from 10^{-6} to 10^{-10}Pa is "ultra-high vacuum". And that of 10^{-10}Pa and beyond is called "extra-high vacuum". Typical pumps are shown in the figure. Each pump has its own operating pressure range. A getter pump, which is also shown here, is operated mainly in the range of high and ultra-high vacuum. The principle of the getter pump is illustrated in Figure 6. An active metal is vaporized or sublimed to

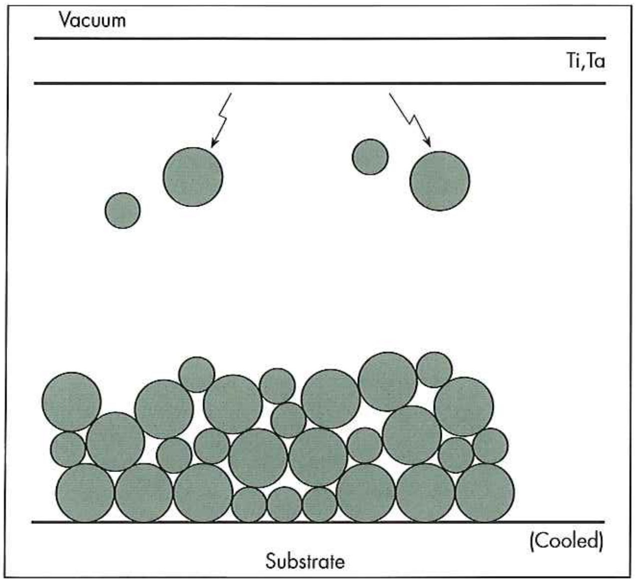

Figure 6 : Principle of getter pump using deposited active metal films (larger particles are Ti or Ta, smaller particles are residual gases)

be deposited on the wall or other parts to cover them with a clean film. The residual gas in the vacuum chamber is absorbed by the film, and held in the film. In this way, gases such as hydrogen, nitrogen and carbon monoxide are absorbed by the film. Figure 7 shows an example of a titanium getter pump. The number of titanium rods is 3, 6 and 12. The size of a single titanium rod is 2mm in diameter and 180mm in length. The titanium rod is directly electrically heated. Figure 8 shows data obtained by Professor Okano of the Institute of Industry, Science and Technology, University of Tokyo (1). With Ti and Ta as getter materials, the deposited film was cooled to 273°K, 196°K and 77°K. After that, the gas species and their amounts were determined by a mass spectrometer. The black marks were obtained by a Ta getter pump, while the white marks were obtained by a Ti getter pump. The mass number and corresponding gas components are: 2-H_2, 15, 16-CH_3, CH_4, 18-H_2O, 28-CO or N_2, C_2H_4, 40-Ar or C_3H_4, and 44-CH_2. As for H_2, there is no significant difference between Ti and Ta. However, other gases such as CH_3 and CH_4 showed a still lower value for Ta than Ti. In all the cases of 273°K, 196°K and 77°K, Ta gives

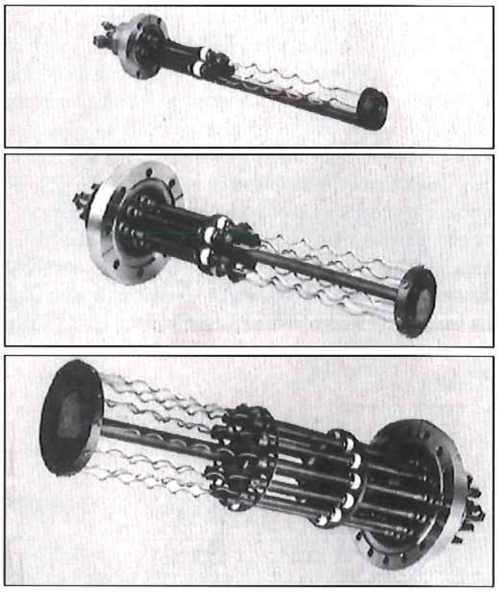

Figure 7 : Ti getter pump : Ti filament ø x180L (mm); number of filaments 3, 6, 12, respectively

less residual gas than Ti. This suggests that the Ti getter pump has a lower evacuating capacity of CH_3 and CH_4 and that the Ta getter pump is superior to Ti in evacuating characteristics (1). However, Ta has the serious disadvantage of having a melting point substantially higher than that of Ti. With the increasing demand for ultra-high vacuum and extra-high vacuum, the Ta getter pump will still, however, create interest.

