

# T I C

## TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

### PRESIDENT'S LETTER

Dear Friends,

The T.I.C plans to hold its Forty-eighth General Assembly on Monday October 22nd 2007 as part of a meeting from October 21st to 24th 2007 in Rio de Janeiro, Brazil. Included in this meeting programme will be plant tours to Fluminense and CBMM.

After the great success of our meeting in Innsbruck we expect this year's meeting also to attract a large number of members, guests and other interested parties to participate.

Therefore I would like to encourage all of you to contribute to this meeting with suggestions for technical, commercial or more general papers to report on the progress our industry has made and will be making.

Members of the Executive Committee, the Technical Promotions Officer and the Secretary General will meet in Brussels in April to review and outline the programme for the forthcoming General Assembly. I would encourage you all to provide your suggestions on how we might improve our association and the service we provide to our members and would welcome your contributions to our deliberations.

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President

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### RIO DE JANEIRO OCTOBER 2007



The Forty-eighth General Assembly meeting of the Tantalum-Niobium International Study Center will be held in Rio de Janeiro, Brazil, from October 21st to 24th 2007. The technical sessions and social events will be held at the Hotel Sheraton Barra, where delegates will also stay. The technical presentations will cover a wide range of aspects of the industries of both tantalum and niobium and feature Brazil in particular, in two half-day sessions to allow delegates a little spare time.

The business and administration of the association will be carried out in the formal General Assembly on the morning of Monday October 22nd, including election of applicants for membership and the appointment of the members of the Executive Committee.

A choice of plant tours will be offered and delegates will be able to select a visit to the mine and plant of Industrial Fluminense of the Metallurg Group or a trip to the mine and processing facility of Companhia Brasileira de Metalurgia e Mineração (CBMM).

Industrial Fluminense was founded nearly 100 years ago, and began processing tantalum and niobium at São João del Rei, Minas Gerais, in 1960, acquiring in 1978 the Mibra mine 78km away as a source of ore containing tantalum and niobium. The company joined the Metallurg Group in 1979, and since 1996 has focused production on tantalum and niobium oxides for export and on aluminium products.

CBMM's large niobium mine is at Araxá, Minas Gerais, and the processing plant is on the same site, producing ferro-niobium, niobium metal in a variety of forms and a range of compounds.

The programme for the meeting will be completed by a welcome reception on the evening of Sunday October 21st, and a gala dinner. There will also be sightseeing tours for those accompanying delegates.

Invitations will be sent to the nominated delegates of member companies about three months ahead of the meeting. Others who would like to attend should contact the T.I.C. as soon as possible.

### CONTENTS

President's Letter.....	1
Rio de Janeiro.....	1
Secretary General.....	2
Future Use of Tantalum within Corrosion Engineering and Energy Production.....	2
Niobium for Coins.....	6
Member company news.....	8



## SECRETARY GENERAL

The new Secretary General will take up the post in July 2007.

## FUTURE USE OF TANTALUM WITHIN CORROSION ENGINEERING AND ENERGY PRODUCTION

*This article is based on the paper presented by Dr Bo Gillesberg of Danfoss Tantalum Technologies, at the meeting of the T.I.C. held in Innsbruck, Austria, in October 2006*

### INTRODUCTION

Tantalum shows immunity to attack by most chemical substances in a wide temperature range. Specialists recognise tantalum as the best corrosion resistant metal available. But despite the unique chemical performance tantalum is perceived today as a less than attractive choice as a construction material within corrosion engineering, due to the high price, limited strength, high density and difficulties in relation to machining processes such as welding. Since the 1980's, Danfoss Tantalum Technologies has been pursuing research in applying tantalum as a functional surface layer on top of more common materials such as steel or stainless steel. The idea behind the Danfoss approach is to benefit from the advantages of the good chemical properties of tantalum but on the other hand to overcome the problems of the cost and limited physical properties of the metal.

The work by Danfoss has shown that thin film tantalum coating may be used effectively in the development of new high performance products, such as medical devices. Published data show that tantalum coating applied to stainless steel, CoCrMo alloys and carbon materials results in an enhanced biocompatibility of implants (ref. 1, 2). An explanation for the unique biocompatibility is to be found in a capability of producing high quality surface layers. By testing in body liquids (saline) the deposited tantalum surface layers have been characterised as being absolutely dense (i.e. 'pinhole free') and therefore they act as a diffusion barrier for the dissolution of metal ions from the substrate (ref. 2).

Pinhole free tantalum layers may however also have technical potential in more aggressive chemical media. This is due to the fact that a fully intact tantalum surface will protect a base material as long as the surface layer itself is chemically resistant. To evaluate the technical potential of tantalum based surface solutions, the current markets for corrosion resistant material have been evaluated. The technical areas being explored are chemical related industries (chemical processing, pharmaceutical, offshore etc.) as well as energy production (fuel cell applications). These industries are today challenged by limited performance of the materials used, and may gain advantage from better technological solutions.

