

## MATERIALS RECOVERY ROBOTICS AND AUTOMATION

**ACADEMICS WORKING WITHIN THE BCSECM, HAVE COLLABORATED ON THE EU REMANENCE PROJECT, WHICH SHOWS HOW CRITICAL MATERIALS FROM COMPUTER HARD DISK DRIVES CAN BE ROBOTICALLY SORTED AND PROCESSED, LEADING TO THE RECOVERY OF RARE EARTH MAGNETIC MATERIAL. IN THE FUTURE, A SMARTER APPROACH WILL INVOLVE THE RECOVERY OF CRITICAL MATERIALS FROM LARGER COMPONENTS. THE AUTOMATED PROCESSING AND SORTING OF COMPLEX WASTE STREAMS WILL BE NECESSARY FOR SUCH PROCESSES TO BE SAFE AND ECONOMICAL WITHOUT ENDANGERING HUMAN HEALTH.**

Approaches from other research groups within the Birmingham Energy Institute can also be leveraged to solve the challenges around Strategic Elements & Critical Materials. Our academics research robotics for use in Nuclear Decommissioning. The RoMaNS (Robotic Manipulation for Nuclear Sort and Segregation) project will advance the state of the art in mixed autonomy for tele-manipulation, to solve a challenging and safety-critical 'sort and segregate' industrial problem, driven by urgent market and societal needs. Using machine vision and artificial intelligence, nuclear wastes can be processed safely, quickly and economically.

The University of Birmingham is also collaborating with the Manufacturing Technology Centre in Ansty Park, on developing new Industry 4.0 approaches to robotics and automation, designing an approach called 'Factory in a Box', where pre-packaged factories can be shipped to markets to assemble new technologies. To solve the problem of resource shortages at scale, one could imagine 'Factories in Boxes', which provide a packaged solution to 'unmanufacture' particular waste streams, to recover the valuable and rare materials they contain.



## LAW AND POLICY

Laws and regulations are vital for the future of strategic elements and critical materials. The role of environmental law is to determine how and why things get regulated, as well as reducing the burden on industry and adopting new approaches to regulation. From the environmental stand point, it is important to develop regulations encompassing waste materials, including waste minimisation, recycling and re-use and the introduction of product composition standards that restrict the use and transportation of hazardous materials. Previous work at the University of Birmingham has led to policy recommendations on the European Waste Catalogue.



# BIRMINGHAM CENTRE FOR STRATEGIC ELEMENTS AND CRITICAL MATERIALS

## RESEARCH HIGHLIGHTS



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# PLATINUM GROUP METALS (PGMS)

## PGM REDUCTION:

PLATINUM REDUCTION IN CATALYSIS IS BEING INVESTIGATED THROUGH MULTIPLE APPROACHES. NOVEL CORE-SHELL ARCHITECTURES ARE BEING DEVELOPED TO REDUCE THE OVERALL PLATINUM CONTENT USING ELECTRODEPOSITION TECHNIQUES.

Careful control of the process conditions enables the platinum concentration to be optimised for a given application. By using 'Click Chemistry' it has been possible to manufacture only the active form of chiral platinum and palladium catalysts, significantly reducing the waste produced in conventional processes.

Electrochemically produced nanoparticles can be used to make more efficient catalysts for use in applications such as fuel cells and electrolyzers by increasing the overall surface area. The development of nanomaterials will be key for designing next generation polymer electrolyte fuel cells for automotive applications.

## PGM REPLACEMENT:

A COMBINATION OF NANO-PATTERNING OF THE EARTH-ABUNDANT MATERIALS AND DOPING WITH FIRST ROW TRANSITION METALS, OR P-BLOCK NON-METALS TO IMPROVE THE CATALYTIC BEHAVIOUR AND PERFORMANCE.

Platinum can also be replaced by employing carbon structures doped with non-metallic and/or non-precious metal elements. We are investigating the development of a new solid oxide fuel cell concept to allow operation at temperatures between 100–350°C. This unique solid oxide fuel cell system will eliminate the need for platinum group metals in the electrode materials.