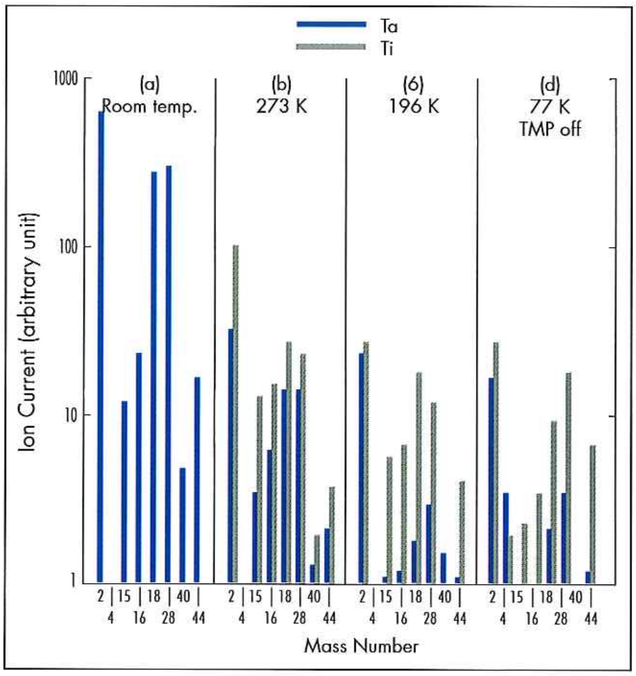

Figure 8 : Mass spectra before and after Ta and Ti are evaporated

3. TA AS ELECTRODE MATERIAL FOR LIQUID CRYSTAL DISPLAY DEVICES

Owing to the technical development of liquid crystal for large-sized display, the thin film transistor (TFT) method became the main method in this field, and commercial production has begun on a full scale. The method of manufacturing devices has adopted the conventional production technology of semiconductors. Target sputtering is mainly used to form the films at present. Various types of materials are used for the electrode and the gate.

The structure of LCD is created by several films, i.e. transference electrode, an oriented film, a liquid crystal, and a colour filter which are inserted between glass substrates. In a TFT the device which is made from various electrodes is formed on the glass substrate on one side. The illustration of the device structure is shown in Figure 9, and described in detail in "Rare Metal News" (2). Tantalum and its alloys are used for the gate electrode and the auxiliary capacity electrode. These electrodes are formed at first on the glass substrate as shown in this figure. The electrodes are then exposed to CVD to form SiN_x at a high temperature. These materials therefore need to have a high corrosion resistance which is the reason for the use of Ta and Cr in the gate electrode. The market is expected to be promising in the near future.

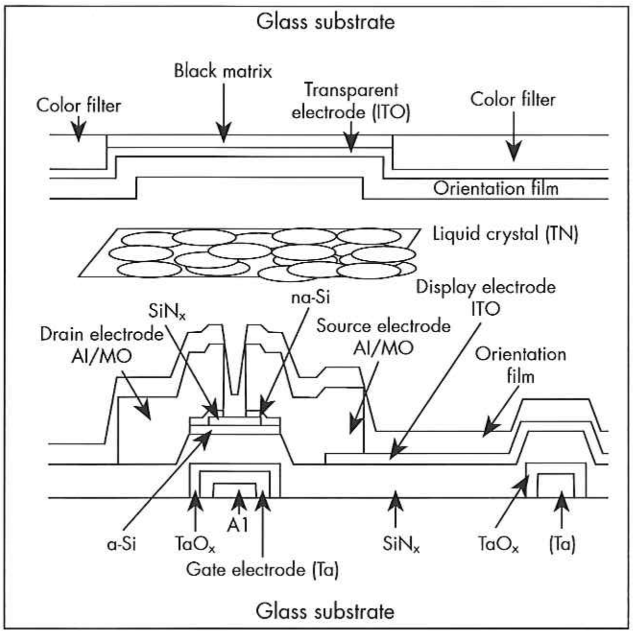

Figure 9 : Structure of LCD device

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1. *T. Okano, K. Iimura and G. Tominaga: Proc. 7th Intern. Vac. Congr. & 3rd Intern. Conf. Solid Surfaces (Vienna 1977) p. 81.*
2. *Rare Metal News, no. 1734, 1994.*