### CHEMICAL-RELATED INDUSTRIES

Historical data indicate that only a few percent of annual tantalum production is applied for purposes involving resistance to corrosion – i.e. probably less than 50 tons. Tantalum must

therefore be considered as a rather 'exotic' choice within corrosion engineering. Nonferrous special alloys (primarily based on nickel and titanium) are, on the other hand, widely used in the industry and the value of nickel and titanium based alloys for corrosion applications is judged to be in the range of US\$300 to US\$1000 million (ref. 3).

### PRICE GAP

The main reason for the poor use of tantalum in corrosion engineering is to be found in the huge price gap between tantalum and traditional non-ferrous corrosion alloys. Figure 1 shows price relationships for corrosion design in different materials. The non-ferrous 'special alloys' are found in a price range of 15-25 times the price of 'plain' stainless steel (i.e. AISI 304L and 316L). Tantalum as the most expensive 'exotic' option is priced in the range 130 times the price of 304L. The prices of nickel, molybdenum and titanium have received attention due to instability during the last three years (ref. 4). Further increases in prices can be expected in the next few decades with increased consumption in new economies in Asia, Russia and South America (ref. 5). Tantalum metal on the other hand has shown a relatively stable price range within the last four to five years. The price gap will however be a permanent constraint on increased use of solid tantalum in corrosion applications.

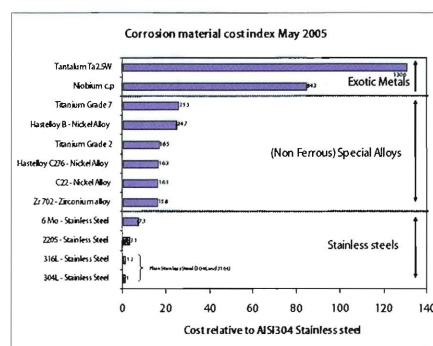


Figure 1: Cost index for corrosion resistant materials. Prices are based on spot prices for 0.25-0.30 inch sheets in May 2005 (ref. 4)

### COMPETITIVE SCENARIO

From the point of view of uses in which resistance to corrosion is required, tantalum is interesting, since it has a unique possibility for direct substitution for any of the other special alloys in Figure 1. The complete special alloy market would therefore be open for substitution if a competitive tantalum price could be reached. This would however imply a reduction in the tantalum component price in the range of 90%. Solutions where tantalum is used as a protecting surface layer are obvious ways to achieve such a goal.

Figure 2 shows the substitution potential of different tantalum surface technologies assuming a special alloy cost 10 times higher than stainless steel. The relative cost of the raw materials for components fabricated in special alloys and in stainless steel surface-treated with tantalum is indicated, with the cost plotted against the component material thickness. The price of the tantalum-surface solutions is based on a tantalum price 130 times that of stainless steel and allowing for 30% material waste in the surface process. The dotted lines indicate that the tantalum solution is more expensive than the special alloys solution, while the solid line indicates that the tantalum solution works out at a lower price than the special alloy.

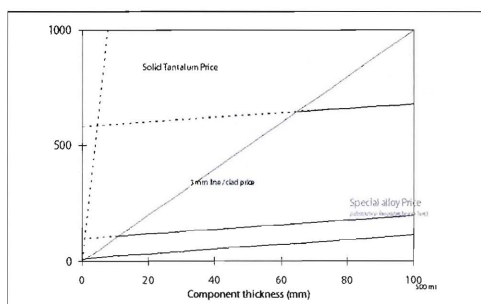


Figure 2: Potential for tantalum to be used instead of special alloy  
Dotted line: tantalum solution more expensive than special alloy  
Full line: tantalum solution less expensive than special alloy

Tantalum lined structures (illustrated by a 3mm tantalum cladding) have higher material costs than special alloys for a material thickness lower than 60mm. Tantalum clad technology is therefore not relevant for a general substitution of special alloy components.

Thick film tantalum solutions include thermal or cold spray processes, which require a layer thickness in the range 0.2 to 0.5mm to create a corrosion resistant layer (ref. 6). Special alloy components thicker than approximately 10mm may in theory be substituted by thick film solutions. In reality thick film solutions would compete against clad solutions based on special alloys.

In conclusion thick film tantalum and tantalum clad solutions are therefore likely to compete in the exotic metal market rather than in the special alloy market. To obtain a general competitive advantage in the special alloy market, tantalum will have to be applied as a thin film solution. A thin tantalum technology, on other hand, may reveal a close to 100% substitution potential.

## MATERIAL SELECTION

Table 1 shows materials which are typically used in corrosion engineering to resist some chemicals in common use. The choice of materials depends on chemical performance and price. AISI 316L stainless steel is a common standard within less demanding corrosion media as well as alkalis. In acidic media other material must be designed in. As seen from the table, tantalum offers a very good all-round performance, but is constrained by the price.

