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SCALE: AN EMERGING PROJECT FOR EUROPEAN SCANDIUM SUPPLY

By

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ABSTRACT

Scandium (Sc) is one of the highest valued elements in the periodic table and an element which is usually grouped in REEs. The technological applications of this valuable element are unique, as it is a key component in producing solid oxide fuel cells, aluminium alloys especially for aerospace industry and 3D printing applications (SCALMALLOY®). Despite its various technological applications, Sc supply is limited due to its scarcity and the high production costs. Sc producing countries are China (66%), Russia (26%), and Ukraine (7%). Between 2010 and 2014, the European demand was covered from Russia (67%) and Kazakhstan (33%). Additionally, the end-of-life recycling rate of scandium was reported to be 0% (COM/2017/0490: FIN).

There is no production of scandium in Europe, but the region is home to many Sc industrial end-users (Airbus, II-VI, KBM Affilips, etc.). In fact, end-users like Airbus, are not deploying their Sc applications due to the lack of a secure Sc supply. As a member of EU H2020, the SCALE project sets about to develop and secure a European Sc supply chain through the development of technological innovations which will allow the extraction of Sc from European industrial residues (i.e. bauxite residue and TiO_2 production waste), ultimately upgrading it to pure scandium oxide, fluoride, metal and alloy. The industrially driven SCALE consortium covers the entire Sc value chain with 7 major European industries and further features 8 academic and research institutes and 4 engineering companies with track records in RTD.

Keywords: Scandium, Secondary Resources, Recovery, Bauxite Residue, Titanium Production Waste

INTRODUCTION

Technological evolution is historically linked with the materials and especially the metals available to mankind. In contrast to base metals (Fe, Al, Cu, Zn, etc.) used traditionally in bulk amounts, today's advances in material science have given rise to a new group of metals, which are used in small amounts to alter drastically the properties of matter. Whether in composite ceramic materials or minor elements in alloys, these trace metals significantly shape modern-day technology and are often termed Technology Metals (REE, In, Ge, Ga, Li, PGMs, Nb, etc.).

Among them, Scandium (Sc) is one of the highest valued elements in the periodic table and an element which is often grouped in REE as it shares many characteristics of Yttrium. Scandium technological applications are unique, as it is a key component in producing solid oxide fuel cells (Scandia-Stabilized-Zirconia solid electrolyte layer), high strength Aluminium alloys used in aerospace, 3D printing applications (SCALMALLOY®) and also finds important applications in electronics and ceramics.

Its average crustal abundance is 15-25 ppm and the possible, independent, scandium mineral deposits are generally insignificant in size and grade, with certain notable exceptions in some clay resources where scandium concentration may be in the range of 100 – 150 ppm. For this reason, most of today's scandium production tends to come as a by-product of the leaching activity associated with production of other metals, minerals, or rare earths, specifically U, Th, Al, W, Sn, Ta, P and REE's.

A potentially significant scandium resource is the bauxite residue (red mud) tailings from the Bayer process, employed in bauxite processing into alumina. Bauxite residue typically contains 50-100 ppm Sc, but certain tailings can show concentrations of up to 150 ppm, rendering them as highly important resources for scandium production, provided that there is a technically feasible and economically viable technology for the recovery of scandium from the bauxite residue. Titanium dioxide production residues (acid waste) also contain similar Sc concentrations.

The principal Sc-producing countries today are China, Russia, Ukraine, and Kazakhstan. Currently there is no Scandium production in Europe. There are important EU based industries including Airbus, II-VI, KBM Affilips and others that need to use scandium in a good number of applications that will give them significant competitive advantage and are not deploying their Sc applications due to the lack of a stable and secure Sc supply. In addition, it is expected to have an increase in demand of Sc especially in aviation industry, as shown in Figure 1.

