Dear friends and fellow T.I.C. members,

It’s exciting to be moving forward into spring, a traditional time of renewal. Here in New England, after record snowfalls, we’re seeing the last vestiges of winter, although it is snowing again as I write this. These are definitely interesting times to be in the tantalum and niobium industries, as change seems to be the one constant.

The T.I.C. exists on behalf of and because of our members. While we are a diverse group, we need to improve and can only do so with the support and help of our members. Your Executive Committee has established working groups in such areas as staffing, supply chain, website, and meetings and is considering others.

We need, rely upon, and eagerly seek your suggestions, recommendations, and criticisms on how we can improve, please. One area of particular interest, for example, would be your help in identifying and attracting potential new members.

While you’ll find more details elsewhere in this Bulletin, I look forward to seeing all of you in Penang, Malaysia at our next General Assembly, to be held 25-28 October 2015, where our host will be Malaysia Smelting Corporation. For those of you who have not yet visited this fascinating country, I urge you to attend.

Sincere best wishes,

David R. Henderson
President

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FIFTY-SIXTH GENERAL ASSEMBLY

The Fifty-sixth General Assembly and associated technical meeting of the Tantalum-Niobium International Study Center will be held in Penang, Malaysia, from Sunday October 25th to Wednesday October 28th 2015. The conference will take place at the Shangri-La Rasa Sayang Resort, where a block booking of bedrooms has also been secured.

The administration of the association will be carried out in the formal General Assembly on the morning of Monday October 26th, including election of applicants for membership of the association and the appointment of the members of the Executive Committee.

Technical presentations will follow, extending until early afternoon on Monday and Tuesday. On Wednesday October 28th, a plant tour will be organised to visit the facility of Malaysia Smelting Corporation, in Butterworth.

A social programme is also being prepared, including a welcome reception on Sunday October 25th and a gala dinner on the evening of Monday October 26th. We are also organising sightseeing tours for those accompanying delegates, to discover the beauty of Penang in general and George Town, a UNESCO World Heritage Site, in particular.

An invitation will be sent in due course to the nominated delegate of each member company. Non-members who would like to attend should contact the T.I.C.
HIGH CV/G TANTALUM POWDER WITH NOVEL PARTICLE MORPHOLOGY

Paper written by James Allen Fife, of KEMET Blue Powder Corp., and presented on October 14th 2014, as part of the Fifty-fifth General Assembly, held in New York, U.S.A.

During the Fifty-fourth General Assembly, I spoke about the theoretical CV/g of cylindrical tantalum particles and cylindrical pores in solid bodies of tantalum as a function of particle sizes and formation voltages. I will now review recent developments in the manufacturing of a different shaped particle: flat or flake shaped particles. By flat particles we mean powder composed of individual coin shaped particles with a small thickness and a much larger diameter. For the following calculations we regard the particles to be circular.

In order to explain more clearly the new manufacturing developments and the significance of the results I need to first take time to more completely describe the implications of flat shaped particles to capacitor anode technology. This requires a brief review of the implications of flat particle geometry to the electrical property of capacitance.

GEOMETRICAL DESCRIPTION OF FLAKE ANODES:

We need to understand the CV/g of flat particles as being a function of the surface area and weight and formation voltage. We will consider the entire anode to be made up of millions of repetitions of anode unit cells, the specific properties of which are the same as the specific properties of the anode as a whole. The anode unit cell will use to approximate the flat particle anode is as follows:

![Flake anode unit cell diagram](image)

In this unit cell the flake is represented by the bottom cylinder. The smaller cylinder on top represents the sinter bond or neck connecting the lower particle to an identical unit cell above (not shown). As this is a unit cell, it is understood that in the anode there will be two unit cells attached to this one, one below via the sinter bond neck of the lower unit cell and one above attached by the sinter neck of this unit cell. Arbitrary numbers of such replicates of this unit cell will produce the entire anode. The area of contact between the sinter bond neck and the flat surface of the particle is obliterated by the junction with the sinter bond so this circular patch of surface area is lost to capacitance. Similarly the upper round surface of the sinter bond neck will itself be consumed in the bonding to the unit cell situated above the subject cell. The other surfaces of the unit cell are exposed in the entire anode and therefore those surfaces are available to provide capacitance. These exposed surfaces include the edge of the lower particle, the vertically standing surface of the sinter bond neck and the two horizontal surfaces of the lower particle excluding the two circular patches of surface area covered by the sinter bond necks.

Using the designations for the dimensions of the particle and sinter bond neck shown in figure 1 we can express the exposed surface area of the unit cell as:

$$S = 2 \times \pi \cdot r^2 - 2 \times \pi \cdot \left(\frac{d}{2}\right)^2 + 2 \pi \cdot r \cdot t_0 + 2 \pi \cdot \frac{d}{2} \cdot L$$

Now, this unit cell, with its attached sinter bond was made by sintering an original flat, coin shaped particle that did not have a sinter bond; and, the size and length of the sinter bond neck is a function of how the anode was pressed and sintered so that $L$ and $d$ are adjustable parameters that we control. Therefore, we can generalize this model to describe a broader range of unit cells as a function of how the anode is made. This generalization can be introduced by regarding the original, non-sintered flake as a circular coin with radius $r_0$ and with the same thickness as the sintered flake, $t_0$ (sintering flake does not change the thickness of the flake, it only creates and grows the sinter bonds between adjacent flakes).

In this generalized description, the original flake with radius $r_0$ was rearranged during anode pressing to become so close to an adjacent parallel flake that they touched at one point and a sinter bond grew from this single contact point during the subsequent high temperature sintering. Metal from the flake flowed into the sinter bond during sintering to grow the bond at the expense of the radius of the flake. Again, I do not allow the thickness of the flakes to reduce by a thermal process so the radius of the circular flake decreases as the bond grows in volume. The volume of metal in the unit cell is conserved. Conservation of matter in the unit cell says:

1 With a little reflection you realize that in a real pressed anode all flakes will be parallel as this unit cell suggests because the pressing action along the direction of the press punch will inevitably align the flakes to be parallel to each other in the anode, transverse to the punch movement.
Equation 2: \( \pi \cdot r^2 \cdot t_0 + \pi \cdot \left( \frac{d^2}{2} \right) \cdot L = \pi \cdot r_0^2 \cdot t_0 \)

This allows us to define \( r \) at any stage of sintering as

Equation 3: \( r = \left( r_0^2 - \frac{L}{4} \cdot t_0 \cdot d^2 \right)^{\frac{1}{2}} \)

Now, it is reasonable that there are constraints on the neck dimensions in this configuration. In particular, I add the constraint that the diameter of the neck should grow as the two flakes are brought closer together (higher pressed density) such that if the two parallel flakes are touching, then the diameter of the neck should be equal to the diameter of the flakes and 100% of the surface area on both sides of the coin shaped flakes will be obliterated by the (zero length) neck; i.e. the complete sintering away of the large surfaces of the flakes when the distance between adjacent flakes is zero. Also, I presume that if the flakes are significantly farther apart than the individual flakes are thick, then no bond will form at all. These two constraints can most simply be introduced by requiring a linear relationship between the length of the sinter bond neck and the diameter of the sinter bond. An appropriate linear relationship is given by:

Equation 4: \( d = \frac{t_0 - 2 \cdot r}{t_0} \cdot L + 2 \cdot r \)

It is evident that this expression forces the diameter of the sinter bond to become equal to \( 2r \) (the diameter of the entire flake) when \( L = 0 \) (when the two adjacent flakes touch). When \( L = b \) (when the distance between the parallel flakes is equal to the thickness of the flake), then the diameter of the sinter bond is equal to \( b \). The diameter of the sinter bond \( d \) will become zero (no bond formed) when \( L = \frac{2 \cdot r}{t_0} \cdot t_0 \) which will generally be a little larger than \( b \) and approaches \( b \) in the limit of flakes that are much larger than they are thick which is the situation for most particles recognized as being flakes, showing that this expression produces no bond when the distance between adjacent parallel flakes is only a little greater than the thickness of the flakes.