Since none of the current metal solutions offers an advantageous all-round option, today's corrosion engineering is characterised by a rather complex decision matrix and a complicated supply chain pattern. Hastelloy C type solutions have therefore gained a preferred position among many manufacturers and users. Despite a limited performance it satisfies a compromise between a reasonable supply chain complexity and a reasonable chemical performance.

In addition to increased component performance and a lower component price (Table 1) the tantalum surface solution will lower internal expenses related to handling a special supply chain for speciality parts. This is due to the fact that very close to 100% of all corrosion media may be handled by one of the only two options:

- 1) AISI 316L stainless steel
- 2) AISI 316 L stainless steel + tantalum surface treatment

Media	Material (relative price)						Current choice	Future choice
	316SS (1)	Hast. B (25)	Hast. C (16)	Ti (16)	Zr (15)	Ta (130)	Cheapest high performance option (price index)	Potential substitution (target price)
Alkali (e.g. NaOH)	*	*	*	o	*	-	316SS (1)	Untreated 316 SS (1)
Sulphuric acid	-	*	o	-	o	*	Hastelloy B (25)	Tantalum treated 316SS (5 to 15)
Hydrochloric acid	-	o	o	-	*	*	Zirconium (15)	Tantalum treated 316SS (5 to 15)
Hydrobromic acid	-	*	o	o	o	*	Tantalum (130)	Tantalum treated 316SS (5 to 15)
Nitric acid	o	-	o	*	*	*	Titanium (16)	Tantalum treated 316SS (5 to 15)

Table 1: Commonly applied materials and potential substitution options in media where stainless steel causes problems

(Corrosion resistance: \* = very good, o = reasonable, - = poor.

Corrosion data deduced from NACE (ref. 7).

Price index is adapted from Nichols (ref. 4))

## EXPERIENCE WITH THIN FILM TANTALUM SOLUTIONS

Several attempts at making thin film tantalum solutions have previously been reported in the literature, but none of these solutions seems to have obtained an economic significance for corrosion applications.

The TANTALINE™ concept by Danfoss includes a programme of standard size tantalum-steel components including valves, fittings and fasteners that have been designed to compete in the special alloy market segment.

The TANTALINE™ process is shown schematically in Figure 3. The tantalum treatment is carried out by a modified high-temperature chemical vapour deposition (HT CVD) procedure, at temperatures in the range 700-1000°C. Overall the process converts the outer 0.05mm layer of stainless steel into chemically pure (c.p.) tantalum without changing the component tolerance. This is possible since 0.05mm of the stainless surface is removed and replaced with a similar volume of tantalum metal. The reason for removing material prior to the tantalum treatment is that 'off-the-shelf' components in stainless steel may be handled in the supply chain. This eliminates time delays related to individual quoting, ordering and producing of special (non-standard) components. The lead time of TANTALINE™ products is in general very favourable compared to similar parts in titanium or nickel alloys.



Figure 3: Production of TANTALINE™ parts

## LABORATORY AND FIELD TEST RESULTS

**Surface composition:** The surface composition of TANTALINE™ surface layers has been evaluated by TOF-SIMS (Time-of-flight Secondary Ion Mass Spectrometry) analysis which shows that the metallic purity of the surface layer is identical with that of a c.p. tantalum reference. The concentrations of selected metallic alloy elements are shown in Table 2.



Tantalum - Ta	> 99.90 % (metal base)
Niobium - Nb	< 0.050 %
Titanium - Ti	< 0.010 %
Tungsten - W	< 0.050 %
Molybdenum - Mo	< 0.020 %
Iron - Fe	< 0.010 %
Nickel - Ni	< 0.005 %
Silicon - Si	< 0.005 %

Table 2: Purity of the TANTALINE™ surface layer confirmed by TOF-SIMS measurement

**Coating integrity, distribution and durability:** The advantage of using a modified HT CVD-type process is a very good material distribution. Figure 4 shows a part with a particularly complex shape and which has been treated by the TANTALINE™ process. As can be seen, the formed tantalum layer is absolutely dense with no porosity. A good material distribution is needed for surface treatment inside such structures as valves and impellers, which may not be treated satisfactorily with 'line of sight' procedures such as spraying processes.

Another advantage is a rather ductile nature which lowers the tendency for cracking. Figure 5 shows marks applied to a TANTALINE™ coated surface. As the surface layer is ductile, it remains intact even after considerable damage has been inflicted, and full corrosion resistance is maintained. This TANTALINE™ treated part was tested by making several indentations 5mm long by 2mm wide with a hammer, and then observing the integrity of the component when it was immersed in sulphuric acid: the coating was intact.