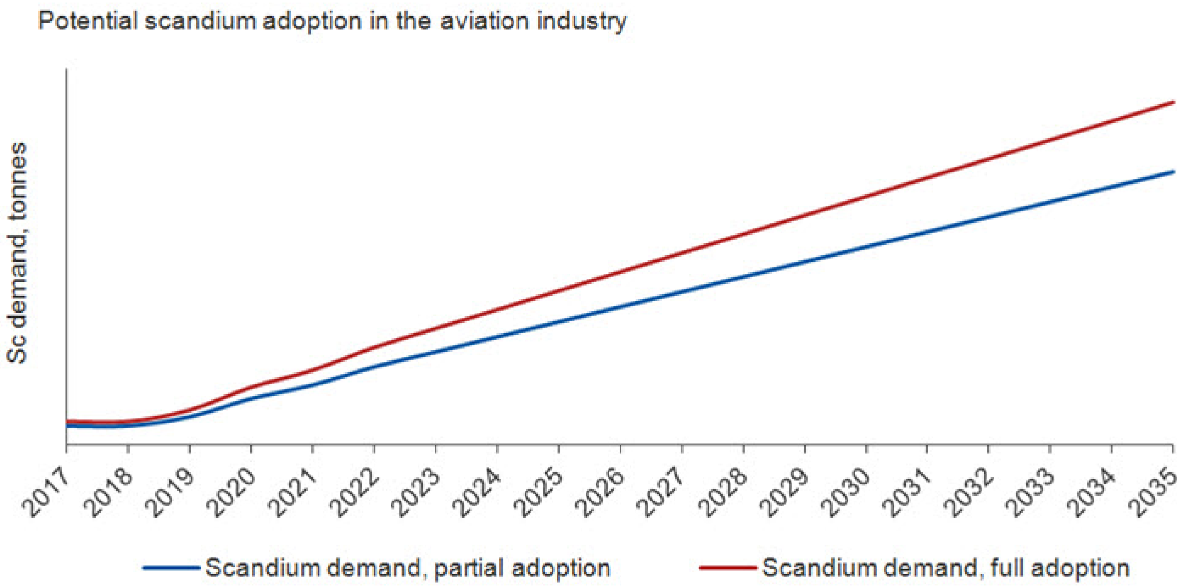

Figure 1. Future Scandium demand for partial and full adoption in the aviation industry

USAGE OF SCANDIUM

3-D Printing

AlMgSc alloy (patented by AIRBUS as Scalmalloy®) has proven to be very suitable for additive manufacturing (laser beam powder-bed melting) enabling best strength-ductility values after printing and post build heat treatment compared to any other 3D-printed Al–alloy. Recently Appworks (a division of AIRBUS) has manufactured through 3D printing a new partition of an Airbus A320. The partition design is almost impossible to manufacture using traditional methods; 122 out of the 162 parts were made of SCALMALLOY®. The partition was assembled for the very first time at Autodesk University in 2015 and weights a massive 45% less than current Airbus A320 partition designs.

Al-Sc Alloys

Al-Sc alloys represent a new generation of high performance alloys with superior properties over all other Al alloys. Small amounts of Sc (<0.5 wt.%) act beneficially to the metal properties enhancing strength, corrosion resistance, grain size and recrystallization resistance(1-3). Al-Sc alloys generate high performance products currently used in sporting equipment and the aerospace industry. For instance, an Al-Sc bicycle frame showed a 12% reduction in weight, a 50% increase in yield strength, and a 24% improvement in fatigue life over the best-selling aluminium bicycle frames. The addition of scandium to aluminium limits the excessive grain growth that occurs in the heat-affected zone of welded aluminium components and has two beneficial effects: the precipitated Al_3Sc forms smaller crystals than are found in other aluminium alloys, and the volume of precipitate-free zones that normally exist at the grain boundaries of age-hardening aluminium alloys is substantially reduced[2]. Therefore, scandium reduces hot cracking during welding and provides the highest increment of strengthening per atomic percent of any alloying element when added to aluminium.

Solid Oxide Fuel Cells

SOFC delivers reliable, efficient and cleaner energy by converting gas into electricity and useable heat (up to 85% efficiency); safe, on-site location, with no fuel combustion.

Scandia-Stabilized-Zirconia (SSZ) as solid electrolyte layer of the SOFC allows oxygen ion diffusion to occur at lower temperatures compared to Yttria-Stabilized-Zirconia (YSZ) thus extending the life of the SOFC components and increasing the power density of the unit [4,5]. BLOOM ENERGY (USA) has already commercialised SSZ- based-SOFC and is currently the biggest Sc consumer globally. Yet further expansion of SOFC technology is undermined by the Sc supply chain insecurity.

Laser Optics

Scandium can impart unique properties in laser applications. Erbium, chromium: yttrium-scandium-gallium garnet (Er,Cr: YSGG) lasers are used for cavity preparation and in endodontics. Scandium allows for the design of unique diode pumped solid-state lasers radiating in the 3 µm range. Flash lamp pumped solid-state lasers using scandium have been demonstrated to have 3 times higher efficiency relative to doped YAG crystals for medium power pulse laser applications. Laser crystals of gadolinium-scandium-gallium garnet (GSGG) have been extensively studied in strategic defence applications (such as the Strategic Defence Initiative (SDI)).

The range of laser applications for scandium is extensive; however, the uncertainty in the supply chain and cost of procuring scandium has limited its investigation in the laser market. II-VI is the world's leading producer of laser materials for various applications and has a vested interest in a reliable Sc supply.

AIMS OF THE PROJECT

The main aim of SCALE is the efficient exploitation of EU high concentration scandium containing resources including bauxite residues (100-150 ppm) resulting from alumina production and acid wastes (50-100 ppm) from TiO_2 pigment production to develop a stable and secure EU scandium supply chain to serve the needs of EU aerospace and high-tech industry. This will be achieved through the development of several innovative extraction, separation, refining and alloying technologies that will be validated in an appropriate laboratory and bench scale environment to prove their technical and economic feasibility.