Substituting equation 4 for \( d \) in equation 3 gives us a quadratic in \( r \). Solving this for \( r \) and taking the positive root (negative particle radius being non-physical) gives:

Equation 5: \( r = \frac{(((4 \cdot r_0^2 \cdot (t_0 \cdot L)^3) + t_0^6 - (2 \cdot t_0^4 \cdot L^2)) + (t_0^5 \cdot ((4 \cdot L \cdot r_0^2) - L^3)))^{\frac{1}{2}}}{2 \cdot (L \cdot t_0^2 + L^3 + t_0^3 - (2 \cdot L^2 \cdot t_0))} \)

This gives the flake radius as a function of the length of the sinter bond \( L \) and the starting dimensions of the flake (remember that forming the bond has consumed metal from the flake; thus, decreasing the radius from its initial value of \( r_0 \) to the new value \( r \)).

It is evident that equation 5 can be substituted for \( r \) in equation 4 to give the diameter of the sinter bond entirely in terms of the length of the sinter bond \( L \) so we are now able to completely describe the detailed structure of the anode unit cell as a function of only the initial dimensions of the flake and the length of the sinter bond between adjacent parallel flakes; and furthermore, we are confident that this calculation is constrained to produce zero surface area for the parallel surfaces of the flakes in the case where the length \( L \) is zero; i.e. if the flakes are brought so close together that their parallel surfaces touch.

**CALCULATION OF CV/G:**

Strictly speaking the shape of the unit cell above involves cylinders. A rigorous approach might be to use the exact expression for the capacitance of cylindrical anodes to calculate the CV/g of these portions of the unit cell; however, because the subject of this model is flake shaped particles wherein the diameter of the “cylinders” is much greater than the thickness of the dielectric film I have chosen to use an easier to visualize calculation based upon the specific surface area of the unit cell so that readers of this paper may more easily see the sources of CV/g in terms of the more familiar geometric calculations of the surface areas of circles and rectangles.

**A DIGRESSION TO JUSTIFY AN APPROXIMATION:**

This approximation is justified because the exact solution for capacitance of a tantalum cylinder that has been anodized to voltage \( V_f \) and has a residual cylindrical anode radius of \( a \) is

Equation 6: \( CV = 2 \pi \varepsilon_0 \varepsilon_r \cdot \frac{V_f}{L} \cdot \frac{\lambda}{\ln \left( \frac{a + \alpha \cdot V_f}{a} \right)} \)

and the simplified calculation we want to use for the same shaped particle is
Equation 7: \[ CV = \frac{2\pi \alpha \lambda \delta \rho \epsilon_r}{\alpha} \] (in both expressions \( \lambda \) is the length of the cylinder and \( \alpha \) is the anode radius).

If we substitute the first three terms of the Taylor's series expansion of the natural logarithm into equation 6 and simplify we find:

Equation 8: \[ CV = 2\pi \delta \rho \epsilon_r \cdot V_f \frac{\lambda}{V_f} \left( \frac{a + \alpha \cdot V_f}{a} \right)^{\frac{1}{2}} = \frac{6\alpha^2}{6\alpha^2 - 3\alpha \delta V_f + 2\alpha^2 V_f^2} \times 2\pi \alpha \lambda \delta \rho \epsilon_r \] \[ \frac{\alpha}{\alpha} \]

What this means is the exact CV/g for a cylinder, when approximated by the first three terms of Taylor's series is equal to the expression \( \frac{6\alpha^2}{6\alpha^2 - 3\alpha \delta V_f + 2\alpha^2 V_f^2} \) multiplied by the CV/g you would calculate based upon a simple calculation of the surface area of the walls of the cylinder (equation 7). The expression \( \frac{6\alpha^2}{6\alpha^2 - 3\alpha \delta V_f + 2\alpha^2 V_f^2} \) approaches 1 in the limit as \( V_f \) approaches zero which is to say in the limit as the radius of the cylinder \( a \) is much larger than the thickness of the dielectric film. This is precisely the situation in flake particles wherein the major dimension of the flake is always much larger than the thickness of the dielectric. Therefore, we are justified to use the calculation of CV/g based simply upon the total surface area of the anode surface of the unit cell.

Accepting the validity of this simplification we can proceed to the calculation of the CV/g of the unit cell.

We will calculate the sum of four surfaces: 1. The surface of the top face of the unit cell flake reduced by the area of the sinter bond; 2. The corresponding surface of the bottom face of the unit cell flake reduced by the area of one sinter bond; 3. The surface area of the edge of the unit cell flake; and, 4. The surface area of the vertical wall of the sinter bond neck.

These surface areas must be calculated for the anode surface of the unit cell after anodizing because the approximation justified above was for the anode surface, not the cathode surface which is larger. Therefore, before we calculate the individual components of surface area we must reduce the dimensions of unit cell to account for metal consumed by the act of anodization. We will use the assumption that the growth of the anodic film and the associated consumption of metal is a linear function of the formation voltage and is the same at all exposed surfaces. For this we will make use of the following expression for conversion of metal to oxide:

\[ V_f \cdot P = \alpha \cdot V_f \] where \( V_f \) is the linear depth of metal consumed by anodizing, \( P \) is the Pilling ratio for the metal (giving the volume of oxide produced from a volume of metal), \( \alpha \) is the formation constant (microns per volt) and \( V_f \) is the formation voltage. From this we can obtain the depth of metal consumption as \( l = \frac{\alpha V_f}{P} \). This distance is how much smaller any valve metal dimension will be after anodizing. In our unit cell the formation process will consume metal on all exposed surfaces reducing the thickness of the flake, reducing the radius of the flake, and reducing the radius of the sinter bond neck. The filling in of the anodic film will also cover some additional surface area on the two flake surfaces around the circumference of the contact with the sinter bond neck (in effect the sinter bond neck will grow in radius) and similarly the growth of oxide film on the parallel faces of the flake will rise up to cover some of the surface on the wall of the sinter bond neck diminishing the effective length of the neck.

Using the Pilling ratio and formation constant as described above applied to the four elements of anode surface area of the unit cell we obtain the net exposed anode unit cell surface area after anodizing as:

Equation 9: Total anode surface area of the unit cell after anodizing

\[ S = 2\pi \left( r - \frac{\alpha V_f}{P} \right)^2 + 2\pi \left( r - \frac{\alpha V_f}{P} \right) \left( t_0 - 2 \frac{\alpha V_f}{P} \right) + 2\pi \left( \frac{d}{2} - \frac{\alpha V_f}{P} \right) \left( L - 2\alpha V_f + 2 \frac{\alpha V_f}{P} \right) - 2\pi \left( \frac{d}{2} - \frac{\alpha V_f}{P} \right) \left( \alpha V_f \right)^2 \]

where we understand that \( r \) is given by equation 5 and \( d \) is given by equations 4 and 5. The first term is the reduced surface area of the two parallel faces of the flake; the second term is the reduced area of the vertical rim of the flake; the third term is the reduced surface area of the sinter bond neck; and, the fourth term is the losses in surface caused by the area lost to attaching the two sinter bond necks to the flake.