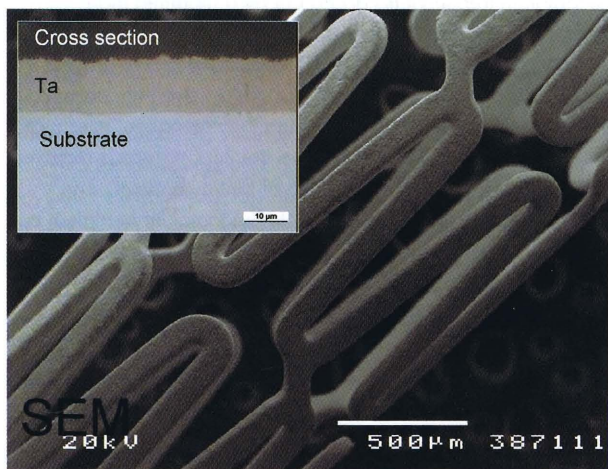


Figure 4: Example of a complex shaped TANTALINE™ treated part evaluated by SEM, as well as a cross section of the surface. (The nature of the coating process gives a very high coating ability inside concave geometries)

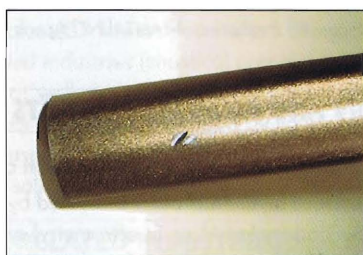


Figure 5: TANTALINE™ coated surface, showing damage (NORAM Engineering, Canada)

**Surface/substrate interface:** A very critical issue when applying surface protecting layers is the interface between the substrate and the coating. Poor adhesion of the surface layers may lead to a risk of 'peeling off'. Since the TANTALINE™ surface layer is deposited at high temperature a slight alloy formation between the substrate and the coating occurs, leaving the surface layer metallurgically bonded to the base part. In the case of stainless steel and CoCrMo materials, the alloy zone is relatively thin (less than 1 micron) and may not be seen from normal micrographs. From TEM (Transmission Electron Microscopy) evaluations it is however possible to identify an alloy zone as indicated in Figure 6, which shows the tantalum concentration of a CoCrMo material with TANTALINE™ treatment. The concentration of the tantalum is measured by TEM combined with X-ray analysis.

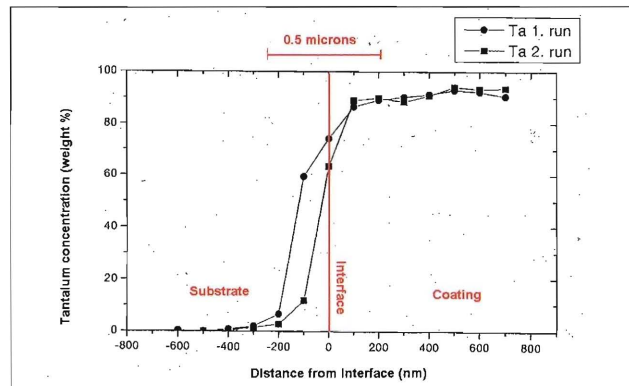


Figure 6: TEM scan of surface/substrate interface (Alloy formation zone less than 1 micron)

**Field tests:** Table 3 shows the results of some field-tests which have been conducted on components. To obtain statistical evidence for performance, studies have been initiated with relatively large numbers of components (up to 250). The parts have been tested individually in media where nickel and titanium are known to have a limited life time. None of the parts installed in the period 1993 to 2005 have failed. The field-tests performed proved that TANTALINE™ parts had a longer lifetime than parts made from titanium or nickel alloys.

Part	Medium	Temperature (in deg C)	No. parts installed	Year of installation	Test status
Temperature sleeves	Hydrochloric acid 30%	100	231	1993-2003	All in service. (No parts failed)
Flow sensor electrodes – flanges	Sulphuric acid 20-40%	30-50	250	2005	All in service (No parts failed)
Electro polishing fixtures	Perchloric acid	30-60	24	2004-2005	All in service (No parts failed)

Table 3: Field test data for TANTALINE™ parts in 'severe' corrosion media

## FUEL CELL TECHNOLOGY

Fuel cell technology is frequently being suggested as a potential substitute for the combustion engine for vehicles to reduce pollution. Further, fuel cell technology offers higher theoretical energy output than power plants fired by fossil fuel. A sketch showing the principle of a (hydrogen) fuel cell is shown in Figure 7. The cell produces an electrical current by the reaction of hydrogen and oxygen.



