MSP-REFRAM

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Third workshop (matching policy/society, technology and market)

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Summary

Third workshop (matching policy/society, technology and market)

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REPORT ON THE THIRD WORKSHOP

(matching policy/society, technology and market)

MSP-REFRAM D 1.7

February 2017

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CONTENT

INTRODUCTION

The third workshop (WS3) within the MSP REFRAM-project was held in Brussels, Hotel Scandic Grand Place, on 28th of November 2016. Based on the results of the first and second workshops (on the state of the art & gaps and innovation potential), this third and last workshop analyzed the opportunities for developing new refractory metal value chains in Europe.

METHOD

The various stakeholders had the possibility to discuss the innovation pathways to change the current and future unbalances between EU reserves and demand assessed in Task 1.3.

Relevant experts were invited to the WS3 and were asked to make specific presentations related with WS3 object.

Finally, barriers and potential solutions regarding the proposed innovation pathways were discussed and potential solutions suggested.

AGENDA

<u>Monday 28th November</u>

9h-11h – Presentation of the innovation pathways in the refractory metals value chains

Tungsten: Pedro Acebes (CARTIF)

Tantalum and Niobium: Stéphane Bourg, Didier Hartmann (CEA) and Soraya Molinero (LGI)

Molybdenum: Xianfeng (MEFOS)

Rhenium: Witold Kurylak (IMN), Jason Yang (GTK)

Substitution : Paivi Kivikytö-Reponen (VTT)

11h-11h30 Coffee break

11h30-13h – Presentations of invited experts

A personal vision of hurdles and limitations to the development of secure industrial uses of refractory metals in the European Union, Patrice Christmann (Krysmine)

Policy and regulatory opportunities/obstacle for raw materials, Julien Schiettecatte, Atlantic Strategy Group

13h-14h Lunch

14h – 17h30 – Discussions and exchanges on the possible barriers and limitations to the innovation pathways in terms of regulations, policy…

Ana Diez de la Rosa, Jose F Diego Calvo (ADE)

Susanna Casanovas (Amphos 21)

SUMMARY: INNOVATION PATHWAYS IN THE REFRACTORY METALS VALUE CHAINS

Current and innovative processes were analyzed from policy/society, market and technology perspectives in order to identify the main barriers to their implementation in Europe. In this section a summary of main innovation pathways and potential barriers presented during the workshop and further developed in Deliverable 1.4 (Report on potential innovation pathways to balance demand and supply of refractory metals in the EU) is presented.

TUNGSTEN

China has most tungsten reserves in the world, 1.9 million metric tons, but notable deposits can also be found throughout Europe. Most of the companies that exploit tungsten mines in Europe extract the ore mineral and perform primary mineral processing to produce tungsten mineral concentrates which are mostly exported.

Many tungsten companies are now exploring the continent with the hope of finding valuable assets to help meet an increasing worldwide demand; however, existing dumps (tailings) are not currently exploited due to the high costs associated.

The estimated increases in primary mine supply are predicted to be outpaced by the use of secondary recycled tungsten raw materials in the next decade. Tungsten recycling is expected to keep growing at about 8% per year over the next five years, increasing global production of recycled tungsten materials from 23% of total supply in 2012 to 28% of global supply in 2018.

Europe has significant primary tungsten resource. The first action would be to this activity.

Second, as tungsten mines were exploited in the past in Europe, there could be an interest of valorizations the tailings, specifically when a high cut-off was applied at the time.

The third option is the recycling, with a focus on the scraps. The main regions for growth in tungsten recycling are most likely to be Europe and Asia, as collection programs for tungsten products are improved and construction of new tungsten recycling facilities are expected.

Main barriers for tungsten recovery are:

- The high melting point of Tungsten makes its recovery very difficult due to economic reasons (high associated energy cost).
- Classical European deposits such as the French of Anglade (Salau) or the Czech district of Krasno are not being investigated at this moment. Yxsjöberg´s deposit (Sweden) is being evaluated and there are no figures for its resources.
- Raw material procurement becomes more difficult, due to lack of investments in new mines and reduced secondary raw material availability.
- The majority of Tungsten primary raw material reserves are located in China or “politically instable “ regions. China is the major producer of primary Tungsten.
- Lack of suitable recycling technologies.