Now, our simplification justified above allows us to directly use this total anode surface area to calculate the CV/g of the unit cell.

Equation 10:

\[ \frac{CV}{gm} = 2\pi \delta \rho \epsilon_r \left( r - \frac{\alpha V_f}{P} \right)^2 + 2\pi \left( r - \frac{\alpha V_f}{P} \right) \left( t_0 - 2 \frac{\alpha V_f}{P} \right) + 2\pi \left( \frac{d}{2} - \frac{\alpha V_f}{P} \right) \left( L - 2\alpha V_f + 2 \frac{\alpha V_f}{P} \right) - 2\pi \left( \frac{d}{2} - \frac{\alpha V_f}{P} \right) \left( \alpha V_f \right)^2 \]

\[ \frac{1}{\alpha V_f \pi \cdot r_0 \cdot t_0 \rho \epsilon_r} \]
For completeness the equivalent Excel expression, including the substitutions for $r$ and $d$ from equations 4 and 5 is:

$$e^0*er*((3*P*t0/(2*a)) - (6*v) + (2*((v^2*a*(4 - P)) - (v*L))/t0) + (((4*v*((t0^6*L*(3 - P)) + t0^7 - (t0^5*L^2*(1 + P)) - (t0^2*L^5) + (t0^3*L^4*(4 - P)) + ((((4*r0^2*((L^3*t0) + t0^4 - (2*((L*t0)^2)))) + (t0^3*((4*L*r0^2) - L^3)))^(1/2))*((L*(1 - P)) + (P*((t0^4*((2*((L*r0)^2)) - (17*L^4/2))) + (4*((t0^6*L^2) +(3*(t0^4*L^2) - L^5))))/a))/((6*t0^3*L^4) - (3*t0^5*L^2) + t0^7 + (2*((t0^6*L) - (t0^4*L^3))) - (4*t0^2*L^5) + (t0*L^6))))/(r0^2*P*rho)

VOLUMETRIC EFFICIENCY, CV/CC:
The anode unit cell can be regarded as residing within a rectangular box which defines the total volume taken up by the flake/neck combination. The height of the box would be $t0+L$ and the length of each side would be equal to the diameter of the flake $= 2r$ before anodizing. Consequently the sintered density of the unit cell and hence of the entire anode is

Equation 11: $D_s = \frac{\pi \cdot r_0^2 \cdot t_0 \cdot \rho_{Ta}}{4^r (t_0 + L)}$ where we must substitute equation 5 for $r$ to obtain a function of $L$

The volumetric efficiency $\frac{CV_{cc}}{gm} = \frac{CV_{gm} \cdot CV_{cc}}{gm} D_s$ is the product of equations 10 and 11.

IMPREGNATION CONSIDERATIONS:
When two unit cells are stacked, as is the case throughout the anode, the distance between the parallel surfaces of any pair of adjacent flakes is simply the length of the sinter bond neck $L$. As noted above, after anodizing the opposed metal surfaces of the flakes are both eaten away to a depth $I = \frac{\alpha V_f}{P}$. This has the effect of increasing the length of the sinter bond neck by $2 \cdot I$ so that the distance between the opposed faces would grow to $L + 2I$. The anodizing process converts the consumed metal to oxide which fills in the space available by a distance of $2 \alpha \cdot V_f$. The net result of both dimensional changes is that the gap between the two opposed faces is decreased after anodizing from the original $L$ to

Equation 12: Flake-to-flake gap after anodizing $= L + 2I - 2I \cdot P = L + 2I \cdot (1 - P)$

For valve metals the Pilling ratio $P$ is always $>1$, therefore the change in the gap between the flakes caused by anodization is always negative. So, during anode design, while we are calculating the CV/g and CV/cc of various scenarios of flake anodes, we must pay attention to the resultant flake-to-flake gap as this space must be filled with PEDT.

COMMENT ON CALCULATIONS:
The model outputs are the CV/g, CV/cc, and residual flake-to-flake gap size for given values of the starting radius, thickness of the flakes and the length of the sinter bond. The calculation results are the composite of calculations of dimensions of various radii, and linear dimensions and so it is required for each step of all calculations that checks be made to assure we are not using non-physical values. When things such as negative radii or negative thickness are encountered the modeling must not proceed further along those lines so as to exclude nonsensical results. All graphs shown in this paper only represent physically meaningful results.

DESIGN OF AN ANODE UNIT CELL:
The first task we put the model to was to design the flakes and anode density that would produce an optimum CV/cc for a formation voltage of 18 volts. For this purpose equations 10, 11 and 12 were solved for $V_f = 18$ and various trial values for $r_0$ and $t_0$. For each combination of $r_0$ and $t_0$, $L$ was incremented from zero to larger values until the equations produce non-physical values for any dimension. Different combinations of flake dimensions were tried until the highest CV/cc was found with flake thickness that we were confident we could make and that produced flake-to-flake gap sizes that we estimated we could impregnate with PEDT.

The model output for a particular set of candidate flake dimensions is shown below in figures 2 through 6 to illustrate the procedure. In these examples, the flake radius $r_0$ is 0.5 micron and the flake thickness $t_0$ is .095 micron. The formation voltage is 18 volts.

The outputs include CV/g (figure 2), CV/cc (figure 3), sintered density (figure 4), sinter bond diameter (figure 5) and residual flake-to-flake gap size in microns (figure 6). All of these outputs are plotted versus the length of the sinter bond $L$ in microns.
The CV/g graph, figure 2, shows the restricted range of valid values of \( L \) that produce physically possible outputs. In particular, it is shown that for values of \( L \) greater than about .095 (equal to the thickness of the flake) the model predicts no bonds will form; thus, the anode does not form a connected network (open circuit); and, for \( L \) less than about .04 micron the gap between adjacent parallel flakes is too small to hold the two 18 volt anodic films, so the anode surface would be largely blocked. Therefore, within the physically allowed limits we can achieve a successful anode with CV/g ranging from about 100000 to about 180000.