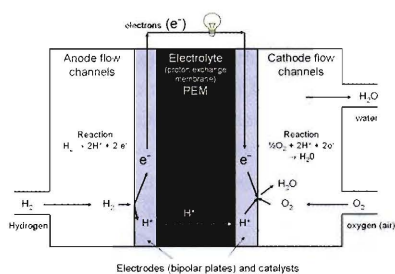


Figure 7: A cell in a hydrogen fuel cell stack

## BIPOLAR PLATES

Most current fuel cell stack technologies for mobile applications are based on carbon based bipolar (collector) plates (see Figure 7). For future mobile applications, metallic bipolar plates are needed to reduce the space taken up by the fuel cell stack. State-of-the-art solutions to overcome such problems are based on gold or platinum plated substrates in stainless steel or copper. The noble metal acts as a conducting corrosion barrier that protects the substrate against corrosion.

If tantalum were used as the conducting corrosion barrier, this could be a future candidate for the bipolar plates. For practical applications a metal layer of a minimum of 3 microns is necessary to create a (pinhole free) protecting surface. As can be seen from Table 4, the price of the noble metal is a limiting factor in the collector plate price. If tantalum is applied as a corrosion barrier it is possible to reduce the component price by more than 95%.

Attempts to use plain tantalum surfaces in fuel cell applications have, however, not shown promise. Tantalum tends to oxidise when anodic currents are applied to the surface, resulting in a sudden change in the potential during electrolysis. New (limited price) solutions are therefore needed to make the tantalum surface electrically conducting during use.

Type	Cu-3Pt		Cu-3Au		Cu-3Ta		Cu-3Ta-0.1Pt	
Description	0.25mm Cu + 3 microns Platinum		0.25mm Cu + 3 microns Gold		0.25mm Cu + 3 microns Tantalum		0.25 Cu + 3 microns Tantalum + 100 nm Platinum	
Copper (8.9g/cm <sup>3</sup> ) – \$8/t	2300g	\$20	2300g	\$20	2300g	\$20	2300g	\$20
Platinum (21.5g/cm <sup>3</sup> ) – \$38/g	66g	\$2500					2.2g	\$80
Gold (19.3g/cm <sup>3</sup> ) – \$19/g			59g	\$1120				
Tantalum (16.6g/m <sup>3</sup> ) – \$0.6/g					50g	\$30	50g	\$30
<b>Total cost pr m<sup>2</sup></b>	<b>\$2520</b>		<b>\$1140</b>		<b>\$50</b>		<b>\$130</b>	

Table 4: Estimated price of material per m<sup>2</sup> (based on metal prices in August 2006)

## TANTALUM/PLATINUM MATERIALS

To compete in the electrode segment, Danfoss has developed a new conducting tantalum material based on a corrosion safe tantalum coating treated by an ultra thin (100 nm) platinum layer that protects the tantalum from oxidising. The Ta/Pt material remains stable during electrolysis (see Figure 8). The ultra thin platinum treatment thus inhibits formation of an oxide layer on the tantalum surface.

The Ta/Pt material thus developed may be used in the basic form or as substrate for further surface treatment by traditional wet surface coating procedures (galvanic coatings), that are relatively

cheap and common. Until now wet surface treatment of tantalum has been difficult. This problem has now been solved.

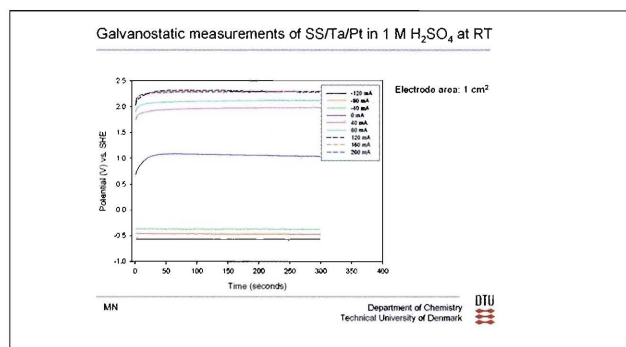


Figure 8: Polarisation curves for tantalum-coated copper treated with approximately 100 nm platinum

## CONCLUSION

Despite the fact that tantalum today has a limited use within corrosion engineering, thin layer tantalum coating technology may be able to compete against non-ferrous special alloys. Tantalum solutions offer higher performance and lower cost compared to special alloys. The potential target market for thin film tantalum solutions within corrosion engineering could increase 10-200 fold the current value of the tantalum market for corrosion applications. Danfoss has developed a TANTALINE™ concept using thin layer (0.05mm) tantalum technology that may be used as a direct substitute for nickel, titanium and zirconium within chemical engineering. Large scale field tests performed during the last 13 years show that the TANTALINE™ technology is safe at elevated temperatures in harsh corrosion environments including hydrochloric acid, sulphuric acid and perchloric acid.

Within fuel cell technology new material concepts are needed to overcome dimensional, chemical and heat conduction problems with state-of-the art carbon based collector plates. Collector plates in noble-metal-coated copper are technically acceptable but have a production cost too high for future large scale production. Danfoss has developed a solution that combines a tantalum corrosion barrier with an ultra thin 100 nm platinum layer that may serve the electrode markets for a fraction of the material price current today.

