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Deposited thin-film nanoelectrocatalysts of non-noble metals for co-capture of CO_2 and reduction of nitrates

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INTRODUCTION & AIM

The co-electrolysis of nitrate and CO_2 can contribute to urea production with low carbon-oxide emission rate, and at the same time can reduce NO_3^- to extremely low permissible concentrations. The synthesis of thin-layer nanoelectrocatalysts containing transition-metal nanoparticles is a promising venture. The study proposes the use of precipitated electrocatalysts from base metals. Such a method makes it possible to obtain an electrocatalysts selective to the reduction reaction of CO_2 or NO_3^-, and their joint reduction product is urea. The electrocatalysts coating should firmly bind C-N, and can proceed with the formation of intermediate compounds (such as $*CONH_2$) and others.

The unique electronic structure of transition metals allows them to be active catalysts in the co-reduction reaction of nitrate and carbon dioxide.

The aim of the study was to create a thin-layer electrocatalysts that would be effective in the reaction of combined reduction of nitrite ions and CO_2 to produce urea.

METHOD

Method of synthesis of catalysts

electrodeposition at direct current or potential

Characterization of synthesized catalysts

- Scanning Electron Microscopy (SEM)
- Measurement of polarization curves

Electrodes

- Ag/C and Fe/C – work electrode
- Pt plate – counter electrode
- Ag/AgCl – reference electrode

Formation of two products :

Overall: $CO_2 + 2NO_3^- + 3H_2O \rightarrow CO(NH_2)_2 + 4O_2 + 2OH^-$

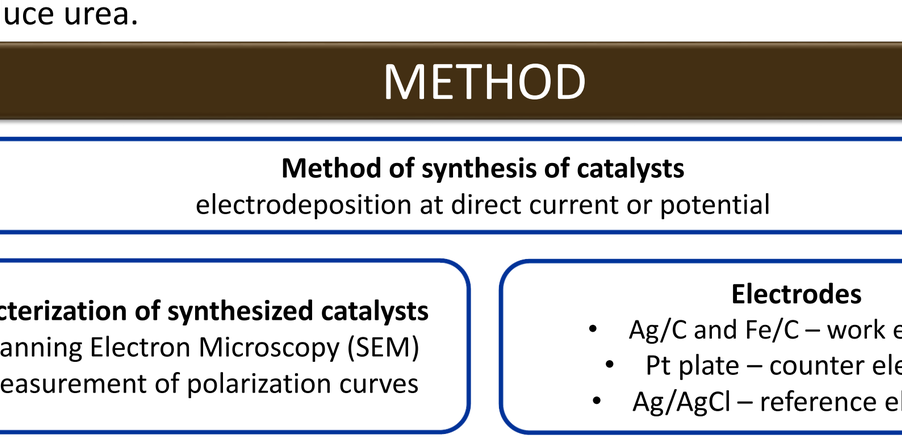
Step 1: $NO_3^- + 2H_2O \rightarrow \mathbf{NH_3} + 2O_2 + OH^-$

Step 2: $2\ NH_3 + CO_2 \rightarrow \mathbf{CO(NH_2)_2} + H_2O$

1. Determination of urea

HPLC, High performance liquid chromatography

2. Determination of ammonia



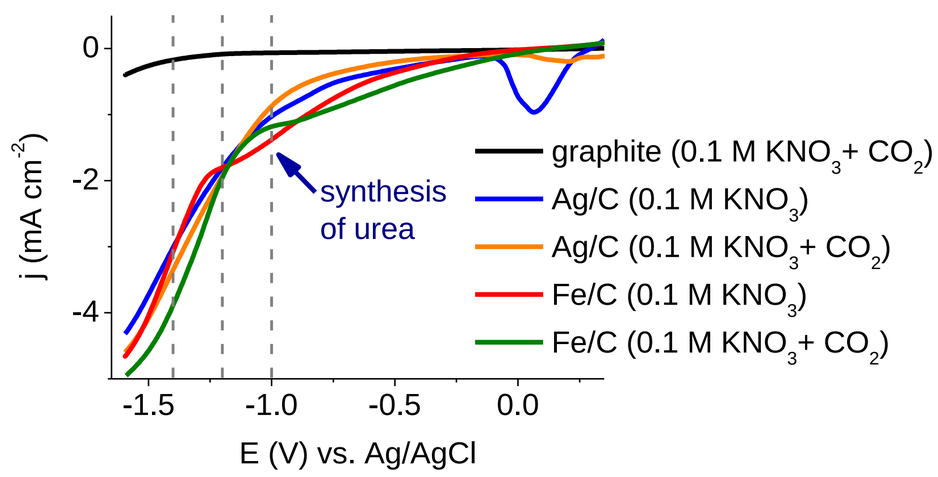
Calibration curves of UV-vis spectroscopy for determining the concentration of ammonia and the calibration equation of a straight line for calculating the concentration of ammonia [1]