CO-DEVELOPMENT OF HIGH PERFORMANCE POWDERS FOR TANTALUM CAPACITORS

by Terrance B. Tripp, H.C. Starck Inc., Hiroo Naito, H.C. Starck-V TECH Ltd. and Klaus Andersson, H.C. Starck GmbH & Co. KG.

ABSTRACT

Development of tantalum powders for high quality and highly reliable tantalum capacitors has been improved by close cooperation of tantalum powder manufacturers in the three major tantalum capacitor producing areas, Europe, Japan and U.S.A. These tantalum powder producers have achieved an outstanding position in the tantalum world by open exchange of information among themselves and open discussions with their individual customers. Different tantalum capacitor makers follow production techniques which require a variety of raw material parameters. This contribution will give an overview of these parameters and their influence on the finished capacitors. Future powders still in the development stage and their potential for improving tantalum capacitors are described. The advantage of excellent cooperation among key raw material suppliers for the performance of the capacitor itself will be demonstrated.

INTRODUCTION

The solid tantalum capacitor has evolved, since its invention in the mid-1950's (1), into one of the most suitable charge storage devices for chip application, high component density, electrical circuits. These capacitors are attractive because of their high reliability, low temperature coefficient of capacitance, and high volumetric efficiency. The tantalum metal, which serves as the heart of the devices is extracted from Ta_2O_5 - containing ores and converted to capacitor grade tantalum powder. In 1993, 400 000 kg of tantalum powder were used worldwide to produce almost 9 billion solid tantalum capacitors.

The capacitor industry's annual tantalum consumption is small compared to the world wide resources : Australia, Thailand, and Brazil each have more than 30 years supply and furthermore a significant percentage of the produced tantalum capacitors is recycled.

To manufacture solid tantalum capacitors, the tantalum powder, often mixed with a binder or lubricant, is pressed into pellets containing from one to several hundred milligrams of powder. The pellets are then sintered in the 1400° - 1800°C temperature range with a significant trend in recent years to the low side. A thin layer of amorphous tantalum oxide is electro-chemically grown on the surface of the tantalum pellet to produce a high surface area body coated with a thin (25 - 300 nm) layer of insulating oxide. This arrangement imparts to the device a high volumetric capacitance which makes it excellent for use in high component density, electrical circuits. Next, the units are impregnated with semiconducting manganese dioxide by pyrolytic decomposition of manganese nitrate to produce the conductor-insulator-conductor configuration necessary for a capacitor. This basic solid tantalum capacitor is finally coated with graphite/silver epoxy and encapsulated more and more frequently in a chip configuration.

The pressing, sintering and impregnation processes are dependent on the physical properties of the powder. The electrical quality of the finished capacitor is strongly influenced by the powder surface chemistry. In this paper, we will outline the relationships between powder properties and solid tantalum capacitor manufacturing processes and performance. We will illustrate how the H.C. Starck Group of companies, using a coordinated international effort, has developed powders which have allowed capacitor manufacturers to expand the performance envelope of the solid tantalum capacitor.

First, we will review in some detail the relationship between powder properties, manufacturing processes and capacitor performance. This will be followed with examples of HCST Group powders with properties suitable for meeting the latest requirements for manufacturing solid tantalum capacitors.

PRESSING

The objective of the pressing operation is to produce stable, porous tantalum compacts with appropriate geometry, constant mass, and uniform density. The powder properties which have the greatest influence on powder pressing are the flow, bulk density, particle size distribution and agglomerate strength. Good and consistent flow is necessary for uniform die fill which is required for good pellet mass replication. Since pellet mass is a major contributor to the capacitance of a unit, this parameter must be carefully controlled within narrow limits. The capacitance is proportional to the electrode surface area, and inversely proportional to the dielectric thickness. Coarse powders flow well but have low surface area. High surface area, high capacitance powders are finer and in general flow poorly. One goal in the development of high capacitance powders is to find the best combination of particle size distribution and agglomerate morphology to optimize both the capacitance and flow characteristics.