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7. Data deduced from COR-SOR, NACE Corrosion Survey Database



## NIOBIUM FOR COINS

### Niobium as Mint Metal:

#### Production – Properties – Processing

*This article is taken from the paper written by Mr Robert Grill of Plansee SE and Mr Alfred Gnadenberger of the Austrian Mint, Vienna, and presented by Mr Grill at the T.I.C. meeting in Innsbruck*

Niobium was selected as core metal for a special 25 euro bi-metallic coin-collector series issued by the Austrian Mint, and the coloured niobium insert is a special feature. Silver is used as the surrounding metal. The 25 euro coin is legal tender in the Austrian republic. The combination of these materials with distinctly different material properties, especially deformation behaviour, and the use of the coloured niobium insert makes an adaptation of production parameters and manufacturing philosophy necessary. The paper describes the experience gathered during project definition, establishment of the production line and production of the bi-metallic coins.

### INTRODUCTION

The Austrian Mint planned to issue a collector's coin to mark the 700th anniversary of the city of Hall in Tyrol. The special commemorative coin would be a continuation of the '25 Euro Millennium Coin' series, which was started with the material combination of silver and titanium, focusing on telecommunications with a coin issued in 2000, and another on mobility, issued in 2001. For the third in this series a new combination of materials was required. The number of coins in this special series was limited to 50 000 pieces per edition.

When the project had been defined by the Austrian Mint early in 2000, Plansee SE was called in for an assessment of candidate materials. A project was started for identification of a metal from the production range of the Plansee group with some connection between the history (700 years of the foundation of the city of Hall), Tyrol as production site for niobium (manufacturing of the mint metal) and the high technology application of the mint metal (in aerospace).

The Ag/Nb bi-metallic coin '700 Jahre Stadt Hall', made available in 2003, combines the past and the future in an impressive way. The obverse side shows an Earth observation satellite symbolically scanning the city map of Hall in Tyrol. The reverse side shows the motif of the 'Guldiner', a historic coin which constituted the tradition of Hall in Tyrol as the site of a mint. The motif of the 'Guldiner' is reflected and should give the impression of a coining die. As a special feature and to intensify the visual impression, a remarkable material property of niobium was used for the first time for coin manufacturing – the possibility of colouring the surface by anodic oxidation. For the 25 euro bi-metallic coin '700 Jahre Stadt Hall' the niobium surface was coloured blue (Figure 1a).

Based on the success of the first 25 euro Ag/Nb bi-metallic coin, the collector series was continued with a similar Ag/Nb bi-metallic coin in 2004 to celebrate 150 years of the train route over the Semmering pass, '150 Jahre Semmeringbahn', using a green coloured niobium insert (Figure 1b). In 2005 on the occasion of '50 Jahre Fernsehen' (50 years of television in Austria) a coin using a purple coloured niobium insert (Figure 1c) followed, and in 2006 a gold-brown coloured niobium insert was used for

'Europäische Satellitennavigation' (navigation by satellite in Europe) (Figure 1d). Since 2005 the number of coins was expanded to 65 000 pieces in each edition. (ref. 1–4)