You will see in figure 3 that the CV/cc has a maximum at \( L \) equal to 0.06 to 0.09 micron. In figure 4 you see that this range of \( L \) corresponds to an anode density of about 7 to 8 g/cc. Figure 5 shows that this range of \( L \) corresponds to sinter bond diameters of 0.2 to 0.4 micron (remember the entire flake diameter is only 1 micron so these bonds cover about 9% of the total surface area of each side of the flake). Finally, figure 6 shows that when \( L \) is in the range of .06 to .09 the gap between the flakes left after filling in with two parallel anodic films is 0.03 to 0.04 micron.
Figure 4

Sintered Density g/cc
\( r_0=0.5\mu M \ t_0=.095\mu M \ V_f=18 \)
Vs sinter bond length \( \mu M \)

Figure 5

Sinter bond diameter
\( r_0=0.5\mu M \ t_0=.095\mu M \ V_f=18 \)
Vs sinter bond length \( \mu M \)

Figure 6

Residual flake-to-flake gap \( \mu M \)
\( r_0=0.5\mu M \ t_0=.095\mu M \ V_f=18 \)
Vs sinter bond length \( \mu M \)
Our instinct may be to simply select a scenario near the maximum CV/cc with particle dimensions as noted, but first we should consider cathode impregnation. To help estimate the difficulty of infiltrating the unit cell with cathode we can note that the model outputs provide us with enough information to actually draw a picture of the unit cell in the range of maximum CV/cc which is shown below in figure 7:

![Figure 7](image)

This unit cell drawing shows the relative sizes of the radius of the flake, the thickness of the flake, the length of the sinter bond and the diameter of the sinter bond, thus providing a dimensionally accurate picture of the unit cell. In addition, I have added two elements in green and yellow to show the size and aspect ratio of the gap between adjacent parallel flakes: these additional elements are to show how difficult it may be to impregnate this unit cell which represents the maximum CV/cc. The green rectangle on the right shows the size of the gap between flakes in the sintered anode. The height of the gap is .076 micron. The depth of this gap from outside to the sinter bond is the difference between the radius of the flake and the radius of the sinter bond. The yellow rectangle on the left shows how much gap is left between the flakes after anodizing to 18 volts. This smaller gap is only .038 micron high. In order to recover the surface area of this unit cell we must get PEDT to fill into the small .038 micron wide gap as shown on the left.

If the PEDT process used is good enough, then this scenario may represent a feasible solution with a volumetric efficiency of 1,224,000 CV/cc. At this point the anode designer must seriously address the question of how good the available PEDT impregnation technology is. If a wider gap is required to compensate for a limited impregnation process, then we will have to use a different design for the unit cell. The most easily impregnated unit cell that can be made from the same flake is shown below:

![Figure 8](image)

In this example, the length of the sinter bond is .096 micron, equal to the thickness of the flake which is the longest possible because an assumption of this model is that the flakes will be disconnected if they are farther apart than little more than the thickness of the flakes. The green gap on the right is therefore now .096 micron high representing the gap after sintering. The yellow rectangle on the left is now .057 micron high showing the much larger gap left after anodizing to the same 18 volts. Because the gap between flakes is larger in this scenario the density of the anode is lower, in fact it is about 6.4 g/cc; the lowest possible before disconnect of the particles within the anode. The CV/g is higher at about 180,000 because the much smaller sinter bond excludes a smaller patch of surface area on the flakes. Because of the lower sintered density the volumetric efficiency of this unit cell is 1,165,000 CV/cc.

So a limitation of the impregnation process, if taken to the extreme, could in this example cost us 59,000 CV/cc in lost volumetric efficiency in comparison to the maximum: a 5% reduction in CV/cc.
UNIT CELL DESIGN CONSIDERATIONS:

The flake shape particle does not suffer the gradual CV/g roll-off with formation voltage as do cylinders or other positive curvature shapes because the surface area of a plane does not change much as the thickness of the plane is reduced: a purely geometric advantage for flat particles. For this reason the optimum CV/g for a flake is determined entirely by the formation voltage in that you would ideally select the thickness of the flake that would be just consumed by the formation. This condition is found by using the Pilling ratio:

Equation 13:  \[ t_0 = 2 \alpha \frac{V_f}{P} \]

This value of \( t_0 \) will exactly be consumed by the formation voltage \( V_f \).

Since CV/g of a flake is (ignoring the sinter bond and edges) proportional to the inverse of \( t_0 \), the maximum CV/g is achieved with the minimum \( t_0 \) as defined by equation 13. However, this is not necessarily the way to choose \( t_0 \). In our example above we use 0.096 micron for \( t_0 \) even though equation 13 would recommend \( 2 \times \frac{0.018 \times 18}{2.442} = 0.0265 \) micron implying the highest CV/g for a flake at 18 volts (about 547,000 CV/g) would be with a 0.0265 micron thick flake.

The reason for selecting 0.096 micron for the thickness of the flake for the design example above is because we can reliably make it with good volume, so we have copious experimental example data to confirm the model (in the experimental section of this paper). So the practical consideration of what can be done (how thin can you reliably make a flake or how small a gap can be reliably impregnated with PEDT) all limit the range of unit cell design parameters. In the end we can model unit cells that we cannot yet reliably make.

VALIDATING THE MODEL BY PREPARING TANTALUM FLAKE POWDER TO THE UNIT CELL SPECIFICATIONS:

The discussions above show that we can design a broad range of unit cells for an 18 volt formation anode. We have chosen one set of unit cell parameters as our example of a practical solution that we can readily manufacture. Now we want to show how this example was actually produced experimentally at KEMET Blue Powder.

The example then is an anode unit cell based upon a circular flake with radius 0.5 micron and a thickness of 0.096 micron. We chose to make this primary particle by deforming a nodular particle that we made by sodium reduction of K₂TaF₇. We used mechanical deformation by an attritor type ball mill.

In our selected process the volume of the flake is conserved. We do not agglomerate or laminate numerous particles into the flake. So the volume of the flake is the same as the volume of the particle it is made from. The volume of our modeled starting unit cell flake is \( \pi \cdot r_0^2 \cdot t_0 = \pi \cdot (0.5)^2 \cdot 0.096 = 0.0754 \) cubic micron. The nodular particle (cube for convenience) with this same volume would be 0.42 micron on a side.
In figure 9 we show how we selected the correct starting powder for the milling process. The blue box illustrates the size of a cube with the same volume as our objective anode unit cell (about 0.42 micron on a side). The scanning electron micrograph shows a typical view of a particular grade of tantalum powder made by KEMET Blue Powder that was selected as the feed material to the milling process. It is asserted that when these agglomerates are broken down into individual pieces the average resultant cluster of particles will have a total volume approximately equal to the targeted value. It should be noted that during the early stages of attritor milling the agglomerates are being broken apart rather than flaked. The single agglomerate shown in this scanning electron image, which is many times larger than the scale of this picture, will become fragmented along the grain boundaries at the necks between the larger crystals. Some fragments will be individual crystals of tantalum whereas most will be small clusters of a few crystals, so we seek an average cluster volume similar to the blue box illustration.

The technical task before us, as stated above, is much more formidable than the modeling and design of the particles. The difficulty of achieving this objective in practice is essentially summed up in the inequality that the force used to deform the very small particles must never be great enough to cold weld the particles together. Very small particles require very little force to cause such agglomeration, so we see we will be constrained to a very unusual milling process using unprecedented low levels of energy. In fact, the entire metal powder milling industry up to now has focused on fast milling of relatively hard materials requiring high energy processes, so we knew from the beginning that we must invent new milling technology in order to achieve this goal. The milling process is further complicated by the fact that our starting powder (0.42 µM nodular particles) are not produced as individual “monomers”, but are only available to us in the form of complex aggregates of many thousands of particles. So our process must have two separate steps: first break up the aggregates into monomers without cold welding them into clusters; followed by a gradual flattening of the monomers into individual flakes of the required BET without cold welding these incredibly thin and small particles with each other.