Because of the unique combination of properties of tungsten, there are limited options for substitution in many applications, especially where optimum performance is required at high temperatures.

Potential substitutes for cemented tungsten carbides or hard metals include cemented carbides based on molybdenum carbide and titanium carbide, ceramics, ceramic- metallic composites (cermets), diamond tools, and tool steels (EC, 2010). Potential substitutes for other applications are:

- molybdenum can replace tungsten in certain mill products;
- molybdenum steels can substitute for tungsten steels for some applications;
- lighting based on compact fluorescent lamps, low energy halogen light bulbs and light-emitting diodes (LEDs) are gradually replacing the traditional use of tungsten in light bulb filaments as inefficient incandescent light bulbs are being phased out;
- depleted uranium can be used in weights and counterweights instead of tungsten alloys or unalloyed tungsten, but generally it has been tungsten that has substituteddepleted uranium for health and environmental reasons;
- depleted uranium alloys can also be used in armour piercing projectiles instead of cemented tungsten carbides or tungsten alloys, with the same comment than above.

NIOBIUM AND TANTALUM

TANTALUM

Globally, it has been estimated that 10-20 % of the global Tantalum supply is produced from tin slags and 20-30% from different types of manufacturing and End-of-Life scrap. According to the "Tantalum-Niobium International Study Center", the production from secondary resources has grown considerably between 2008 and 2012. Due to reduction of tin mining, the most interesting sources are old slag dumps.

Based on the available information, potential tailings and slags can be found in Spain, Portugal, France, and UK (Tin belt reaching through these countries), but also in Germany and Czech Republic. In addition to mine waste areas, Ta can be found also from municipal waste landfills, industrial landfills (such as landfills of WEEE recycling companies) and from incineration slags. It has been estimated that about 5 % of WEEE ends up to municipal landfills or incineration plants. Because Ta containing components are mainly used in high-tech electronics, such as portable electronics, it is likely that the Ta concentrations in MSW landfills and slags are very low.

Other potential sources are scraps from manufacturing of Ta powders and ingots, manufacturing of Ta containing products as well as end-of-life scrap containing Ta. Although for example the largest capacitor manufacturers are situated in USA and Asia, there is still considerable manufacture of Ta containing products in Europe. These means that both manufacturing and end-of-life areavailable in Europe.

NIOBIUM

The Niobium world production in 2010 was 62,900 t in 2010, 92% of which coming from Brazil. Niobium does not occur as free element and commonly is grouped with Tantalum.

The highest potential for Niobium recovery in Europe is addressed to Greek and Macedonian sites. Buchim Mine's potential (Macedonia) high potential (up to 313,270 t) is linked to the mine waste dump (surface storage). Greek potential is much lower but still reaches a national average sum of 65,440 tones of Nb that may eventually be recovered.

INNOVATION POTENTIALS FOR NB AND TA

Innovation potential for Ta and Nb in Europe should focus on secondary resources. Currently, an overall Ta recycling rate of approximately 20% is reported which can be similar to the EU rate based on the production of synthetic concentrates (mainly HC Starck) and recycling of cutting tools and capacitors.

Innovation potentials are to be focused on:

1. Recovery from slags:
    - High grade tin slags
    - Copper smelting slags.
2. Recovery of low grade Nb as by-products
3. Recovery of Ta from alloy scrap
4. Recovery from tungsten carbide sludge

Innovative processes have been identified in both solvent extraction and pyrometallurgical processes.

MOLYBDENUM

In EU the production of Mo ores is very limited. Due to the sharp gap between local supply and consumption, Mo is imported, mainly in the form of primary ore, molybdenum oxides and metals. The obtained primary Mo ores are metallurgically processed by roasting, reduction, etc. to produce various intermediate products. The produced intermediate products are further metallurgically processed/manufactured to produce various end-user products (mainly Mo-containing steels and catalysts). These products after ending their lives are regarded as urban mines of molybdenum.