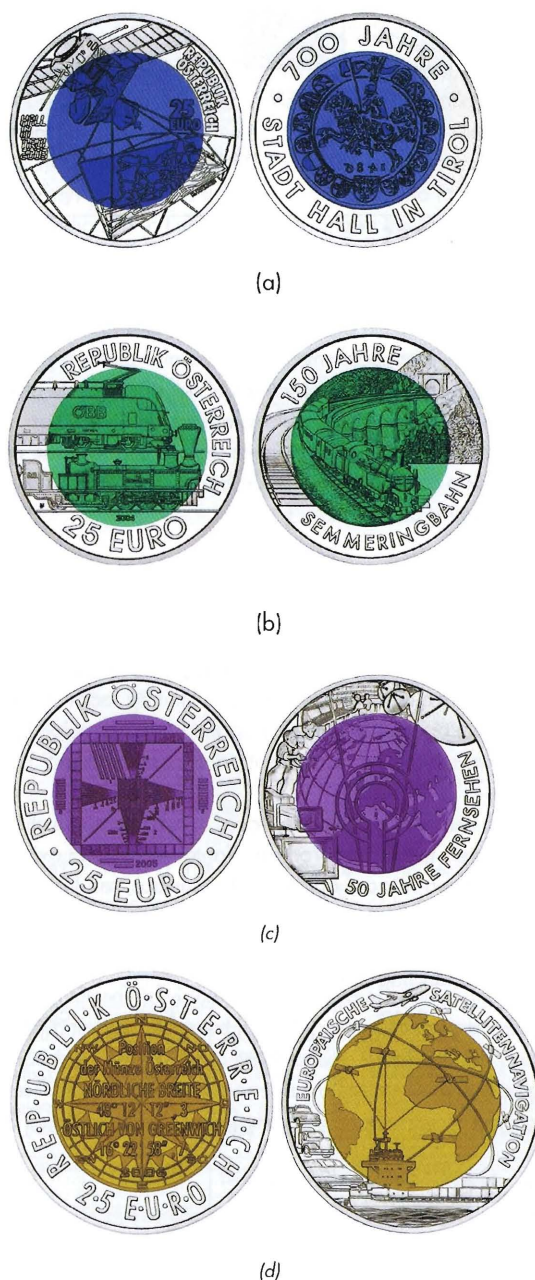


Figure 1: Obverse and reverse side of 25 euro bi-metallic coins  
(a) '700 Jahre Stadt Hall' (edition 2003, 50 000 pieces)  
(b) '150 Jahre Semmeringbahn' (edition 2004, 50 000 pieces)  
(c) '50 Jahre Fernsehen' (edition 2005, 65 000 pieces)  
(d) 'Europäische Satellitennavigation' (edition 2006, 65 000 pieces)

### NIOBIUM

After refining of the ores the niobium metal is available in the form of metal sponge or metal powder. The processing to almost full density and the reduction of impurities (especially the interstitial elements) is possible by techniques of powder metallurgy (high vacuum sintering at temperatures of about 2000°C) or melt metallurgy (electron beam melting under vacuum). The sintered or melted blocks thus obtained are further processed by forging, rolling or drawing. Deformation is made at room temperature, and heat treatment operations must be performed under high



vacuum. The physical and mechanical properties of niobium are mainly influenced by the purity of the metal, as even small amounts of interstitial impurities cause degradation of material properties. Figure 2 shows typical contents of impurities for technical grade niobium semi finished products according to ASTM specification. (ref. 5–7)

Impurities		Niobium (technical grade)
Oxygen	[µg/g]	30
Nitrogen	[µg/g]	20
Hydrogen	[µg/g]	< 1
Carbon	[µg/g]	30
Iron	[µg/g]	< 50
Molybdenum	[µg/g]	< 100
Tungsten	[µg/g]	< 100

Figure 2: Typical chemical analysis of technical grade niobium semi-finished products (ref. 5, 6)

Niobium is ductile at room temperature and a high degree of deformation without intermediate heat treatment can be applied. A slight increase of oxygen and nitrogen content leads to a strong increase in hardness and the brittle/ductile transition temperature, which for technical grade niobium is about -200°C, is raised to values above room temperature. (ref. 8, 9) The corrosion resistance of niobium is provided by the formation of a very dense and adhesive oxide layer. This is not to be confused with the oxide layer responsible for the colouring of the niobium, which has a different stoichiometry.

## NIOBIUM AS MINT METAL

From a historical point of view the first metals used as materials for coinage and medals were noble metals such as gold, silver and platinum. Today the most important mint metals for daily use are alloys made from copper, nickel, iron and aluminium. Since the middle of the 20th century alternative materials have been investigated for higher-value collector coins. Niobium is one of the candidate materials for mint and medal production. (ref. 10–13)

Niobium is also used, especially in the U.S.A., for jewellery and for *objets d'art*. The use of niobium for coin and medal production has so far been limited to special occasions with a relatively low number of pieces per edition, such as:

- the 'Charles Hatchett Medal' of the Institute of Materials (London) awarded annually to chemists since 1979 for notable scientific publications on the science and technology of niobium and its alloys (ref. 14)
- the commemorative medal for participants in the world championship in rowing in Germany in 1983 (ref. 15)
- a series of commemorative medals to commemorate the 100th anniversary of aviation, published by Wah Chang since 2001 (ref. 16)

The series of 25 euro Ag/Nb bi-metallic collector coins published by the Austrian Mint was the first niobium coin to be legal tender in a member state of the European Community. With a limited number of 65 000 pieces per edition the number of coins produced is equal to other collector series made from standard coin materials.

## PROFILE FOR COINAGE METALS

Besides the selection criteria for the bi-metallic coin '700 Jahre Stadt Hall' – correlation between material, production site and the design – general criteria must also be fulfilled by a mint metal:

- workability at room temperature (for forming and stamping)
- homogeneous surface structure (for optical appearance)
- colour (possible contrast to the silver outer ring)
- corrosion resistance (avoid corrosion due to contact with the silver ring)
- availability of semi-finished products (no special production needed)
- low tendency for cold welding (low tool wear during striking)
- image (material relating to the design)
- material price (in context with the image)

Based on the defined requirements profile, the material programme of Plansee SE, which is focused on the production of refractory materials and alloys based on powder metallurgical production techniques, was assessed. After pre-selection and stamping tests with candidate alloys, a market assessment was made considering the following criteria:

- image
- possible future editions
- additional features such as colouring of the metal by special surface treatments (decorative colouring by painting, printing or enamelling is not desired)
- price

After two years of cooperative effort, niobium was selected as the material of choice, best fulfilling the selection criteria: ability to be processed, marketing strategy, colouring of niobium insert and quality.