MECHANICAL MILLING OF 0.42 µM TANTALUM PARTICLES UNTIL THEY ARE 0.096 µM THICK

The technical task before us, as stated above, is much more formidable than the modeling and design of the particles. The difficulty of achieving this objective in practice is essentially summed up in the inequality that the force used to deform the very small particles must never be great enough to cold weld the particles together. Very small particles require very little force to cause such agglomeration, so we see we will be constrained to a very unusual milling process using unprecedented low levels of energy. In fact, the entire metal powder milling industry up to now has focused on fast milling of relatively hard materials requiring high energy processes, so we knew from the beginning that we must invent new milling technology in order to achieve this goal. The milling process is further complicated by the fact that our starting powder (0.42 µM nodular particles) are not produced as individual “monomers”, but are only available to us in the form of complex aggregates of many thousands of particles. So our process must have two separate steps: first break up the aggregates into monomers without cold welding them into clusters; followed by a gradual flattening of the monomers into individual flakes of the required BET without cold welding these incredibly thin and small particles with each other.

State of the art milling equipment typically uses spherical media in a stirred or vibrated or rolled container. The particles to be milled are loaded into the container along with the spherical media and a liquid lubricant. A common arrangement is shown schematically below:
This particular configuration is known as an attritor mill as is made by Union Process Company in Akron, Ohio. Other types of mills, utilizing different means of imparting mechanical energy to the mill can be used.

In the above attritor mill example, a vertical steel drive shaft with numerous horizontal steel arms is situated in a vertical cylindrical chamber. The chamber contains the spherical media (shown here as small blue circles). Also present within the vertical cylinder, though not drawn in this illustration, is the tantalum powder and the lubricant liquid. In our process we use ethanol as the lubricant.

The two circles to the right above illustrate a typical collision between two media spheres. Such collisions would occur many millions of times in the mill during the course of the milling process. The small dot between the colliding spheres represents the much smaller tantalum particle being deformed in the collision.

Over the course of hours of milling, while the rotating shaft stirs the media and powder imparting energy to the collisions, the particles are progressively deformed from their nodular starting state to their final flat shape.

Depending upon the size of the milling chamber several kilograms of tantalum powder can be transformed in this way from a nodular to the desired high BET flake shape. What I have shown so far is typical of many processes used in industry to make flake metal powders including tantalum flake. The novel difference that KEMET has introduced is to reduce the energy of the collisions by several thousand times below what has been used in the past in order to avoid the deleterious effects of cold welding which vitiates the CV/g and traps impurities which cause leakage current.

Remembering that kinetic energy (energy of motion) is given by $KE = \frac{1}{2}mv^2$ wherein we have two factors: $m$, the mass of the moving object and $v^2$, the square of the speed of the moving object.

Therefore, the achievement of this new low energy regime in mechanical milling required two fundamental changes to the milling equipment.

First, the mechanical power input to the mill was reduced by changing the mechanical driving mechanism so as to limit the motion of any portion of the milling environment to very low speeds.

Second, the media was reduced in size from the smallest commercially available media by more than an order of magnitude so that the mass of the media spheres when multiplied by the square of the low speeds of the slowed down mill, represents insufficient energy to cause cold welding during the low energy impacts. To do this, KEMET had to develop new media with sizes normally considered typical of powder particles. The newly developed media is tens of millions of metallic spheres in the range of 30 to 300 microns across. Compare this to the smallest commercially available media which is 500 to 1000 microns (millimeter) steel shot or ceramic spheres.
Prior art tantalum flake, as is evident in the patent records, has been limited to a few tens of thousands of CV/g, so flake tantalum has up to now been restricted to high voltage applications where it has performed very well though the CV/g was limited. With the new KEMET technology flake tantalum CV/g appears to be unlimited as we have routinely achieved flake with BET greater than 8 square meters per gram. Furthermore SEM examination of the flake product of this new process shows the particles to be uniform, separate and very small flakes with high aspect ratios characteristic of non-agglomerated and non-broken flakes proving the lack of cold welding and breakage from excessive cold working and cold welding.

**Experimental Preparation and Testing of Flake Powders Made According to the Model:**

Four lots of flake were made by attritor milling the selected tantalum particles. Flakes achieved were consistent with 0.096 micron thick and 1 micron across as judged by SEM pictures. The flakes were conventionally processed into capacitor grade agglomerated tantalum powder. The CV/g of the four powders was measured at the KEMET Innovation Centre in Simpsonville South Carolina with results shown in table 1 below:

<table>
<thead>
<tr>
<th>Lot number</th>
<th>38-36-4</th>
<th>38-36-5</th>
<th>38-36-6</th>
<th>38-36-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental Pressed Density</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Modeled Sintered Density</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Pressed weight</td>
<td>.01671</td>
<td>.01671</td>
<td>.01671</td>
<td>.01671</td>
</tr>
<tr>
<td>Ta weight</td>
<td>.0164</td>
<td>.0164</td>
<td>.0164</td>
<td>.0164</td>
</tr>
<tr>
<td>Measured 18 volt CV/g</td>
<td>176,508</td>
<td>176,647</td>
<td>178,997</td>
<td>180,589</td>
</tr>
<tr>
<td>Modeled 18 volt CV/g</td>
<td>180,138</td>
<td>180,138</td>
<td>180,138</td>
<td>180,138</td>
</tr>
</tbody>
</table>

Table 1: Electrical test results for four lots of flake powder manufactured according to the geometrical conditions used in the model calculations

These experimental results support the validity of purely geometrical descriptions of the CV/g expected from micron and submicron scale tantalum particles. No adjustable parameters were included in the model calculations, so the results are based entirely upon the chemical and physical properties of tantalum and tantalum oxide and upon calculations of surface area of particles composed of simple Euclidian shapes. These results reinforce the promise that engineers can pursue the development of capacitor anodes composed of well-defined and predictable modeled particle morphologies with confidence in the outcomes achieved.
CRITICAL MATERIALS SUPPLY CHAINS: A PUBLIC POLICY PERSPECTIVE

Paper written by Jeffery A. Green and Matthew D. Zolnowski, of J.A. Green & Company, and presented on October 13th 2014, as part of the Fifty-fifth General Assembly held in New York, U.S.A.

For want of a nail the shoe was lost,
for want of a shoe the horse was lost;
and for want of a horse the rider was lost;
being overtaken and slain by the enemy,
all for want of care about a horse-shoe nail.

~Benjamin Franklin

INTRODUCTION

Governments, historically, have devoted considerable resources to ensuring a reliable supply of materials deemed critical to their defense industrial base. During the Napoleonic Wars, Great Britain engaged in multiple campaigns against Denmark, Russia and France to ensure the continued supply of 2,500,000 cubic feet of timber, largely from the Baltics, for Royal Navy shipwrights. In the run-up to the Second World War, the United States spent $54 million to stockpile materials whose supply might be interrupted by war in Europe and Asia. During the war, both Great Britain and the United States engaged in preclusive purchasing to deny wolframite and chrome supplies to Germany.

The wartime exigencies of the above examples have long passed, but in the case of the U.S. National Defense Stockpile (NDS) program, the authorities that created this program have remained largely unchanged from their roots in the inter-war period. Despite this foundation, the Department of Defense (DoD) increasingly engages and relies upon commercial supply chains to drive innovation. As such, many of the new risk mitigation procedures selected by the DoD take a less interventionist approach.

The purpose of this paper is to describe some of the elements of U.S. federal government policy and activities towards “critical materials”, in general, while maintaining a focus on how tantalum may be affected, in particular. The first segment will discuss prescriptive elements of federal acquisition regulations, including formal requirements and looser preferences. This is juxtaposed with more market-based approaches which emphasize material substitution and process optimization research. The final section will describe the interaction between “policy” and “politics”. For the purposes of this paper, the former refers to the day-to-day management of government affairs, while the latter refers to catalysts and other forces that move federal government action.