Bulk density determines the size of the press die cavity and the length of the plunger stroke. At low bulk density, there will either be insufficient room in the die to hold the necessary mass of powder, or a long plunger stroke is required which can lead to smearing of powder on the surface of the pellet. Pellets with a smeared surface will have a large fraction of closed pores which makes impregnation difficult. At the other extreme, powders with high bulk density are not compressed much during pressing. The pellets tend to be fragile and difficult to handle.

The crush strength of a powder is related in a complex and not well understood way to the particle size distribution, agglomerate strength, and agglomerate morphology. Maximizing the volumetric capacitance is important for the manufacturing of chip type capacitors. This requires, in general, that the powder be pressed at a low density. Unfortunately, modifications to the powder properties which lead to higher surface area and increased specific capacitance tend to degrade the crush strength of the powder. Special attention to the powder properties which influence the crush strength is necessary for the production of high CV powders with suitable crush strength. These include controlling the agglomerate strength, particle shape, and particle size distribution. In general, weak agglomerates and a high percentage of very fine material should be avoided. The crush strength is also related to the hydrogen content of the powder. Dissolved hydrogen embrittles tantalum and degrades the crush strength. An excess concentration of hydrogen can also cause problems during sintering. The hydrogen released as the pellets are heated can overload the pumping system in some sintering furnaces causing an undesirable pressure burst. Capacitor grade tantalum powders should contain less than 50 ppm hydrogen in order to minimize the effect of dissolved hydrogen on the crush strength and furnace performance.

SINTERING

The objectives of the sintering operation are to produce structurally stable, porous, compacts with good bonding to the lead wire and traditionally to remove impurities at or near the surface of the powder. Within limits, the capacitor manufacturer can control the final physical and electrical (surface chemistry) properties of the pellets by adjusting binder type and loading, pellet press density, sintering temperature, and sintering time.

Powder properties can strongly interact with the sintering operation. Weakly agglomerated particles shrink excessively at the necessary sintering temperature and the pellets will deform and have low porosity. On the other hand, a powder which was agglomerated at high temperatures, while likely to have good pressing characteristics, will not shrink sufficiently during sintering to bond with the lead wire or yield a strong compact. The sintering process has traditionally been used to clean the surface of the powder preparatory to anodization. Sintering temperatures of at least 1500°C are required to remove potentially damaging impurities like carbon and alkali metals. In order to take advantage of the capacitance potential of the next generation of high capacitance powders, sintering temperatures below 1500°C are necessary. This means that these high performance powders must have inherently low concentrations of electrical quality degrading impurities.

The sintering temperature dependence of the leakage of old and new generation powders is compared in Figure 1. Notice the significant decrease in the leakage of the old generation powder between 1500°C and 1600°C sinter compared to the low leakage of the new generation powder - leakage which is almost independent of sintering temperature. Furthermore, the "old" powder has a much higher formation voltage dependence of leakage compared to the "new" powder. The differences in the performance of these two powders are predictable from their respective chemistry; the new generation powder has very low concentrations of electrical quality degrading elements like sodium and carbon and, thus, does not require an aggressive sintering process to clean the tantalum surface.

