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◆ **WHITE PAPER** **2023-09-15**

First white paper on research and development needs of material availability in the field of hydrogen – availability of iridium

PREFACE

The following white paper is the first in a series on the topic of material availability in the field of hydrogen and the resulting necessary research and development needs. It starts by discussing the availability of iridium.

1 INTRODUCTION

Iridium belongs to the platinum group metals (PGM) and is mainly used as a catalyst component in chemical and electrochemical processes due to its properties (high melting point, corrosion- and acid-resistant, good electrical conductivity). Buyers are mainly found in the electrochemical and automotive sectors, where the precious metal is difficult to substitute due to its special properties. The use of iridium for hydrogen applications currently still accounts for a small part; however, it will increase greatly in the next few years with the planned market ramp-up (link to the development H_2 requirements of the industries in the NWR whitepaper).

Despite the variety of uses for iridium, its occurrence is very rare. This is partly because iridium is a by-product of platinum. Extraction currently takes place mainly in South Africa and Zimbabwe (90 per cent), with Russia and North America accounting for the rest. Since iridium is only a by-product of mining other metals and only accounts for about 4 per cent of platinum extraction, the supply is strongly linked to that of platinum. Currently, the annual amount of iridium extracted is about 8 to 9 t, which is significantly lower than the amount of platinum (190 t). Mining specifically for iridium is not advantageous due to the poor sales volume compared to platinum; moreover, an expansion of platinum mining is not expected in the next few years. In addition to the primary extraction of iridium, the use of recycled iridium is also possible and makes absolute sense in terms of the environment. However, only 25 per cent of the iridium used in industry is fed into secondary recycling. The reason for this is, on the one hand, the difficulty of separating the substance in applications with low iridium concentrations, which is not economical. On the other hand, recycling takes place primarily as a service business, where iridium from the company's own applications is recycled together with the customer. There is currently no independent recycling market for pure iridium.

It is becoming apparent that the increasing demand for materials is leading to a shortage of materials in the coming years, which can neither be absorbed by primary extraction nor by secondary recycling. In addition, the market for iridium is illiquid due to limited supply and the small number of market participants, making it susceptible to unforeseen price fluctuations. It would have a drastic impact on industrial processes in various areas – and especially on the market ramp-up in the fast-growing hydrogen sector – if the availability of the required quantities of iridium or the early development and scaling of corresponding alternatives cannot be guaranteed in the medium term.

2 APPLICATION IN PEM ELECTROLYSIS

A distinction can be made between two hydrogen electrolysis processes based on the material properties: electrolysis with precious metal electrodes (PGM) and electrolysis without precious metal electrodes (non-PGM). Proton exchange membrane (PEM) electrolysis belongs to the first category because the electrodes are coated with the precious metals platinum and iridium. It is considered a fast-growing technology, with estimates predicting that its market share will increase to 40 per cent by 2030. The fact that PEM electrolysis is gaining ground is due to its many advantages over alternative technologies, which make it particularly predestined for the production of green hydrogen: (1) dynamic operation at a wide current consumption range and at higher current densities; (2) fast heating and cooling times and in turn greater flexibility with the volatility of electricity generated from renewable energies; (3) hydrogen delivery at higher pressure; (4) low space requirement. In exceptional cases, iridium is also used in alkaline electrolysis, which is why alkaline electrolysis should also be considered in further developments.

In PEM electrolysis, the electrodes are separated by a proton exchange membrane, which enables operation without liquid electrolytes. The catalysts can enable higher current densities at moderate cell voltages by using precious metals. For these high current densities, this increases efficiency as well as durability compared to other catalysts that require higher cell voltages for such current densities. Iridium plays the role of a catalyst for the formation of oxygen in this process. This is a core process that ensures an efficient electrolysis process. Iridium is ideally suited for this process due to its electrochemical activity and stability. There are practically no other precious metals that can be used as a substitute for this. However, a reduction of the iridium coating is conceivable and already the subject of some research work. There is a need for further development in the direction of stability, long-term behaviour and increased performance. Depending on the manufacturer, iridium currently accounts for about 20 to 25 per cent of stack costs. Approximately 300–400 kg of iridium is required for each gigawatt of PEM electrolysis capacity using the current technologies. It has been forecast that electrolysis capacities of 170 GW will be needed worldwide by 2030. If we assume that 40 per cent of this is covered via PEM electrolysis, it would result in an iridium demand of about 27 t by 2030.