PRESCRIPTIVE ACTIVITY

The public procurement process is one of the most potent tools available to the federal government to influence a company’s conduct. The discretionary portion of the U.S. federal budget is estimated to be approximately $1.096 trillion in 2014, of which 55% or $605 billion, may be spent on national defense and foreign assistance programs. The DoD can leverage this buying power in a number of ways to influence or require a company to produce a component in the United States or incorporate materials produced in the United States or by close U.S. allies. One such example is the specialty metals clause (10 U.S.C. 2533b).

This statute prohibits the acquisition of the end items or components of aircrafts, missiles, ships, tanks, automotive items, weapon systems and ammunition that contain a specialty metal not melted or produced in the United States. Similarly, the direct acquisition of specialty metals not melted or produced in the United States, by the DoD or by one of its contractors, is prohibited. For the purposes of this statute, a specialty metal is defined as the following:

1. Steel
   a. with a maximum alloy content exceeding one or more of the following limits: manganese, 1.65 percent; silicon, 0.60 percent; or copper, 0.60 percent; or
   b. containing more than 0.25 percent of any of the following elements: aluminum, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, or vanadium.
2. Metal alloys consisting of nickel, iron-nickel, and cobalt base alloys containing a total of other alloying metals (except iron) in excess of 10 percent.
3. Titanium and titanium alloys.

2 President, J.A. Green & Company
3 Director – Research Programs, Labyrinth DC
4 Patrick Melby, Insatiable Shipyards: The Impact of the Royal Navy on the World’s Forests, 1200-1850 (Western Oregon Univeristy, June 2012)
8 10 U.S.C. 2533b
9 10 U.S.C. 2533b
Tantalum is not listed as one of the metals that must be melted or produced in the United States, but some tantalum applications, such as nickel superalloys, are covered by the clause. However, one of the important exceptions to the specialty metals clause is for “qualifying countries”. Due to reciprocal defense ties, any specialty metal that is melted or produced in the following countries is treated as though it were produced in the United States:

- Australia
- Austria
- Belgium
- Canada
- Czech Republic
- Denmark
- Egypt
- Finland
- France
- Germany
- Greece
- Israel
- Italy
- Luxembourg
- Netherlands
- Norway
- Poland
- Portugal
- Spain
- Sweden
- Switzerland
- Turkey
- United Kingdom
- United Kingdom

Outside of this specific statute, the DoD also uses another set of acquisition tools to either exclude suppliers or support U.S. companies. One official currently exercising this authority is the Secretary of the Army as the Single Manager for Conventional Ammunition. Again, tantalum is not specifically listed as a metal that must be produced in the United States, but tantalum-containing parts in the following items would be covered by this authority:

- Small arms, mortar, automatic cannon, artillery, and ship gun ammunition;
- Bombs (cluster, fuel air explosive, general purpose, and incendiary);
- Unguided rockets, projectiles, and submunitions;
- Chemical ammunition, as permitted by the Organization for the Prohibition of Chemical Weapons Convention with various fillers (incendiary, riot control for permitted use, smoke, burster igniters, peptizers, and thickeners for flame fuel);
- Land mines (ground-to-ground and air-to-ground delivered);
- Demolition materiel;
- Grenades;
- Flares and pyrotechnics;
- Related ammunition containers and packaging materials.

Though tantalum mining and smelting may be indirectly impacted by the aforementioned procedures, one branch of the DoD that purchases tantalum directly is the NDS. Currently managed by the Defense Logistics Agency-Strategic Materials (DLA-SM), the defense stockpile holds approximately 3,802 lbs of contained tantalum. Although the stockpile made no acquisitions from 1998 to 2013, the DLA-SM announced plans to stockpile more material and new materials in the National Defense Authorization Act for Fiscal Year 2014. DLA-SM also is planning to acquire an additional 46,750 lbs of contained tantalum for the fiscal year 2016 Annual Materials Plan (AMP).

There are no statutory restrictions on suppliers that may acquire or sell materials to the NDS. However, there are strong informal pressures on companies to produce or use NDS materials in the United States. For example, after the DoD expended $6.5 million to establish a domestic source of space-qualified solar cells (germanium), the DLA-SM awarded $1.32 million to the same company to upgrade some of the NDS’ germanium metal inventory. Similarly, the DoD spent $16.6 million to establish a domestic source of lithium-ion batteries, and the DLA-SM announced plans to purchase the following lithium-ion precursor materials in the fiscal years 2015 and 2016 AMPs:

<table>
<thead>
<tr>
<th>FY2015 AMP</th>
<th>FY2016 AMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium Cobalt Oxide</td>
<td>150 kg</td>
</tr>
<tr>
<td>Lithium Nickel Cobalt Aluminum Oxide</td>
<td>540 kg</td>
</tr>
<tr>
<td>Mesocarbon Microbeads</td>
<td>648 kg</td>
</tr>
</tbody>
</table>

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10 DFARS 225.003
11 10 U.S.C. 2304
12 10 U.S.C. 2304 (note)
13 Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Directive 5160.65 (1 August 2008)
14 Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Strategic and Critical Materials 2013 Report on Stockpile Requirements (January 2013), pg. 6-6
Outside of these specific and more informal acquisition requirements, the DoD and other segments of the U.S. Government also take a more deliberate approach to critical materials supply chains, funding studies and basic research that aims to diversify the supply of at-risk materials through substitution and process optimization. Again, one of the most significant actors for critical materials is the DoD through the DLA-5M.

Every two years, the DLA-5M embarks on an in-depth and statutorily-required report on the raw mineral and downstream refining requirements of the defense industrial base and essential civilian services.\(^{20}\) Formerly, DLA-5M focused exclusively on raw mineral supply, but in an attempt to better reflect the global structure of mineral supply chains, reports after fiscal year 2015 will include a focus on downstream weak links or “single points of failure” in the value-added processing of these minerals.

These supply chain inputs are then compared to the demand requirements of the defense industrial base and essential civilian services within national defense emergency scenarios. Though many details of this analysis are classified, scenarios considered by DLA-5M are generally characterized by a one-year wartime period, followed by three years of regeneration. Sample scenarios have included (1) a catastrophic attack on a U.S. city by a foreign terrorist organization or rogue state, (2) two major overseas conflicts, and (3) significant counter-insurgency activities.\(^{21}\) These scenarios represent a “base case” of NDS requirements, but DLA-5M also prepares a range of alternative case scenarios that also consider peacetime supply disruptions (e.g. embargos or force majeure events) and modified supply or demand assumptions (e.g. expanded availability of overseas suppliers or more efficient material substitution).

This reporting process serves as the baseline for recommendations by the DLA-5M to acquire or dispose of NDS materials, and it also informs the research priorities of other DoD agencies to develop alternate materials or optimize existing manufacturing processes. For example, before the fiscal year 2016 AMP decision to acquire additional tantalum, the 2013 report on stockpile requirements found a shortfall of 619,505 lbs of tantalum, most of which would be met by U.S. Government not guaranteeing the availability of tantalum for export products.\(^{22}\) This may be carried out under Title I of the Defense Production Act, whereby domestic entities and, under certain circumstances, foreign entities are required to meet U.S. defense requirements ahead of commercial orders.\(^{23}\) The circumstances of the applicability of Title I of the Defense Production Act to foreign entities are contingent upon the particular terms of Security of Supply Arrangements between the DoD and the defense ministry of a foreign nation, and the following countries participate in the DoD program: Australia, Canada, Finland, Italy, the Netherlands, Sweden and the United Kingdom.\(^{24}\)

As previously mentioned, this study process also informs research and development priorities at other segments of the DoD and the military services. To date, the military services and the Office of the Secretary of Defense (OSD) have funded 41 small business awards on tantalum, ranging from optimized metallurgical techniques to development of substitute refractory metals.\(^{25}\) Outside of these small business programs, each of the military services and military research institutes engage in long-running solicitations to partner with materials companies to more efficiently produce critical materials or reduce their consumption in weapon systems.