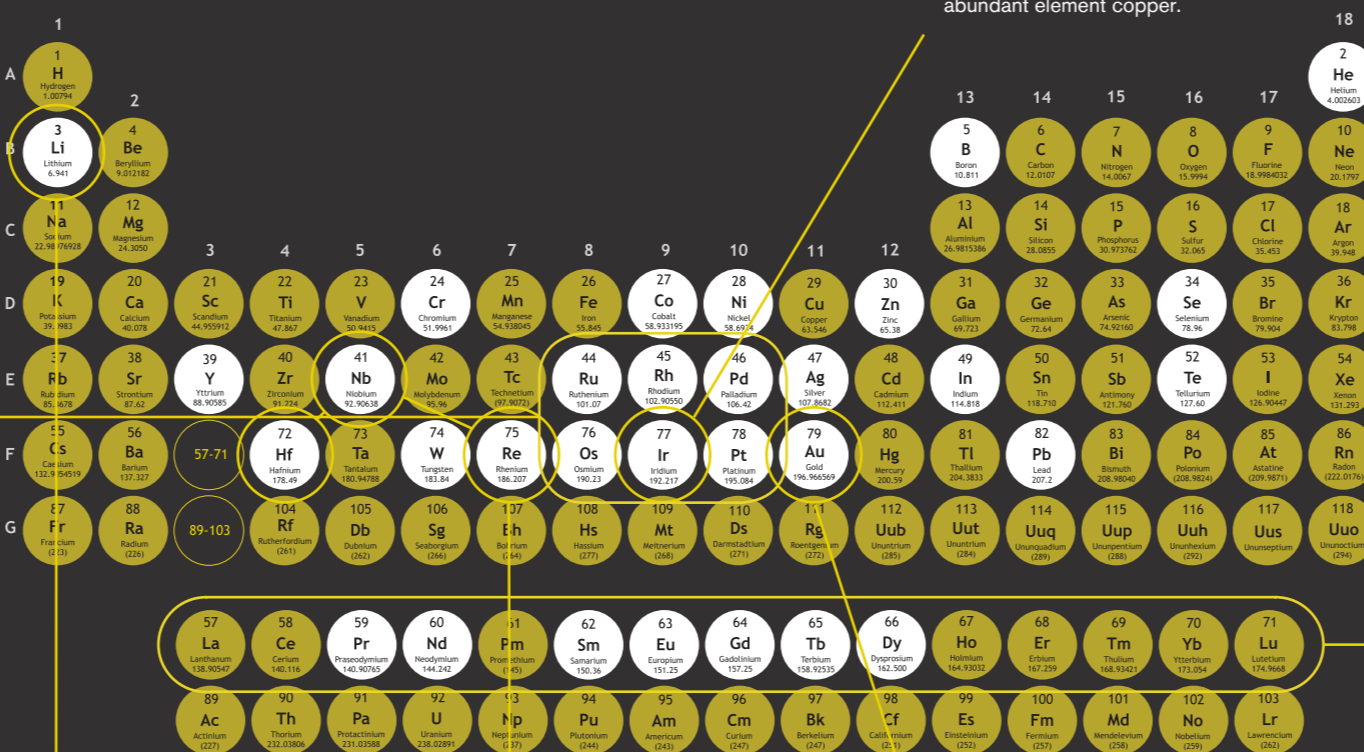
## PGM RECOVERY:

ELECTROCHEMICAL METHODS HAVE BEEN SHOWN TO BE EFFECTIVE FOR RECOVERY AND RECYCLING OF PRECIOUS METALS FROM PRINTED CIRCUIT BOARDS.

Bio-platinum and bio-palladium has been recovered and recycled from waste catalytic converters and utilised in the chemical production of fuels based on sugars that can be mixed with fossil fuels suited for transportation.

# PERIODIC TABLE OF THE ELEMENTS

AT THE BCSECM WE HAVE IDENTIFIED THE HIGHLIGHTED ELEMENTS AS BEING OF STRATEGIC IMPORTANCE AND/OR AT CRITICAL RISK OF SUPPLY. OUR SCIENTISTS ARE WORKING ON WAYS TO MITIGATE THE CRITICALITY OF THESE ELEMENTS AND MATERIALS THROUGH A RANGE OF APPROACHES INCLUDING REPLACEMENT, REGULATION, REDUCTION AND RECOVERY.