Bauxite Residues and TiO_2 Pigment Acid Waste Waters

Scandium is rarely concentrated in nature and remains widely dispersed in the lithosphere as it lacks affinity to combine with the common ore-forming anions. So, due to its nature Sc usually derives as a by-product in waste streams that are generated from primary metal production and circumstantially are enriched in Sc(6,7). The enrichment of a waste stream in the range of a few hundred parts per million in Sc, can be designated as an exploitable resource. Some of scandium highly exploitable secondary resources are associated with uranium, tungsten, nickel, titanium and aluminium primary production(8,9). SCALE examines and screens two main categories of European by-products as highly promising Sc resources: bauxite residues from the alumina industry (5 million tons on dry basis per year in Europe) and TiO_2 pigment industry residues (1.4 million tons on dry basis per year in Europe).

Extracting Scandium from Waste

SCALE develops technologies that can extract cost efficiently and sustainably Sc from complex dilute mediums (Sc ~100 mg/kg) such as the bauxite residue and the TiO_2 acid waste and upgrade it to commercial concentrate (Sc >100 g/kg). Selective Bauxite Residue leaching followed by 'SIR' ion-exchange technology for extracting Sc and acid nano-filtration for Sc extraction from TiO_2 acid waste are developed and further tested in industrial environments.

Refining Scandium Concentrates

Scandium concentrates have to be refined in order to produce pure scandium compounds for the industry. Available technologies rely on multi-stage and resource intensive hydrometallurgical routes. In order to propose and enhanced processes, Sc concentrate will be refined with different routes. To shorten the Sc refining process to produce pure Sc oxides, newly patented extractants or techniques will be investigated. Additionally, ScF_3 will be produced by avoiding the use of HF gas to propose a safer and simpler route for production.

Producing Scandium Metal and Alloys

Production of Sc metal and alloy is achieved only through calciothermic reduction, which is a very expensive and small-scale technology, thus resulting in very expensive and limited metallic Sc products. SCALE develops novel technologies to overcome such barriers by achieving:

- Sc-electrolysis from Sc_2O_3 instead of ScF3,
- methods for direct Al-Sc alloy production, and
- room temperature Sc electrowinning from Ionic Liquid solutions.

PROCESSES PROPOSALS

MEAB Chemie Technik GmbH is one of the responsible partners for refining and purifying a Sc concentrate from different Sc-containing secondary resources in the SCALE Project(10). The major feeds that will be processed are bauxite residue, TiO_2 production acid waste and Sc-containing scraps or wastes.

Processing of Bauxite Residue

Figure 2 shows a possible processing route for Sc recovery from bauxite residues. According to this process, two different routes can be followed after leaching of bauxite residue. The first one is eliminating most of the impurities by Selective-Ion Recovery technology (SIR) developed by II-IV which is then purified even more to reach high purity Sc product. The second method is to treat bauxite residue with a selective precipitation process to synthesize a Sc concentrate, purifying this concentrate with solvent extraction to obtain a high purity Sc product(11-14).

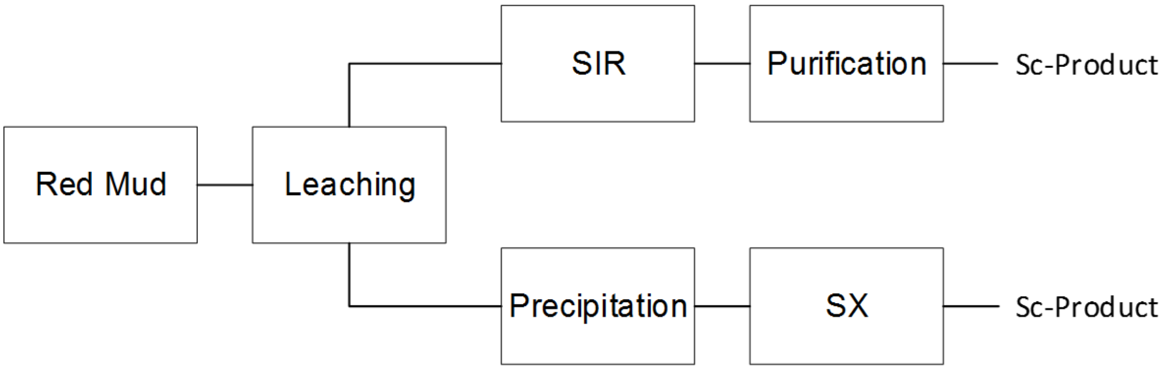

Figure 2. Proposed Sc recovery process based on bauxite residue

Processing of TiO_2 Pigment Acid Waste

Process proposal from Ti pigment acid wastes can be seen from Figure 3. According to this proposed operation, after applying solvent extraction to isolate Sc from major impurities, it can be further treated and purified by selective precipitation.