Faradaic efficiency

- $n(NH_3)$ denotes the amount (mol) of NH_3
- F is the Faradaic constant (96,485 C mol^{-1})
- Q is the total charge passed through the electrode
- 8 is the number of electron (n) transfers required to form 1 mol of ammonia

$$FE(NH_3) = \frac{8 \times F \times n(NH_3)}{Q}$$

RESULTS & DISCUSSION



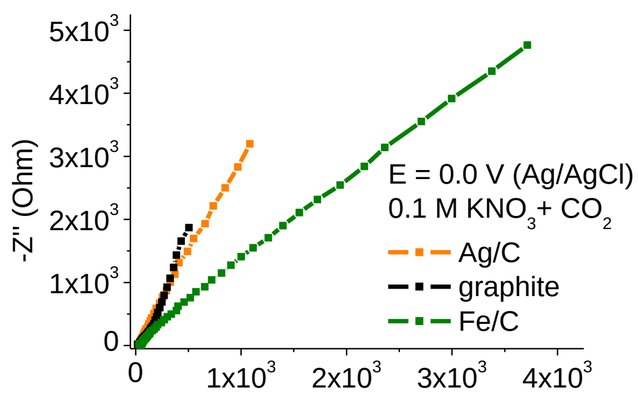
Cathode: $CO_2+2NO_3^-+18H^++16e^- \rightarrow CO(NH_2)_2+7H_2O$, E = 0.811 V (1)

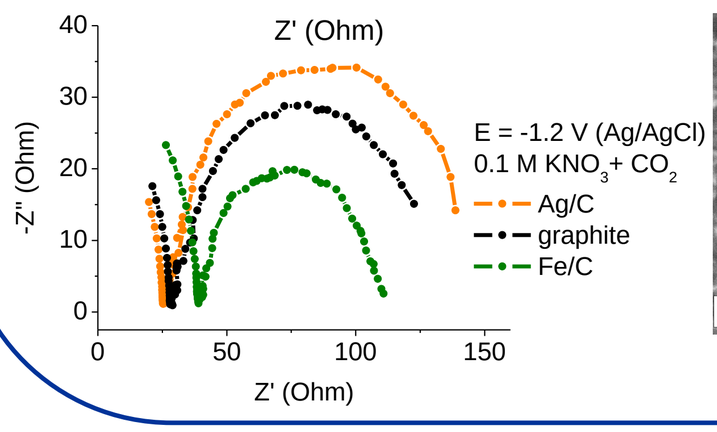
Anode: $8H_2O \rightarrow 4O_2+16H^++16e^-$, E = 1.23 V (2)

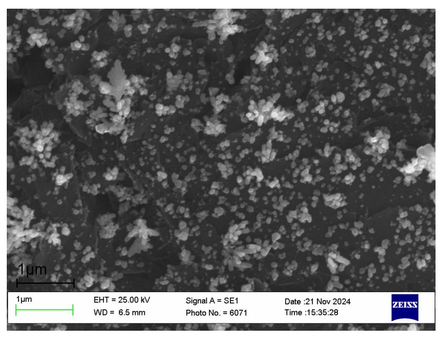
Overall: $CO_2+2NO_3^-+2H^++H_2O \rightarrow CO(NH_2)_2+4O_2$, E = -0.419 V (3)

[2]

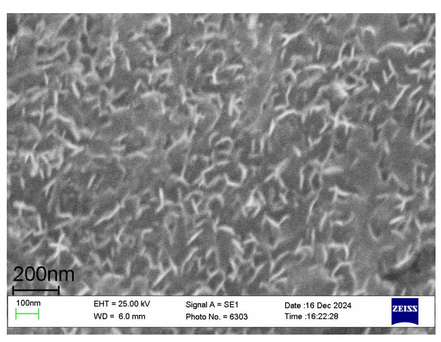
Electrochemical impedance spectroscopy







Ag/C



Fe/C

CONCLUSION

- The choice of metal or different combinations of components in bimetallic catalysts, as well as exploring the conditions of electrochemical synthesis, may allow us to improve the kinetics of the process and increase the selectivity of the process.
- The synthesis of urea is accompanied by the process of producing ammonia, where the Faraday efficiency of the latter is up to 14.5% for Ag/C and up to 33.0% for Fe/C.
- The selected metals can potentially be used for the synthesis of catalysts for the combined reduction of NO_3^- and CO_2.

FUTURE WORK / REFERENCES

1. Kuznetsova I., Kultin D., Lebedeva O., Nesterenko S., Murashova E., Kustov L. *Int. J. Mol. Sci.* **2025**; 26 (13), 1650.
2. Zhao Q., Zhang Y., Cao D., Shao, M. *Curr. Opin. Electrochem*. **2024**; 101479.

Acknowledgments