Another popular approach to addressing critical material issues is through the establishment of regional “hubs” for engineering and materials science research. Two of the most prominent industry-government institutes established by the DoD include the Lightweight and Modern Metals Manufacturing Innovation (LM3I) Institute and the Digital Manufacturing and Design Innovation (DMDI) Institute. The primary U.S. Government lead for these “hubs” is the Office of Naval Research and Redstone Arsenal (AEDC), and each of these institutes will contribute towards separate materials science and rapid prototyping challenges in manufacturing, the key objective of both institutes is to bridge the gap in U.S. Government investment between applied research (technology readiness level 3-5) and commercialization (technology readiness level 7-9).\(^{27}\)

Outside of DoD, the Department of Energy (DOE) is another supporter of basic research into critical materials. However, much of this development has been driven by the DOE’s Critical Materials Strategy, which circumscribed “critical materials” to supply risk and the intensity of material demand in only four applications: hybrid and electric vehicles, wind turbines, solar cells and fluorescent lighting.\(^{28}\) As such, tantalum was not considered to be a critical material by the DOE, nor was it included within the remit of the Critical Materials Institute, a $120 million research hub based in Ames National Laboratory.

\(^{20}\) 50 U.S.C. 98h-5  
\(^{22}\) Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, Strategic and Critical Materials 2013 Report on Stockpile Requirements (January 2013), pg. 6-9, 11-3  
\(^{23}\) 50 U.S.C. App. 2601 et seq.  
\(^{25}\) Search of SBIR and STTR awards available at http://www.dodsbir.net/Awards/Default.asp  
\(^{27}\) Philip M. Coyle, “The Missing Middle,” presentation at National Defense Industrial Association Science & Engineering Technology Division Executive Breakfast (10 May 2011)  
\(^{28}\) Department of Energy, Critical Materials Strategy (December 2011), pg. 3
POLICY ENVIRONMENT

Though the majority of this work has focused on the role of the DoD and the military services, a number of other agencies have a stake as well. The U.S. Geological Survey (USGS) provides most of the underlying data on mineral production in the United States and globally, and they in turn rely upon International Trade Commission and the Department of Commerce for estimating the level and type of imports and exports of these materials, including finished products in which materials are embedded.

Though these roles appear to be distinct, there are some significant areas of overlap as well. For example, just as the DoD and DLA-SM engage in numerous studies of the defense industrial base, these agencies partner with the Department of Commerce, specifically the Bureau of Industry and Security, to conduct defense supply chain mapping studies, also known as “Sector-by-Sector, Tier-by-Tier” (S2T2). Similarly, the DOE has defined critical materials largely by the applicability of a material to select renewable energy and energy-efficient products. By contrast, the OSD has adopted a more narrow view of “criticality”, namely materials for which

1) the Department of Defense dominates the market for the material,
2) the Department’s full and active involvement and support are necessary to sustain and shape the strategic direction of the market, and
3) there is significant and unacceptable risk of supply disruption due to vulnerable U.S. or qualified non-U.S. suppliers.29

DLA-SM, on the other hand, statutorily must take a broader view of critical materials, encompassing both national defense requirements and essential civilian demand. As such, a critical material for DLA-SM is defined as a material that

(A) would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency, and
(B) are not found or produced in the United States in sufficient quantities to meet such need.30

To coordinate these disparate interests, the White House has established a working group on critical materials, chaired by the Office of Science and Technology Policy. More specifically, the Critical & Strategic Mineral Supply Chain subcommittee has met several times to produce policy recommendations on critical minerals, and it continues to seek input from industry on minerals and materials that it should monitor.31

Outside of the executive branch, Congress plays an equally important role in formation and oversight of policy towards critical materials. Aside from the actions of individual members of Congress, the Congressional Research Service (CRS) and the Government Accountability Office (GAO) are non-partisan institutions that assist members in carrying out their duties. The former is Congress’ internal think tank, providing reports and memos on issues requested by any member. The latter provides a combination of audit and investigatory services to Congress.

GAO has produced a number of reports on the tantalum supply chain, derived from its reporting requirements under the Dodd-Frank financial reform legislation.32 CRS also provides more regular updates and briefings to members of Congress on this issue. As one example of how these institutions sometimes influence one another, recently the CRS produced a report which found significant discrepancies in tantalum supply data (primary production) and demand data (smelter output). CRS contacted USGS about its findings, and “USGS experts noted that they believe the tantalum industry operates under a ‘shroud of secrecy’, with incomplete access to data and a lack of transparency.”33 As such, CRS was unable to make definitive conclusions on tantalum production, capacity and reserve levels on a global basis, noting three major impediments:

1. The non-reporting or under-reporting of all forms of supply (primary, byproduct, tin slag, scrap) from industry associations and elsewhere;
2. High inventory levels as a result of the 2008 global financial crisis; and
3. Illicit mining and trading of tantalum ores and concentrates from Central Africa and elsewhere.

These findings led to several members of Congress to request that GAO investigate the due diligence frameworks and procedures of smelters of tantalum and conflict minerals in subsequent reports pursuant to the Dodd-Frank law.

29 Deputy Under Secretary of Defense (Industrial Policy), Report of Meeting – Strategic Materials Protection Board (12 December 2008), pg. 2
30 50 U.S.C. 98h-3
33 See Appendix A.
POLITICAL ENVIRONMENT

Outside of the structural policy environment described in the previous section, another highly-relevant influence on critical materials is the “political” environment. In general, political events around critical materials appear to swing between two ends: the urge to “do nothing” and the urge to “overreact”. Usually there is an exogenous “trigger” event that encourages political leaders to take action, but with the passage of time, initiatives begun immediately after that trigger tend to fall into neglect.

Several materials reflect this trend, but in the recent past, one of the more famous groups of materials is rare earth elements. Prior to 2010, rare earth elements were almost non-existent as a policy issue or concern for Congress. However, after a maritime incident between China and Japan in late 2010 and subsequent price increases over the summer of 2011, members of Congress drafted dozens of bills, and many executive branch agencies initiated public reviews of their policies. Millions of dollars were spent to establish a rare earth “hub” at Ames National Laboratory and a World Trade Organization case was launched.

Despite this apparent flurry of activity, very few provisions related to rare earths were signed into law, and as prices for rare earths have declined from 2012 to the present, the urgency of executive and legislative branch interest in rare earths has also declined. Even the rare earth hub at Ames National Laboratory is looking to expand its purview to lithium and tellurium. On the other hand, even after this relative lull, periodic trigger events can re-emerge, such as the discovery of Chinese-manufactured rare earths in the F-35 Lightning II and the release of a DoD Inspector General report sharply criticizing DLA-SM research on rare earth supply and defense requirements.