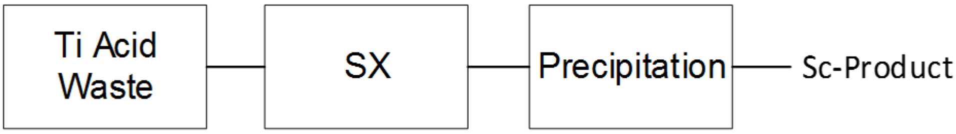

Figure 3. Proposed Sc recovery process based on Ti acid wastes

Processing of Scandium Containing Wastes

Another important Sc source is Sc containing wastes such as; metallic powders or aluminium alloys. These scraps can be leached easily since these wastes are mainly metallic materials or stoichiometric oxides as it can be seen from Figure 4. After leaching these materials, solvent extraction can be applied to mainly isolate Sc from Al. Then the liquor obtained after SX can be further treated with various purification operations in order to produce a high purity Sc-product.

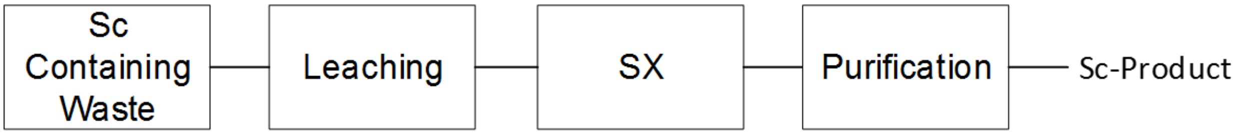

Figure 4. Proposed Sc recovery process based on Sc-containing materials

CONCLUSION

Sc is one of the highest valued elements in the periodic table and an element which is usually grouped in REEs. The technological applications of this valuable element are unique, as it is a key component in producing solid oxide fuel cells, aluminium alloys especially for aerospace industry and 3D printing applications. Despite its various technological applications, Sc supply is limited due to its scarcity and the high production costs.

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REFERENCES

1. Lathabai S, Lloyd P, "The effect of scandium on the microstructure, mechanical properties and weldability of a cast Al–Mg alloy", Acta Materialia, 50 (17):4275-4292 (2002).
2. Marquis E, Seidman D, "Nanoscale structural evolution of Al 3 Sc precipitates in Al (Sc) alloys", Acta materialia, 49 (11):1909-1919 (2001).
3. Røyset J, Ryum N, "Scandium in aluminium alloys", International Materials Reviews, 50 (1):19-44 (2005).
4. Ormerod RM, "Solid oxide fuel cells", Chemical Society Reviews, 32 (1):17-28 (2003).
5. Yamamoto O, "Solid oxide fuel cells: fundamental aspects and prospects", Electrochimica Acta, 45 (15):2423-2435 (2000).
6. Evans K, "The History, Challenges, and New Developments in the Management and Use of Bauxite Residue", Journal of Sustainable Metallurgy, 2 (4):316–331 (2016).
7. Y. Liu RN, Ravi, "Hidden values in bauxite residue (red mud): Recovery of metals", Waste manag, 34 (12):2662–2673 (2014).
8. Gambogi J, "USGS Minerals Information: Scandium". Mineral Commodity Summaries. U.S. Geological Survey, (2017)
9. Horovitz CT (2012) Scandium Its Occurrence, Chemistry Physics, Metallurgy, Biology and Technology. Elsevier,
10. MEAB Web Site. (2018). http://www.meab-mx.se/. 2018
11. Alkan G, Xakalashe B, Yagmurlu B, Kaussen F, Friedrich B, "Conditioning of red mud for subsequent titanium and scandium recovery–a conceptual design study", World of Metallurgy–ERZMETALL, 70 (2):5-12 (2017).
12. Alkan G, Yagmurlu B, Cakmakoglu S, Hertel T, Kaya Ş, Gronen L, Stopic S, Friedrich B, "Novel Approach for Enhanced Scandium and Titanium Leaching Efficiency from Bauxite Residue with Suppressed Silica Gel Formation", Scientific Reports, 8 (1):5676 (2018).
13. B. Yagmurlu CD, B. Friedrich, "Precipitation Trends of Scandium in Synthetic Red Mud Solutions with Different Precipitation Agents", Journal of Sustainable Metallurgy, 3 (1):90–98 (2017).
14. Yagmurlu B, Alkan G, Xakalashe B, Friedrich B, Stopic S, Dittrich C Combined SAF Smelting and Hydrometallurgical Treatment of Bauxite Residue for Enhanced Valuable Metal Recovery. In: ICSOBA 2017, Germany, 2017.

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