Institute of Solid State Physics Partner Portrait

CO_2EXIDE – CO_2-based electrosynthesis of ethylene oxide

Partner portrait and research highlights

Click here to view the CO2EXIDE ISSP's partner film

The role of the Institute of Solid State Physics (ISSP UL) in the project is manyfold. Activities that ISSP is engaged in include:

a) to create an alternative structure of the cathode (graphene sheets coated with copper nanocrystals) for electrocatalytic reduction of CO2 to ethylene;

b) to perform theoretical calculations from the first principles of the graphene sheet modified with copper atom clusters;

c) to adjust electrochemical cell with FTIR spectrometer to monitor the adsorption of CO2 on copper electrode and detect reduction products;

d) synthesize SPEEK polymer membrane that is compatible with the commercial material and in composite with ion liquid stimulates the adsorption of the CO2 on the copper electrode.

Research Results

a) ISSP designed and tested an alternative structure of the cathode for electrocatalytic reduction of carbon dioxide, based on copper–coated graphene sheet stacks (GSS) integrated with carbon substrate (Fig. 1). Electrochemical deposition of copper nano-crystals was applied to cover GSS material integrated with carbon paper substrate. Electrocatalytic CO_2 reforming to ethylene with such electrode under low current conditions has been experimentally proven with highest Faraday efficiency – 27%.

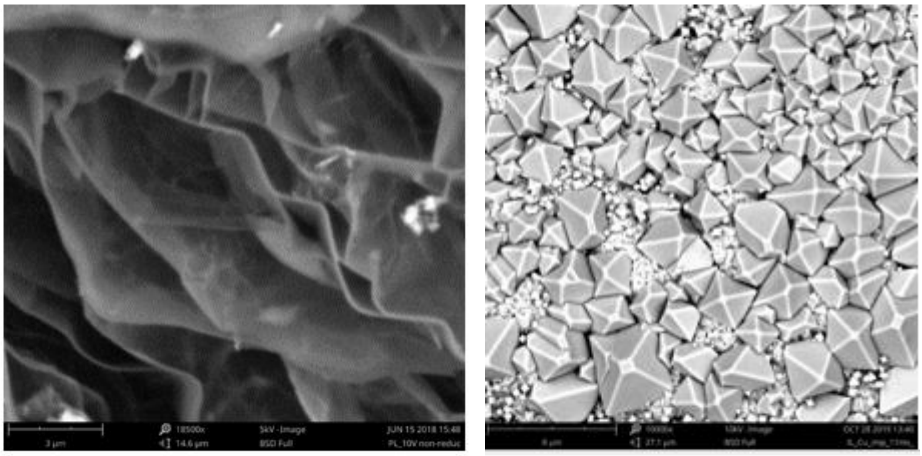


Figure 1. Graphene sheets (left) and copper nano-crystals coated on GSS/carbon paper (right).

b) ISSP also performed theoretical calculations from the first principles of the graphene sheet modified with copper atom clusters (Fig. 2). Our calculations predict increased adsorption energy of CO_2 molecules and CH_2 counterparts placed atop of Cu-decorated graphene comparing to adsorption energy at pristine transition metal surfaces. Atomic configuration of the most selective toward CO_2 reduction reaction nanostructured catalyst is suggested. The CH_2-CH_2 dimerization reaction is responsible for the C_2H_4 evolution. The lowest dimerization barrier can be predicted for the pristine graphene due to the lowest adsorption energy, meaning that the whole CO_2 reduction reaction taking place at the grain boundary of Cu_n-graphene nanocluster may lead to improved selectivity to ethylene. This approach can be applied to any activated carbon catalyst support, as it is also based on graphene-type structural elements.

