

## Brief information about the project

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| Name of the project           | AP27511091 «Advanced mechanisms in bimetallic catalyst electrodeposition from deep eutectic solvents»                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Relevance                     | Despite growing interest in DES as environmentally friendly and versatile electrolytes, there is limited research on the nucleation mechanisms of bimetallic deposition in these systems. This project aims to address this knowledge gap by systematically investigating the correlation between nucleation kinetics and deposit morphology. Understanding these mechanisms is crucial for optimising catalyst structure and achieving superior performance in eCO <sub>2</sub> RR. By addressing HER suppression, enhancing catalyst durability, and improving selectivity, this work seeks to establish a robust framework for designing next-generation eCO <sub>2</sub> RR catalysts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Purpose                       | Enhancement of selectivity and stability of copper catalysts modified with indium for electrochemical reduction of carbon dioxide (eCO <sub>2</sub> RR) through comprehensive investigation of kinetics and mechanisms during the electrochemical nucleation stage of Cu-In bimetallic catalysts from deep eutectic solvents (DESs). Adaptation and refinement of existing models of electrochemical nucleation, taking into account the characteristics of deep eutectic solvents.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Objectives                    | <ol style="list-style-type: none"> <li>1. Analysis of the electrochemical reduction kinetics for Cu-In bimetallic catalysts obtained from a choline chloride ethylene glycol deep eutectic solvent. Determination of the electrochemical nucleation mechanism and its kinetic parameters to enable precise regulation of nanostructure size and configuration.</li> <li>2. Establishment of pivotal correlations between electrochemical nucleation parameters and grain radius in core-shell type catalysts.</li> <li>3. Evaluation of the electrochemical surface area of copper catalysts modified with indium, produced via electrochemical synthesis. Investigation of Cu-In catalyst sensitivity and selectivity towards C<sub>2</sub> products during the eCO<sub>2</sub>RR.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Expected and achieved results | <ol style="list-style-type: none"> <li>1. The electrochemical nucleation mechanism for Cu-In bimetallic catalysts synthesised from deep eutectic solvents will be elucidated, and the kinetic parameters will be determined. These findings are anticipated to facilitate precise regulation of nanostructure size, configuration, and phase formation during electrodeposition.</li> <li>2. Correlations between nucleation kinetics and grain radius in core-shell type catalysts will be established.</li> <li>3. The electrochemical active surface area (EACSA) of Cu-In catalysts will be evaluated, and their performance in eCO<sub>2</sub>RR will be investigated. High sensitivity and selectivity towards C<sub>2</sub> products are anticipated, providing critical insights into the influence of composition and structure on catalytic efficiency.</li> </ol> <p>Also, publication of following articles are expected:</p> <ul style="list-style-type: none"> <li>- at least <b>2 (two) articles</b> and (or) reviews in peer-reviewed scientific publications in the scientific direction of the project, indexed in Science Citation Index Expanded and included in the 1st (first), 2nd (second) or 3rd (third) quartile of the impact factor in the Web of Science database and (or) having a CiteScore <b>percentile of at least 50</b> (fifty) in the <b>Scopus</b> database;</li> </ul> |

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|                                                                                                                                    | - at least <b>2 (two) articles</b> or review in a peer-reviewed foreign or domestic publication recommended from lists 1 and 2 of the <b>KOKNVO</b> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles | <ol style="list-style-type: none"> <li>1. Avchukir Khaisa – the project leader-supervisor, PhD, leading scientist.<br/>Web of Science Researcher ID: P-5738-2017,<br/><a href="https://www.webofscience.com/wos/author/record/P-5738-2017">https://www.webofscience.com/wos/author/record/P-5738-2017</a><br/>Scopus ID: 57207207777,<br/><a href="https://www.scopus.com/authid/detail.uri?authorId=57207207777">https://www.scopus.com/authid/detail.uri?authorId=57207207777</a><br/>ORCID: 0000-0001-6612-0775<br/><a href="https://orcid.org/0000-0001-6612-0775">https://orcid.org/0000-0001-6612-0775</a></li> <li>2. Rakhymbay Gulmira – PhD, associate professor.<br/>Web of Science Researcher ID: A-5356-2016,<br/><a href="https://www.webofscience.com/wos/author/record/825115">https://www.webofscience.com/wos/author/record/825115</a><br/>Scopus ID: 56436642400,<br/><a href="https://www.scopus.com/authid/detail.uri?authorId=56436642400">https://www.scopus.com/authid/detail.uri?authorId=56436642400</a><br/>ORCID ID 0000-0002-8814-9752.<br/><a href="https://orcid.org/0000-0002-8814-9752">https://orcid.org/0000-0002-8814-9752</a></li> <li>3. Bekey Akbayan – PhD student, researcher.<br/>Web of Science Researcher ID: JCV-9290-2023<br/><a href="https://www.webofscience.com/wos/author/record/48777556">https://www.webofscience.com/wos/author/record/48777556</a><br/>Scopus ID: 58538083500<br/><a href="https://www.scopus.com/authid/detail.uri?authorId=58538083500">https://www.scopus.com/authid/detail.uri?authorId=58538083500</a><br/>ORCID: 0009-0002-2333-1761</li> <li>4. Manarbek Magrife – junior researcher.<br/>ORCID: 0009-0004-5169-4994</li> <li>5. Kudaibergen Olzhas – junior researcher.</li> <li>6. Bolat Shakura – junior researcher.</li> </ol> |
| Usage                                                                                                                              | The project results can be used for the development of highly efficient catalysts for the electrochemical conversion of CO <sub>2</sub> into valuable chemical products and fuels. The knowledge gained on nucleation mechanisms and structure formation will enable optimization of electrodeposition processes. In addition, the developed approaches can be applied to create stable and selective catalytic systems for green energy and carbon footprint reduction.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Priority compared to real-world alternatives                                                                                       | The project has a significant advantage over existing analogues, as, unlike most studies focused on catalyst composition and overall performance, it is aimed at a fundamental understanding of electrochemical nucleation and phase formation mechanisms in deep eutectic solvents. In current research, the main focus is on surface modification and composition of Cu-based catalysts, while the relationship between nucleation kinetics, morphology, and selectivity remains insufficiently explored. Furthermore, the use of deep eutectic solvents as both a synthesis and reaction medium represents a more environmentally friendly and promising alternative to conventional electrolytes, enhancing the scientific novelty and competitiveness of the project.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| List of publications with links to them                                                                                            | <ol style="list-style-type: none"> <li>1. Manarbek Magrife, Ainaz Abildina, and Khaisa Avchukir. "Potentiostatic Electrodeposition of Copper from 1-Butyl-3-Methylimidazolium Bis (trifluoromethylsulfonyl) Imide Ionic Liquid." <i>Electrochemical Society Meeting Abstracts</i> 248. No. 22. The Electrochemical Society, Inc., 2025. DOI: 10.1149/MA2025-02221282mtgabs</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

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| Patents | — |
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