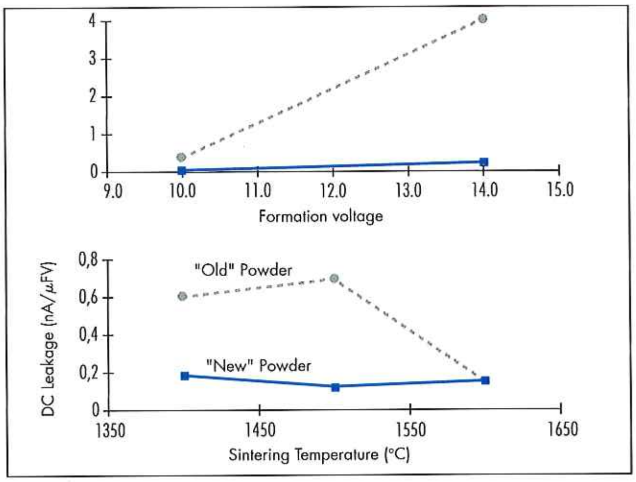

Figure 1 : Leakage current characteristics of old and new tantalum powders

ANODIZATION

The process of electrochemically depositing a layer of amorphous anodic tantalum oxide on the surface of the sintered tantalum pellet, known as anodization, is an extremely important step in the manufacturing of solid tantalum capacitors. The dielectric integrity of this thin insulating film controls the quality of the finished capacitor. In turn, the chemical properties at or near the surface of the tantalum, the conditions used for anodization, and possibly the morphology of the sintered pellet determine the quality of the oxide dielectric.

The mechanism for DC leakage in anodic tantalum oxide has been the subject of numerous investigations (2-19) but is still not well understood. In general, the leakage paths can be separated into two categories; intrinsic leakage through the bulk of oxide film and localized dielectric breakdown due to field crystallization or chemical/physical defects in the film. These defects arise as a result of impurities on or near the surface of the powder or heterogeneous impurities entrapped in the sintered matrix.

Carbon is known (9) to degrade the quality of anodic oxide films on tantalum. Traditionally, the carbon concentration in capacitor grade tantalum powders has been in the 30 - 100 ppm range with 40 - 60 ppm carbon common. Several powders are now appearing on the market with less than 15 ppm carbon as a result of recent technological breakthroughs by the HCST Group. Another source of carbon is the residue left from organic binders or lubricants added to the powder by the capacitor manufacturer. These additives are put in the powder to improve handling, increase capacitance, and lubricate the die mechanism. The new very low carbon powders will present an added challenge to powder users to develop binder/lubricant systems and removal techniques which reduce the level of residual carbon to well below that achieved with the present technology.

A high oxygen concentration in the sintered pellet can cause leakage current problems (20). While the oxygen concentration at which the oxide quality starts to degrade is somewhat dependent on powder and sintered pellet surface area, as a rule of thumb when the oxygen concentration exceeds about 3500 ppm in the sintered pellet, dielectric quality is likely to decline. Pellets made from high specific capacitance powders tend to have more oxygen than those made from older powders. To date, for the powders with 30 000 CV/g and above capacitance, it is not possible to make capacitors with pellets produced by the welded lead, double sinter technology. Furthermore, high oxygen concentration is probably the main barrier to the expedient development of powders with over 50 000CV/g.

Controlling oxygen concentration is a good example of the need for cooperation between the powder producer and the capacitor manufacturer. The powder producer must strive to make powders with a minimum of oxygen and provide them to the user in a form which reduces or eliminates oxygen pick-up over time. Examples of how the HCST Group has achieved these objectives are described below. For their part, the capacitor manufacturers must use or develop processes which reduce the pick-up of oxygen. Examples would be modifications to the binder removal process and not double sintering pellets.

The transition metallics like nickel, iron, and chromium have long been considered detrimental to the electrical quality of tantalum powders even though there is little documented evidence that these metals, when alloyed in the powder, degrade electrical quality. Heterogeneous metallic impurities have the potential of causing catastrophic failure of a capacitor. Alloying will occur during the reduction process when corrosion products dissolved in the molten salt mixture become incorporated in the tantalum metal matrix as it grows. Heterogeneous impurities usually find their way into the powder during post-reduction processing as a result of mechanical abrasion of equipment. The concentration of homogeneous transition metal impurities can be eliminated by careful attention to post-reduction powder handling and employing processes to remove magnetic particles. Another possible source of heterogeneous transition metals contamination is die wear during anode pressing.

The alkali elements, sodium and potassium will cause leakage problems. As seen in Figure 2 there is a strong correlation