## IRIDIUM (Ir)

Iridium complexes can be made to emit any colour, for example they have been used in OLED smartphone displays as well as in high accuracy oxygen sensors. We have shown that iridium can be successfully replaced with complexes based on the much more abundant element copper.

# RARE EARTH ELEMENTS (REES)

## REE REDUCTION:

A NOVEL HYDROGEN DUCTILISATION PROCESS (HYDP) HAS BEEN DEVELOPED (PATENT PENDING) WHICH ALLOWS FOR ROOM TEMPERATURE DEFORMATION, SHAPING AND COMPRESSION OF SOLID NEODYMIUM–IRON–BORON ALLOYS.

This process should lead to the production of anisotropic magnetic material at a low cost without the typical material losses associated with shaping and machining of sintered compacts.

## REE REPLACEMENT:

REPLACEMENT OF RARE EARTHS IN ENERGY CONVERSION DEVICES SUCH AS FUEL CELLS IS BEING EFFECTED THROUGH SUBSTITUTION OF ELEMENTS SUCH AS LANTHANUM, GADOLINIUM, SAMARIUM AND PRASEODYMIUM WITH ALKALINE EARTHS (CALCIUM, STRONTIUM, BARIUM).

These alkaline earth containing compounds are being stabilised through the introduction of oxyanions, eliminating the need for rare earths.

## REE RECOVERY:

THE MAGNETIC MATERIALS GROUP HAVE BEEN WORKING ON THE RECOVERY AND REPROCESSING OF SINTERED NEODYMIUM–IRON–BORON MAGNETS FROM END-OF-LIFE PRODUCTS SUCH AS HARD DISK DRIVES, LOUDSPEAKERS AND DRIVE MOTORS.

By utilising hydrogen as a processing tool it is possible to break the recovered magnets down to a coarse, friable powder which can be mechanically liberated from the discarded products. Sieving with mechanical agitation has been shown to be an efficient route to remove virtually all of the impurities to make the powder suitable for reprocessing into new cast alloys, new sintered magnets and also bonded magnets. Novel processing routes have been adopted to remove selectively the oxidised components of the recovered powder in an attempt to enhance the magnetic properties.

Novel processes and systems have been developed where bacteria can be used to recover and extract heavy metals from waste feeds, nuclear waste treatment and for hydrogen production from food waste. We have shown that recovery of rare earth elements from mine tailings can be performed successfully by placing bacteria on a sponge and feeding it with a solution of metal tailings and phosphates. The bacteria convert the mixture into Nd phosphate, which can be extracted for use as a NdPO<sub>4</sub> catalyst or leached to produce Nd-metal for alloy production. This process has also been adjusted to separate Nd from the radioactive elements uranium and thorium, which are also found in mine tailings.



## LITHIUM (Li)

A novel bioleaching technique has been developed in order to recover lithium from kaolin waste. The substitution and replacement of strategic elements and critical materials in batteries and fuel cells has been investigated for both the electrodes and electrolytes. For batteries the main focus has been on replacing lithium to reduce the criticality of these applications by implementing new sodium-ion and potassium-ion energy storage systems.

As the number of Electric Vehicles on Britain's roads increases, the challenges of lithium supply will place increasing pressure on automotive supply chains. Our academics are working on techniques for recycling Electric Vehicle batteries at the end of life.

## HEAVY TRANSITION ELEMENTS

High temperature superalloys in aerospace jet engine technology use expensive elements such as rhenium, niobium and hafnium. We are utilising advanced modelling techniques to reduce our reliance on these elements in nickel-superalloys whilst maintaining their ability to withstand extreme operating conditions.

## GOLD (Au)

There are many applications where molecular synthesis and catalysis uses precious metals such as gold. The development of novel and more efficient methods for synthesis reduces the steps and processing required to access targets and leads to a more sustainable and cost-effective supply chain. This work expands into the field of metal-sustainability, exploring catalyst design to enhance the reactivity, selectivity and recyclability of catalysts and in replacing precious metals with more abundant, less critical materials.