This demand cannot be met with the current levels of iridium extraction and recycling in the medium term. The quantities produced are currently used in other applications (medical technology, chemical catalysts, electronics industry, spark plugs and so on), so only a certain amount of iridium will be available for PEM electrolysis (probably about 12 t to 2030). This means that a significant price increase as well as distribution bottlenecks are to be expected, both of which would delay the envisaged market ramp-up worldwide.

3 NEED FOR RESEARCH AND RECOMMENDED COURSES OF ACTION

It is not possible to ramp up production for the reasons mentioned above, so there are two main levers to reduce and, in a best case scenario, avoid bottlenecks. These are increasing the recycling rate of iridium and reducing the iridium demand in the electrolysis system by increasing efficiency or using alternative technologies. Stockpiling iridium would have a distorting effect on the already illiquid market and is therefore out of the question.

3.1 EXPANSION OF RECYCLING CAPACITIES

Up to now, the recycling of iridium has been very costly and only economical to a limited extent, which explains the low recycling rate currently. Targeted financing for the development of a sustainable recycling strategy could accelerate the necessary development process, in which the economic aspects should be considered from the beginning. The United Kingdom has already implemented the corresponding support programmes, and in China these are currently being set up. In Germany, the iridium to be recycled currently belongs to a user and is not intended for the open market. For this reason, recycling from end-of-life materials that are not currently fed into secondary recycling should also be expanded. It means that about 200–300 kg of iridium per year could already be recovered through spark plugs and electrodes.

A balance of new PEM electrolysis plants (new iridium demand) and old/retrofitted plants (= new iridium supply from recycling) can be expected from 2030 onwards. In the meantime, strategies should be built up promptly through support programmes and funds for the recycling of iridium and implementation should be started without delay. Appropriate funding should be made available for this purpose to establish closed loop recycling, in addition to the provision of unused recycling streams (including cost–benefit analysis).

3.2 REDUCTION OF IRIDIUM DEMAND

The amount of iridium needed in PEM electrolysis must be reduced by a factor of 4 to avoid a material shortage in the coming years. At the same time, current density, temperature and stability must be increased. To this end, new electrode and cell concepts for catalysts and porous transport layers for high-performance PEM electrolysers with optimised iridium packing density must be researched (currents up to at least 4 A/cm2, approx. 0.1 gIr/kW by 2030, <0.1 gIr/kW by 2040) and rapidly scaled up. When it comes to PEM electrolysers, there are initial developments regarding low-load catalysts that have been successful, but there is a lack of testing and validation possibilities from material right through to system qualification.

In order to test the low-load PEM electrolysers, we advise setting up a top-runner programme in addition to a long-term research programme. This programme should support manufacturers who reduce the amounts of iridium they need (2nd generation material) into the application. Appropriate funding programmes for PEM electrolysers are also needed to develop and industrialise solutions with sustainable alternative materials. In this context, faster follow-up funding for the scientific projects and the transfer of the scientific results to industrial scale must be ensured. This should be meaningfully coupled with the question on materials with PFASs (per- and polyfluoroalkyl substances)[1] in order to generate synergies at an early stage in the development of the following generations of products.

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[1] NWR statement 'Effects of the ban on perfluorinated and polyfluorinated chemicals (PFAS)' from 1 February 2023.

3.3 FURTHER DEVELOPMENT OF ALTERNATIVE ELECTROLYSER CONCEPTS

There is currently no real alternative to iridium – only alloys, but they also consist partly of iridium. However, these alternatives are not yet mature enough for the hydrogen market to take off, and their use would only be conceivable in 10 to 15 years.

The funding of alkaline membrane technology as a transitional technology/project should continue. The focus should be placed more on the availability of raw materials. This calls for an approach that is open to all types of technology. This is also beneficial due to the issues with PFASs[2]. This will require an investment in fundamental research on degradation mechanisms of PGM and PGM-free catalysts under extreme conditions (1. AEM WE at pH 7; 2. PEM/AEM WE at higher flows and temperatures; 3. PEM/AEM WE operating with process/sea/brackish water). Joint activities by industry, research and politics are necessary in order to be able to provide solutions suitable for series production in a timely manner. This requires bringing the players together and promoting discussion and knowledge sharing.

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[2] See footnote 1.

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THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 26 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Katherina Reiche.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

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