## COIN PRODUCTION AND QUALITY MANAGEMENT

In Figure 3 the production steps for the manufacture of bi-metallic coins are shown. The starting materials for the silver ring and the niobium insert are melted ingots, which are cold rolled to final sheet thickness. Intermediate heat treatment steps are applied if necessary. From the conditioned strips the silver rings and niobium inserts are punched to the required dimensions. For the silver rings no further special surface treatment is necessary before stamping. For the niobium insert, before stamping a special surface treatment is applied for adaptation of surface structure and colouring. The colouring is carried out by anodic oxidation of the material: an oxide layer of controlled thickness is formed by electrochemical processing. Refraction of light in the oxide layer creates interference colours which give the niobium its noble appearance, with different colours depending on the thickness of the layer. A special feature of this process is the fact that the colouring layer is not deposited on the surface, it is an intrinsic feature of the formed anodic oxide layer.

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**e-mail to info@tanb.org**



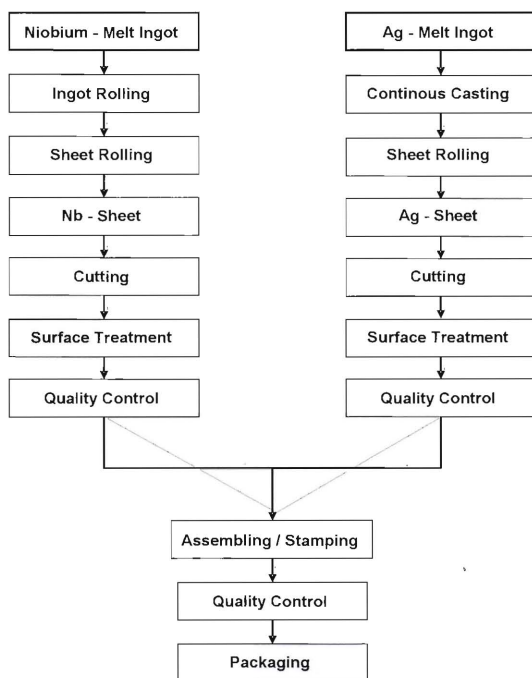


Figure 3: Production steps for manufacturing of bi-metallic Ag/Nb coins from the melt ingot to the coin

To ensure that the quality of the coins was consistent throughout the entire production campaign, an interactive network between the different production locations and a project team from the Austrian Mint and Plansee SE were established, with a logistic network between three production sites and a continuous exchange of information. Special surface treatment techniques were developed to satisfy the requirement for an excellent appearance, and an advanced quality management system was established to ensure that a constant shade and high quality of the colouring of the niobium insert were maintained over the production run.

For the production of the first 25 euro bi-metallic Ag/Nb coins it was the first time for the Austrian Mint that an external partner was responsible for production steps which determined quality.

The success of the first Ag/Nb coins confirmed the Austrian Mint in its decision to invest in this innovative product line, with the first series in 2003 and the fourth in 2006, and a continuation of the special series for collectors is planned.

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## MEMBER COMPANY NEWS

### Commerce Resources

Commerce Resources continues its vigorous programme of exploration to extend the company's mineral claims around its current tantalum and niobium projects. On January 24th it announced an agreement to acquire two mineral claims adjacent to its Fir claims in British Columbia, and at the end of February it acquired an additional 79 mineral claims adjacent to its Blue River project, bringing the latter property to about 500 square kilometres. Commerce Resources continues to be enthusiastic about the potential quality and quantity of the minerals in the region of its interests.

### Jiujiang Tanbre Smelter

The nominated delegate to the T.I.C. for Jiujiang Tanbre Smelter is now Mr Yuan Yuanming.

### NEC Tokin

Following the transfer of Mr Masayuki Yamane to the company's capacitor plant in Thailand, the nominated delegate of NEC Tokin is now Mr Yoshihiko Saiki, General Manager of the Capacitor Operation Unit in Toyama. His address is:

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### Rexwell Mining

We have heard that the telephone numbers for Rexwell Mining have been changed to +255 75 4949790 in Tanzania and +7 985 9696979 in Russia.

### H.C. Starck Co., Ltd

Dr Christian Eh, Managing Director, is the nominated delegate to the T.I.C. for H.C. Starck Co., Ltd, the Starck company at Map Ta Phut, Thailand.

### TVEL

The nominated delegate to the T.I.C. for TVEL is now Mr Vladimir Rozhdestvenskiy.

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