With this pendulum between little activity and significant attention, it is worth considering what events, or types of events, might act as a “trigger”. Some of these are already well-known to the tantalum industry, such as pressure to implement conflict-free supply chains. Others may be beyond the control of individual companies or industry as a whole, such as force majeure events in the Democratic Republic of Congo or other major tantalum-producing regions. Similarly, the various political, policy, and institutional influences of the U.S. Government, in isolation or in combination, can also impact the market.

CONCLUSIONS

This paper opened with a discussion of the historical basis for government involvement in ensuring a reliable flow of materials deemed critical to their respective defense industrial bases. Many of the United States’ critical materials institutions, like the National Defense Stockpile and domestic preference statutes, have their foundations in the inter-war period, and though they remain in effect, the Department of Defense is actively seeking more market-based approaches to resolving critical materials constraints. These include supporting innovative small businesses and establishing industry-government consortia.

On the other hand, each of these institutions and programs operates in a political environment that can quite suddenly swing from relatively little attention to debate within the highest levels of the U.S. Government. Industry often can prepare for these “trigger” events ahead of time through constant monitoring of their sector and communication of their concerns to government leaders. Though the unexpected is bound to occur, having pre-established lines of communication to various branches of the U.S. Government can help to shape the follow-on surge in activity.

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February 7, 2014

Mr. Gene L. Dodaro
Comptroller General of the United States
United States Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Comptroller General Dodaro:

The Wall Street Reform and Consumer Protection Act requires certain companies to file a report on whether conflict minerals, essential to the function or manufacture of a product, have originated in the Democratic Republic of Congo or adjoining countries. We note that the Act also requires the Government Accountability Office (GAO) to report to Congress on the effectiveness of regulations promulgated under the Act. In light of certain supply chain inconsistencies and the difficulties experienced by some reporting companies, we request that the GAO include in this report, as required by the Act, information on the extent to which upstream due diligence processes, such as the “conflict free smelter program,” follow Securities and Exchange Commission (SEC) and GAO guidance.

In addition to any related matters the Comptroller General deems relevant, this section of the GAO report should address whether due diligence frameworks and procedures of smelters of conflict minerals:

- Follow due process procedures, including broad distribution for public comment;
- Are consistent with the standards in GAO’s Generally Accepted Government Auditing Standards;
- Are free from organizational conflicts of interest; and
- Are reconcilable against other industry or government data benchmarks, such as trade association data or U.S. Geological Survey (USGS) data.

Reporting companies have taken the Act’s requirement on conflict minerals sourcing very seriously, undertaking expensive and continuous monitoring programs of their supply chains. However, these reporting companies are many tiers removed from producers, traders, and processors of conflict minerals; in fact, most such producers, traders and processors of conflict minerals are privately-held or foreign companies that are not required to report under the Act. As such, many reporting companies have experienced roadblocks to obtaining data from their suppliers that is both sufficient and verifiable with regards to the progeny of conflict minerals.

On the other hand, the processors or “smelters” of conflict minerals represent a natural chokepoint in the supply chain, affording them much greater visibility into the source of material. Therefore, ensuring that the smelters’ due diligence processes conform to SEC and GAO
guidance and standards is essential to the successful implementation of the Act and the broader public policy goal of encouraging stability and sustainable development in the Democratic Republic of Congo.

The source of our concern about the due diligence frameworks and processes of smelters is based upon recent Congressional Research Service (CRS) findings regarding discrepancies within the tantalum supply chain. For example, smelters’ receipts (a proxy for demand) for the first three quarters of 2012 were approximately 949 tonnes of tantalum, while primary producers and traders only held receipts for approximately 283 tonnes of tantalum (both figures measured in Ta₂O₅ content). On average from 2011 to 2012, the gap between primary production and smelters’ receipts is 381 tonnes of tantalum per quarter. During this period, we also are aware that an increasing number of smelters were certified and continue to be certified as “conflict free smelters,” pursuant to certain private sector due diligence processes.

When CRS contacted the USGS for comment on this industry data, USGS experts noted that they believe the tantalum industry operates under a “shroud of secrecy,” with incomplete access to data and a lack of transparency. CRS concluded that there is insufficient data to make definitive determinations on tantalum production, capacity, and reserve levels on a global basis, highlighting:

1. The non-reporting or under-reporting of all forms of supply (primary, byproduct, tin slag, scrap) from industry associations and elsewhere;
2. High inventory levels as a result of the 2008 global financial crisis; and
3. Illicit mining and trading of tantalum ores and concentrates from Central Africa and elsewhere.

Mid-sized and global companies that employ thousands of Americans have established costly and proactive supply chain monitoring programs to ensure that conflict minerals are sourced in a responsible and ethical manner. This is a positive step towards ultimately halting the endemic violence in the Democratic Republic of Congo, but it is equally important to prevent backsliding on this progress through less than adequate due diligence frameworks and procedures at upstream smelters of conflict minerals.

We thank you and GAO staff for the work you have undertaken on this important issue to date, and we look forward to reviewing your findings on the private sector due diligence processes related to conflict minerals.

Sincerely,

[Signatures]

JIM MCDERMOTT
Member of Congress

ANDRI CARSON
Member of Congress

JIM MORAN
Member of Congress
MEMBER COMPANY NEWS

Mr Nurlan Kapparov

The T.I.C. was very sad to learn that Mr Nurlan Kapparov, Chairman of the Board of NAC Kazatomprom, had passed away on March 26th, at the age of 44. We present our deepest sympathy to all employees of NAC Kazatomprom and Ulba Metallurgical Plant JSC. Mr Kapparov was also the nominated delegate to the T.I.C. for his company.

CHANGES IN MEMBER CONTACT DETAILS

Chee Ng Minerals Sdn. Bhd.

Chee Ng Minerals Sdn. Bhd. has announced a new e-mail address: cheengminerals@gmail.com. The delegate to the T.I.C., Mr Chee Yoke Hin can also be reached on cheeyokehin@hotmail.com.

Mitsui Mining & Smelting Co Ltd

Mitsui Mining & Smelting Co Ltd has nominated Mr Daisuke Nakayama as delegate to the T.I.C., in the place of Mr Jun Sugimura, who has been transferred to another division of the company. He can be reached on d_nakayama@mitsui-kinzoku.co.jp.

EXECUTIVE COMMITTEE

According to the Charter of the T.I.C., the Executive Committee may consist of between two and eleven people, plus the President. The Executive Committee is drawn from the membership, and committee members may be, but need not also be, the delegates of member companies.

The Executive Committee composition was approved by the T.I.C. members at the General Assembly on Monday October 13th 2014, and it currently consists of (in alphabetical order):

- Conor Broughton conor@amgroup.uk.com
- John Crawley jcrawley@mmmc.com.hk
- David Gussack david@exotech.com
- Dale Gwinnutt dalegwinnutt@elitematerial.com
- David Henderson (President) dhenderson@rittenhouseir.com
- Marc Hüppeler marc_hueppeler@bcstarck.com
- Jiang Bin jiangb_nniec@otic.com.cn
- Ian Margerison ian.margerison@metalysis.com
- William Millman bill.millman@avx.com
- Daniel Persico danielpersico-rc@nec-tokin.com
- Itamar Resende itamar.resende@mtaboca.com.br
- Alexey Tsorayev tsorayevaa@ulba.kz

The Executive Committee of the T.I.C. meeting in New York on Sunday October 12th 2014