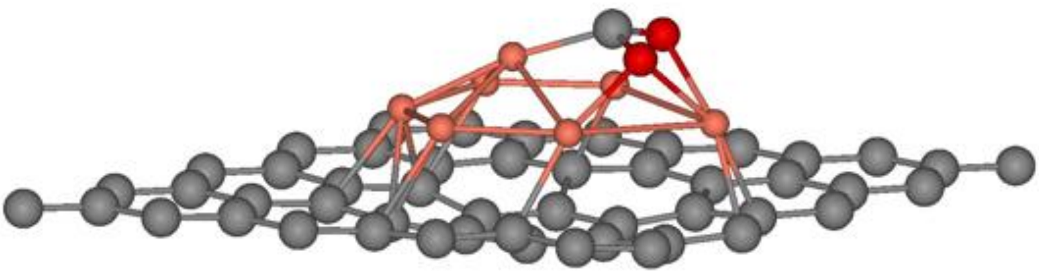
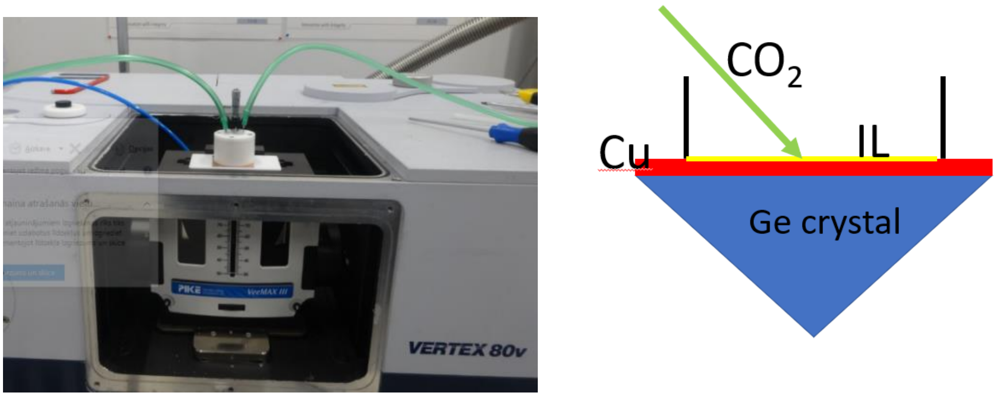


Figure 2. Schematic representation of the most energetically favourable adsorption position of CO_2 (top) of Cu_7/graphene nanostructure. Grey balls stand for carbon atoms, orange for copper, while red balls are oxygens.

c) Work was performed on an electrolysis cell coupled with FTIR spectrometer both indirectly by a gas cell and directly on the ATR crystal to monitor CO_2 adsorption and reduction processes on copper catalyst-based electrodes (Fig. 3a). An increase of adsorption of CO_2 on copper electrode surface was detected in presence of an ionic liquid IL (Fig. 3b). In the future, the graphene monolayer will be grown on a polished Ge single crystal sheet with thin layer of copper electrode and applied as a cathode for an electrolysis cell mounted above ATR crystal. If the vibration bands of CH_2 will appear in the FTIR spectrum together with ethylene C_2H_4 absorption bands, then we will have direct proof that the experiment coincides with the theoretically calculated model.



(a) (b)

Figure 3. FTIR spectrometer with electrolysis cell (a) and CO_2 adsorption on copper Cu electrode coated with ionic liquid IL (b).

d) Different aspects of self-synthesized polymer SPEEK membranes were research and discussed. It was shown that it is possible to prepare membranes as SPEEK composites with ionic liquids and zirconium oxide particles which allows electrolysis cell to work at higher temperatures. Research of SPEEK membrane was made in an electrolysis cell and found similar performance at average currents but more pronounced curvature at high currents compared to commercial Nafion membranes (Fig. 4).