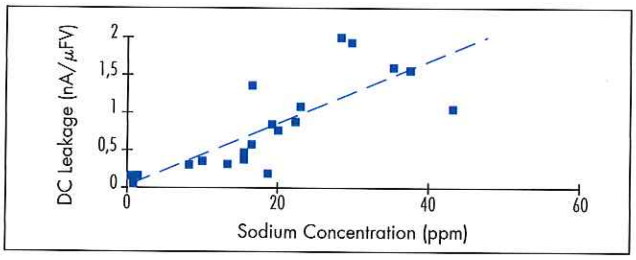

Figure 2 : Leakage current vs. sodium concentration

between the sodium impurity level and the DC leakage current. Traditionally, this element was frequently present in the powder in the form of heterogeneous sodium tantalum oxygen compounds. These compounds were removed by sintering at temperatures above 1550°C. Since the full potential of the new high CV powders requires the use of sintering temperatures as low as 1350°C, the powder manufacturer must produce products with sodium levels less than a few parts per million. A characteristic of virtually all of the latest generation of capacitor grade tantalum powders is the very low concentration of alkali metals, e.g. VFI/STA-18KT tantalum powder has a sodium concentration of about 1 ppm and a wet leakage current in the range of 0.2 nA/μFV.

EXAMPLES OF PRODUCTS DEVELOPED

Deoxidized tantalum powders pick up oxygen over time as shown in Figure 3. The H.C. Starck Group offers vacuum packaged tantalum powders which ensure that the capacitor manufacturer receives powder with the lowest possible oxygen content. As another approach to controlling the oxygen concentration, we have refined a process for deoxidizing sintered pellets (21). This treatment is especially useful for an anode preparation process which requires double sintering. By deoxidizing the pellets, e.g. after the first sintering, it is possible to keep the oxygen concentration below 3000 ppm even in anodes made from very high specific capacitance powders.

The HCST Group has invented a process to reduce the oxygen

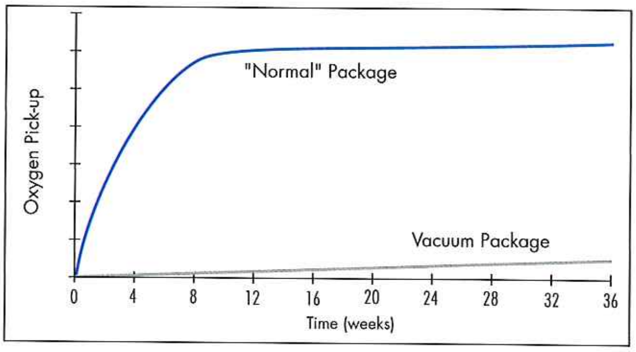

Figure 3 : Oxygen pick-up of tantalum powder

content of tantalum powder by surface nitriding. A properly nitrided powder contains 300 - 800 ppm nitrogen and between 1000 and 2000 ppm less oxygen, as illustrated in Figure 4.