During mining and mineral processing, waste rock and tailings are generated; during metallurgical process, dust (such as steelmaking dust), slag (such as Mo-containing copper slag), etc. are generated as industrial residuals; during processing and manufacturing dust, mill scale, etc. are generated also as residuals.

These generated waste rock, tailings and industrial residuals are regarded as secondary mine of molybdenum. The secondary mine is believed to be partially recycled and the leftover being deposited as potential mines (such as historically dumped Mo-containing slag) for the future or lost in the environment forever. The molybdenum from urban mines is partially recycled and the leftover is either lost to the environment due to wearing, corrosion, discard, etc., or down-graded into other steels without using its Mo content.

The key facts regarding molybdenum production in the EU can be summarized as the following:

1) Production of Mo is mainly dependent on the primary Mo ore, which is largely imported from non-EU countries;
2) Oxidative roasting of primary Mo ore is an important technical step for producing technical grade MoO_3, which is an important intermediate product;
3) Molybdenum is largely used to produce steels and catalysts ;
4) Due to 3) mill scale and dust are regarded as an important secondary mine of molybdenum ;
5) Due to 3) steel scrap and spent catalysts are regarded as an important urban mine of molybdenum.

Main barriers (technological and non-technological) identified to increase Mo production in the EU are as follows:

1) Roasting of molybdenum ore: emission of sulfurous gas and dust to the environment.
2) Mo loss from the secondary mine: quite a large portion of Mo is lost or locked in the environment.
3) Mo loss from urban mine: lack of efficient sorting and collection infrastructure.

In summary, there are no technological barriers to recover Mo from various types of materials; however, some innovative technologies are difficult to be industrialized due to low economic incentives. New technological breakthrough may make a change for the future.

The low prices of Mo result in the recycling of Mo from secondary mine and urban mine being less competitive.

According to the reported deliverables on Mo, the critical transition steps to re-design the current value chain include the following aspects:

1) Zero hazardous emission: development of more environment-friendly process to replace the present oxidative roasting process. This may change the present Mo industrial layout in EU and increase its competitiveness.
2) More recovery: establishing more efficient sorting and collection infrastructure for EOL products. This will reduce the dependence of EU on Mo supply from non-EU countries.
3) Higher integration of the processes. This will increase the competitiveness the Mo industry in EU.
4) No wastes: Increasing the added value of the generated wastes by using them as by-products. This will increase the competitiveness and sustainability of the Mo industry in EU.

RHENIUM

About 8 t of Re are produced annually from primary resources in Poland which is the only EU country producing Re as by-product of the copper production process. Promoting primary Re production by the increase of the recovery of Re in mining and enrichment and in smelting and refining, meanwhile, reprocessing Re-containing secondary wastes (tailings, residues) could be significant innovation paths.

INNOVATION PATHS ON PROMOTION OF RE PRODUCTION FROM RECYCLING

Some 55-60 tons of Re are produced in the world of which the vast majority used in super-alloys, the remaining used in catalysts, medical anodes and filaments etc. For instance, in 2012, in the 54 t of Re production, 45 t (83.3%) were used in super-alloys for the aerospace and industrial gas turbine industry; 5 t (9.3%) were used in catalysts; and 4 t (7.4%) used in others.

The key to increase the recycling rate of Re is promoting the recycling of Re from super-alloys. Because Re occurs in small quantities in the super-alloys the energy use, greenhouse gas (GHG) emissions and economic cost associated with collecting, sorting, cleaning, and otherwise processing of the alloy scraps would be higher than most of other metals.