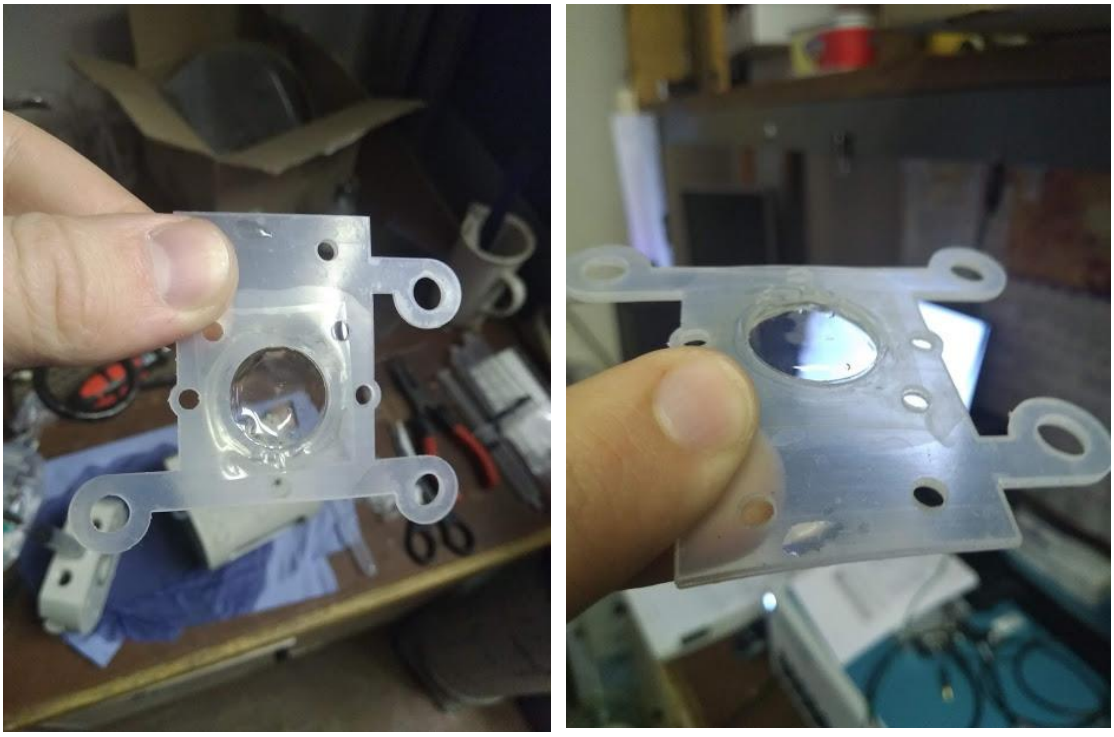


Figure 4. SPEEK membrane (area 3.4 cm^2) performance in electrolysis cell with GDL/GSS/Cu cathode, Pt anode, 0.5M $KHCO_3$ electrolyte at 1.5 V and 700 mA.

The Institute of Solid State Physics, University of Latvia (ISSP UL) is an internationally recognized leader in materials science and cross-disciplinary topics, conducting competitive research, educating students and offering innovative solutions for industrial needs. Its scientific competitiveness as well as its research and innovation ecosystem is enhanced through the Centre of Excellence in Advanced Material Research and Technology Transfer CAMART2 project. ISSP UL is a National Excellence centre in Materials science in Latvia with over 40 years of experience in fields like Photonics and Electronics, Material Modelling and Design, Materials for Energy Storage and Harvesting, Nanomaterials and Ceramics, and Thin films and Coatings. With over 230 employees and over 100 PhDs ISSP is leading industry partner in R&D actions for industry in Latvia. Institute is part of large scientific actions as EUROfusion, EPIC, Hydrogen Europe – through Latvian Hydrogen association, KET centers, Latvian IT cluster, Baltic Photonics Cluster etc. ISSP UL cooperates with more than 100 scientific institutions around the world, developing an average of 50 scientific projects per year. ISSP UL actively cooperates with international scientific organizations and universities to raise the qualification of both students and scientists as well as to attract entrepreneurs and investors.

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