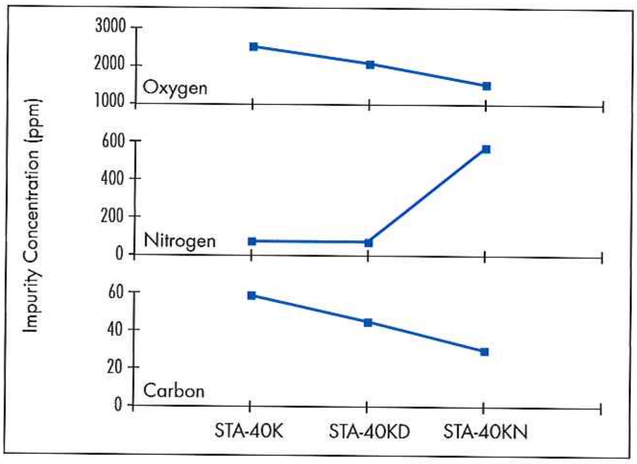

Figure 4 : Oxygen, Nitrogen and Carbon of 38 000 CV/g Powders

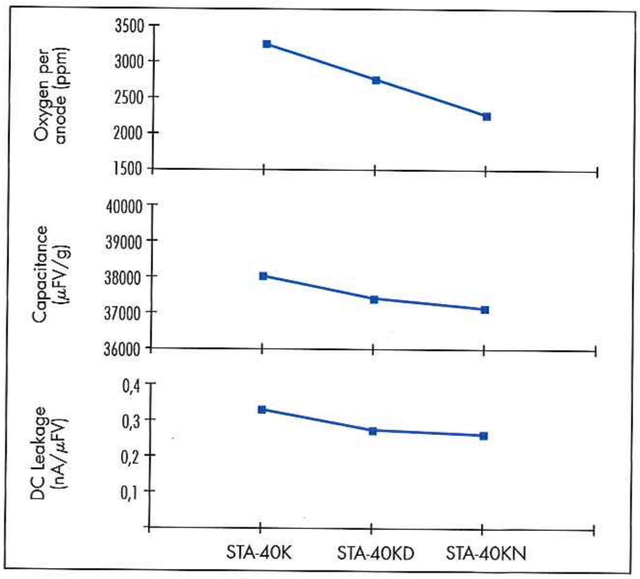

Figure 5 : Characteristics of sintered anodes made from 38 000 CV/g Powders

As seen in Figures 4 and 5 this low powder oxygen translates to lower oxygen in the anode with no degradation of the electrical properties. The lower initial oxygen concentration in the nitrided powder can be critical in preparing anodes made from high specific capacitance powders by the double sintering process. The nitriding process has potential for controlling the oxygen content in the 70K and higher class powders now under development.

The new HCST powder NH175 is the first produced by the latest technology developed by the HCST Group. The data summarized in Table 1 demonstrate the excellent chemical characteristics of this powder.

Impurity	Content (ppm)
Carbon	15
Oxygen	1260
Potassium	8
Sodium	3
Chromium	11
Iron	5
Nickel	8

Table 1 : NH175 powder chemistry

The carbon concentration is less than 15 ppm, the transition metallics are near or below the detection limit, the alkali metals are extremely low in concentration, and the oxygen is at the minimum for a powder with this surface area. While the powder has a modest high capacitance of about 20 000 CV/g, we have made good 35 V solid capacitors with 17 000 CV/g. The excellent electrical quality of the powder is illustrated in Figure 6.

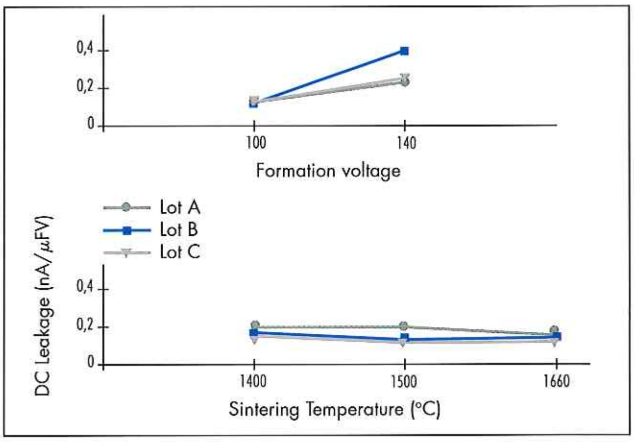

Figure 6 : Leakage current characteristic of NH 175 tantalum powder for 35 V capacitors

Notice the near independence of the leakage on sintering temperature and formation voltage. Work now in progress suggests that higher capacitance versions of this very high purity sodium reduced powder are feasible.

Figure 7 traces the growth in the specific capacitance of tantalum powders since 1960. The accelerated increase in capacitance experienced in recent years is expected to continue into the foreseeable future in response to pressure from down sizing of chip capacitors as outlined in Figure 8. The HCST Group is actively working to develop powders in the 70 000 CV/g and higher class. We have already demonstrated the feasibility of making powders with 60 000-80 000 CV/g. Work is in progress to perfect the physical properties and electrical quality of this new class of powders.