The following aspects would be important for implementation of a successful end-of-life recycling system of Re:

- Establishing database of Re containing product inventories, sales, product info of components, expected wastes (such as in the next 20 years, 40,000 aircrafts will come out of service according to a study)

- Promoting sorting logistics and collection efficiency of Re containing end-of-life products, and establishing a stable supply source
- Promoting pre-processing efficiency by using innovative and scale-up technologies
- Innovating processing technologies by taking account of economic cost and environmental impact
- Scale-up market access and have large companies, suppliers and specialized groups engaging in Re recycling
- Encouraging manufacturers to improve design of products taking account of easy disassembly, reuse and recycling.

INNOVATION PATHS ON PROMOTION OF NEW APPLICATIONS OF RE

Rhenium has a great innovative potential due to its application in numerous new products and materials. The following examples confirm that rhenium can present very high potential to be a metal applied in innovative solutions.

1) Address technological issues to increase the amount of rhenium-containing wastes coming from processing by large volume materials e.g. dross formed during superalloy smelting, scraped superalloy products and other wastes formed during superalloy products manufacturing which are recycled. Currently, rhenium is not recovered from such components. Moreover, there are not many companies in the world which are dealing with recycling of that metal. Nowadays, rhenium is recovered mainly from wastes formed during processing of superalloys of diameter ≤30 mm. Development of rhenium recovery method for materials of diameter >30 mm, which are not currently processed, will allow to increase ammonium perrhenate world production.

2) Development of new, ecological and innovative technologies for conversion of commercially prepared rhenium compounds (mainly ammonium perrhenate) to more technologically advanced and processed functional compounds, materials or components. Within this part it is proposed to manufacture numerous compounds, materials and composites for application in developing economic sectors using rhenium products, like:
    - armaments industry;
    - aviation;
    - pharmaceutical industry and medicine;
    - chemical industry, including in particular catalytic processes;

   as well as in economic sectors, where rhenium has never been applied:
    - drilling industry;
    - mining industry [2-5].

Innovative rhenium products include:

- electrochemical rhenium-nickel and rhenium-cobalt alloys containing tungsten and/or molybdenum;

- electrochemical rhenium-nickel and rhenium-cobalt coatings doped with tungsten and/or molybdenum;
- powders of rhenium and nonferrous metals;
- rhenium carbonyl and its derivatives – basic substrate for manufacturing of homogenous catalysts with rhenium as an active centre;
- homogenous and heterogenous rhenium catalysts;
- inorganic rhenium compounds with application properties to be used in many industrial branches.

3) Utilisation of rhenium superalloys contaning materials which are not currently processed due to the lack of appropriate technologies for production of ammonium perrrhenate and other rhenium compounds.
   Nowadays, recycling of rhenium from waste materials covers mainly spent catalysts, scrap from metallic rhenium production and wastes formed during mechanical processing of superalloy products. Only rhenium contained in catalysts is systematically recovered, but rhenium from this source is fully utilised for preparation of new catalysts and data covering production volume and recovery methods are not published.

   Defective and spent superalloys products are not processed due to lack of effective reprocessing method. Additionally, their smelting and manufacturing of new elements is often limited by strict regulations that are applied e.g. in aviation industry - the main recipient of superalloys. That new rhenium source may be exploited thanks to a technological innovation based on development of electrodigestion using symmetric alternating current with a very small frequency.

BARRIERS AND LIMITATIONS TO THE INNOVATION PATHWAYS

Potential barriers presented and discussed during the workshop as well as suggested potential solutions have been collected and classified in the following table:

METAL	BARRIER	POTENTIAL SOLUTIONS
Primary mining		
All	Long and complex permitting procedures with local administration, including land qualification uses and periods for public consultation, among others Differences between countries regarding permission procedures	Mining and metallurgical activities within the EU should be promoted and strengthened, e.g. incentives, taxes, etc. Same general rules for the EU could be useful EC should interfere if the regional or national administration does not make a decision.
	Legal frameworks are unstable (e.g. in Spain and France) so social pressure jointly with the lack of communication of the mining company can influence the final decision	Ecolabelling of minerals and metals should be developed to enhance the use of minerals and metals from mines and smelters that operate according to the best sustainability practices and report their sustainability performance ISO 26000, GRI-based sustainability reporting, among others, should be fostered by EU-policy and rewarded Mix of private and public (e.g. Finland) Communication, social awareness, transparency policies adopted by mining companies
	Lack of investigation of existing and/or new deposits in the EU	Update Prospecting Guides Develop the public 3D/ 4D geologic knowledge of the EU Variscan as a common good.
Tungsten	Accompanying metals in the W mines are not considered (except for gold) nor their quantities.	Elaboration of a database Higher integration of the processes to increase the competitiveness of EU industry
Molybdenum	Oxidative roasting of primary Mo ore has significant environmental impacts	More R&D is needed; pilot scale trials should be carried out to improve the economic, environmental and technological feasibilities of the process

METAL	BARRIER	POTENTIAL SOLUTIONS
Secondary resources (tailings and industrial waste)		
All	Tailings recovery from existing/old mines: even more difficult than new mines if they have been already restored as in new mines tailings are currently minimized.	Environmental studies The activity should solve instead of create an environmental problem to convince society.
	EU companies export their production due to economic reasons.	Mining and metallurgical activities within the EU should be promoted and strengthened, e.g. incentives, taxes, etc.
Tungsten	The high melting point of Tungsten makes its recovery very difficult due to economic reasons (high associated energy cost) Lack of suitable recycling technologies	More R&D and innovating technologies are needed to improve the economic, environmental and technological feasibilities of the recovery process
	Reduced secondary raw material availability.	Recovery of tailings and tungsten scraps
Tantalum - Niobium	Important secondary resources such as copper smelting slags are not fully recovered	More R&D is needed; pilot scale trials should be carried out for the recovery of different valuable metals from copper smelting slags.
	Scrap containing Ta is not recovered in the EU	Mining and metallurgical activities within the EU should be promoted and strengthened, e.g. incentives, taxes, etc.
Molybdenum	Low prices of Mo: important secondary resources (mill scale, dust) are not fully recovered for not being competitive	Higher integration of the processes and increase of the added value of generated wastes by using them as by-products with the aim to increase the competitiveness of EU industry

METAL	BARRIER	POTENTIAL SOLUTIONS
Secondary resources (urban mines)		
All	Product design that makes disassembly and material separation difficult or impossible.	Encouraging manufacturers to improve design of products taking account of easy disassembly, reuse and recycling Regulations, incentives for eco design
	Absence of recovery technologies for dismantling parts with refractory metal content (low metal contain and irregular shape)	Promoting pre-processing efficiency by using innovative and scale-up technologies.
	Target metals present in small quantities and their high dispersion in the waste generate high emissions and economic costs associated with their collection and sorting.	More efficient collection, sorting logistics and cleaning infrastructure for EoL products, establishing a stable supply source
	A lack of social and economic awareness of the loss of resources and the recycling potential	Raise awareness about the lower environmental and economic costs of metal recycling than those for primary resources
	Presence of “grey recycling”, the informal collection sector.	Regulations, incentives, enforcement
Molybdenum	Low prices of Mo: important urban mines (steel scrap, spent catalysts) are not fully recovered for not being competitive	More efficient collection, sorting logistics and cleaning infrastructure for EoL products, establishing a stable supply source
Rhenium	Recycling of superalloys and other metal containing wastes mostly takes place out of the EU	Scale-up market access and have large companies, suppliers and specialized groups engaging rhenium recovery
	Lack of effective logistic system of Re containing spent materials. They are not segregated, which hampers their further processing.	Establishing database of Re containing product inventories, sales, product info of components, expected wastes

METAL	BARRIER	POTENTIAL SOLUTIONS
		More efficient collection, sorting logistics and cleaning infrastructure for EoL products, establishing a stable supply source
	Rhenium superalloys containing materials are not currently processed due to the lack of appropriate technologies for production of ammonium perrhenate and other rhenium compounds.	More R&D and innovating technologies are needed; pilot scale trials should be carried out to verify the economic, environmental and technological feasibilities of the process