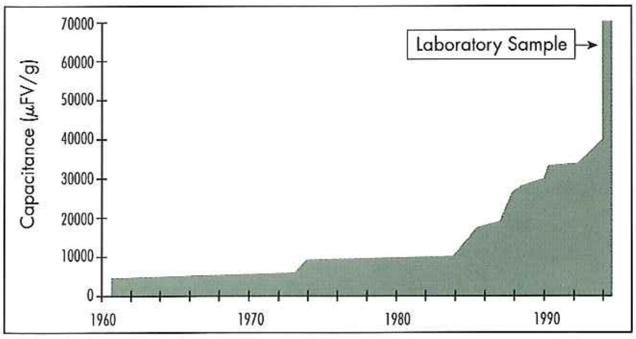

Figure 7 : Specific capacitance of tantalum powders

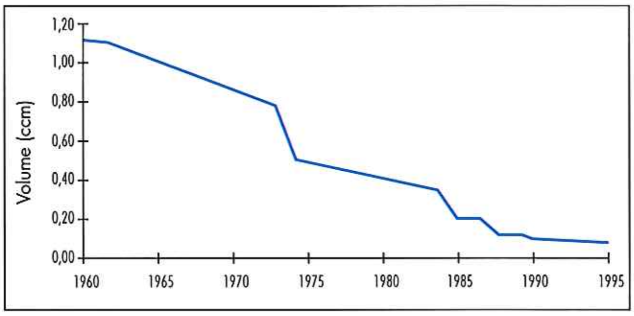

Figure 8 : Volume of a typical 10μF/16 V tantalum capacitor

SUMMARY

The demands imposed on the solid tantalum capacitor by modern electrical circuits have translated to the need for higher performance and quality capacitor grade tantalum powders. In this paper, we outlined how the chemical and physical properties of powders interact with the manufacturing processes used to make solid tantalum capacitors. An understanding of these relationships provides direction to the ongoing efforts to develop new powders and improve existing products. A number of examples were presented which illustrate how the international collaborative approach used by the HCST Group has resulted in the development of powders which can meet the needs of solid tantalum capacitor manufacturers now and in the future.

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INFORMAL MEETING

The members of the Executive Committee met on the afternoon of Monday April 24th 1995 to carry out the business of the association. They were pleased with the progress of plans for the International Symposium to be held in Goslar, Germany, from September 24th to 28th 1995, announced in Bulletin no. 81.

The financial situation of the association was reviewed, and the Committee decided that the annual membership fees would remain unchanged for the coming year.

The Technical Adviser reported on the range of his activities over the past few months, and explained his ideas for promotion of niobium and tantalum to a wider audience in the world.

A drive for new members of the T.I.C. is to be undertaken: the association is seeking candidates both for full membership and for associate membership. Companies or individuals with a commercial interest in production or processing of tantalum and niobium, trading in these metals, or services connected with the metals or their industry are eligible: if your firm is interested, or if you know of firms which might be interested, please let us know.

On the morning of Tuesday April 25th other delegates joined the Committee members for informal discussions on the Symposium and other T.I.C. activities, and matters of general interest to the industry such as European Union decisions on the transport of materials.

ASSOCIATE MEMBERSHIP

In addition to full membership, the T.I.C. has created a category of associate membership for individuals or organisations not in commercial business. Associates receive the collected statistics, monthly abstracts news and invitations to meetings, as well as the Bulletin. The list of associates is beginning to grow, so if you would like to know more about joining it please get in touch with us.

SEMINAR

An International Seminar on Assessment of Carcinogenic Risk from Occupational Exposure to Inorganic Substances is being organised by Eurometaux, the European Association of Metals, in conjunction with Edintox, and with the support of the European Commission DG V. The seminar will take place in Luxembourg, at Plateau du Kirchberg, from October 17th to 20th 1995. Contact Mr Chantelot, Eurometaux, 12 Avenue de Broqueville, 1150 Brussels, for details.

Mr Chet LeRoy

We were very sad to learn of the death on May 24th 1995 of Mr Chester E. LeRoy, the retired vice president of technology of Teledyne Wah Chang in Albany, Oregon. Chet LeRoy joined Teledyne in 1969 as manager of the TaNb product division, became in 1980 vice president of special products and retired in 1990.
He came to Wah Chang from Fansteel Inc. in North Chicago where he was general manager of the metals division. Chet LeRoy was one of the leading personalities in the tantalum niobium industry for many years and a good friend to many of us.
He was the official delegate of Teledyne to T.I.C. and contributed greatly to the success of this organisation. He will be sorely missed by all of us.

Mr Keith R. Garrity

Fansteel Inc., of North Chicago, Illinois, has announced that Keith R. Garrity, Chairman of the Board and Chief Executive Officer, passed away on June 1st 1995 after an extended illness. He had reduced his day-to-day activities with the company in February of this year in order to devote more time to cancer treatments.

Mr Garrity joined the company in 1954 and served as Chairman and Chief Executive Officer since 1982. He played an important role in the tantalum and niobium business for many years and became a friend to many of us. We will all be missing him.

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