INVESTIGATIONS OF HYDROGEN PERMEABILITY OF NICKEL CAPILLARIES

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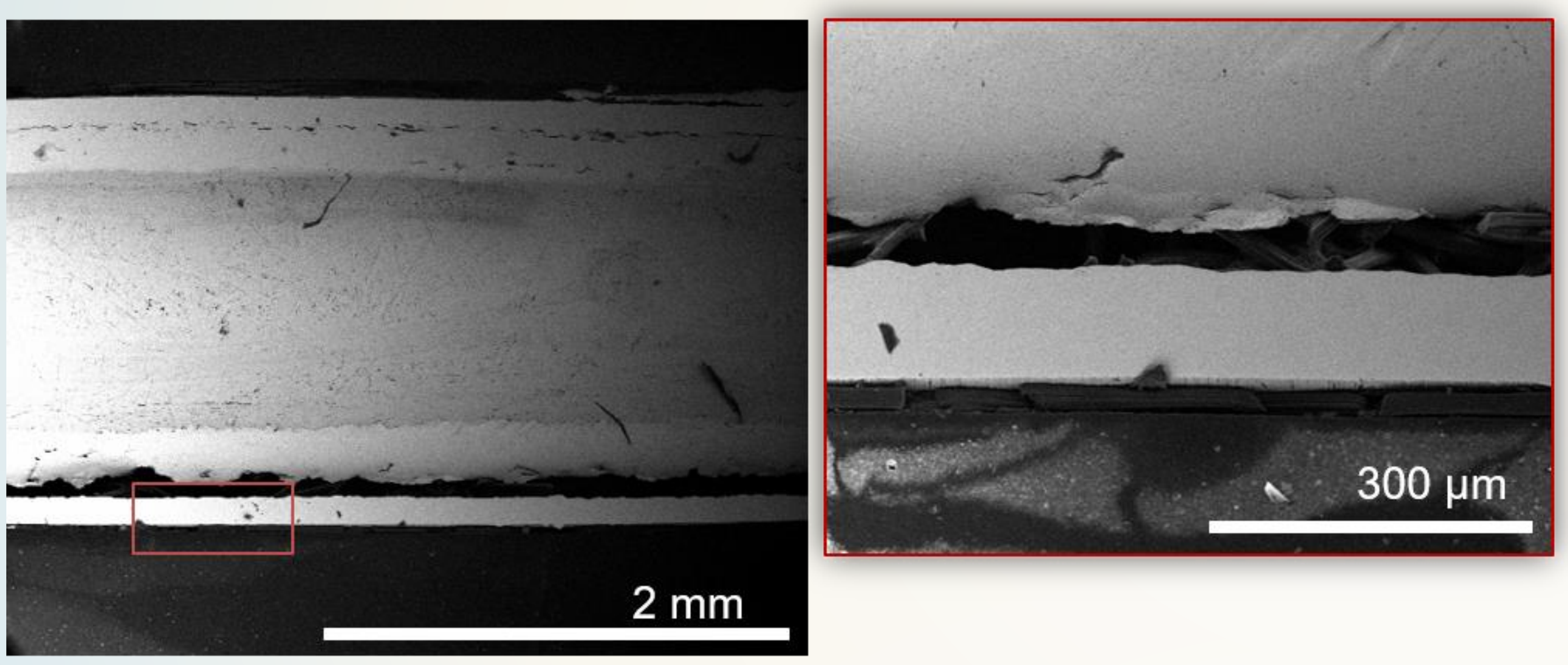
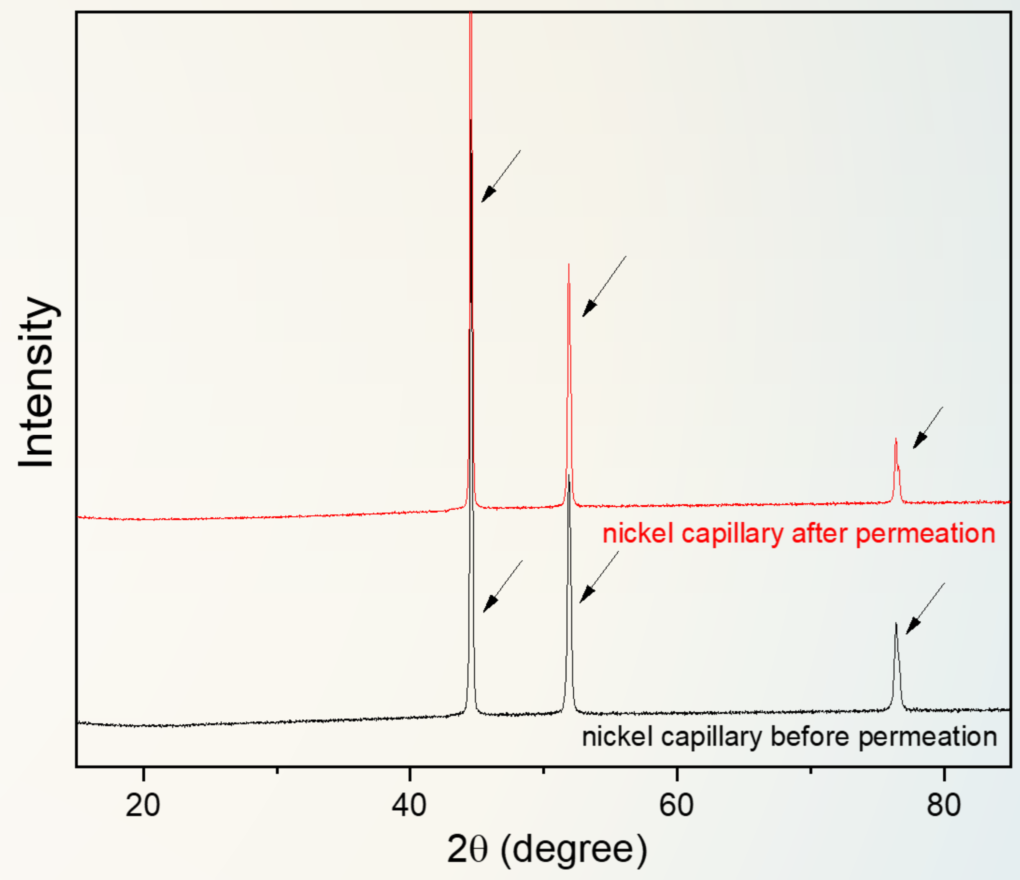
Introduction

One of the global problems of our time is ecology; environmental pollution caused by the growing number of emissions from the combustion of hydrocarbon fuels, including vehicles with an internal combustion engine, which is growing every year . One of the promising directions in this regard is the transfer of transport to hydrogen-oxygen fuel cells, which effectively convert the chemical energy of hydrogen into electrical energy, releasing only water vapor into the atmosphere. At present, fuel cells with a proton exchange membrane (Proton Exchange Membrane fuel cell, PEMFC) are the most promising for transport. However, their application requires the use of ultrapure hydrogen, since even small amounts of CO (at the level of several ppm) in hydrogen, usually obtained by reforming hydrocarbons, poison the electrocatalysts and reduce the efficiency of the fuel cell. The solution to this problem can be the production of ultrapure hydrogen using hydrogen-selective membranes.

This work is devoted to the study of the transport characteristics of nickel hydrogen-selective membranes (nickel industrial capillaries of various thicknesses). In this work, the hydrogen permeability of nickel capillaries of various thicknesses was measured; studies of the mechanism of hydrogen transport through nickel capillaries were carried out using computer simulation.

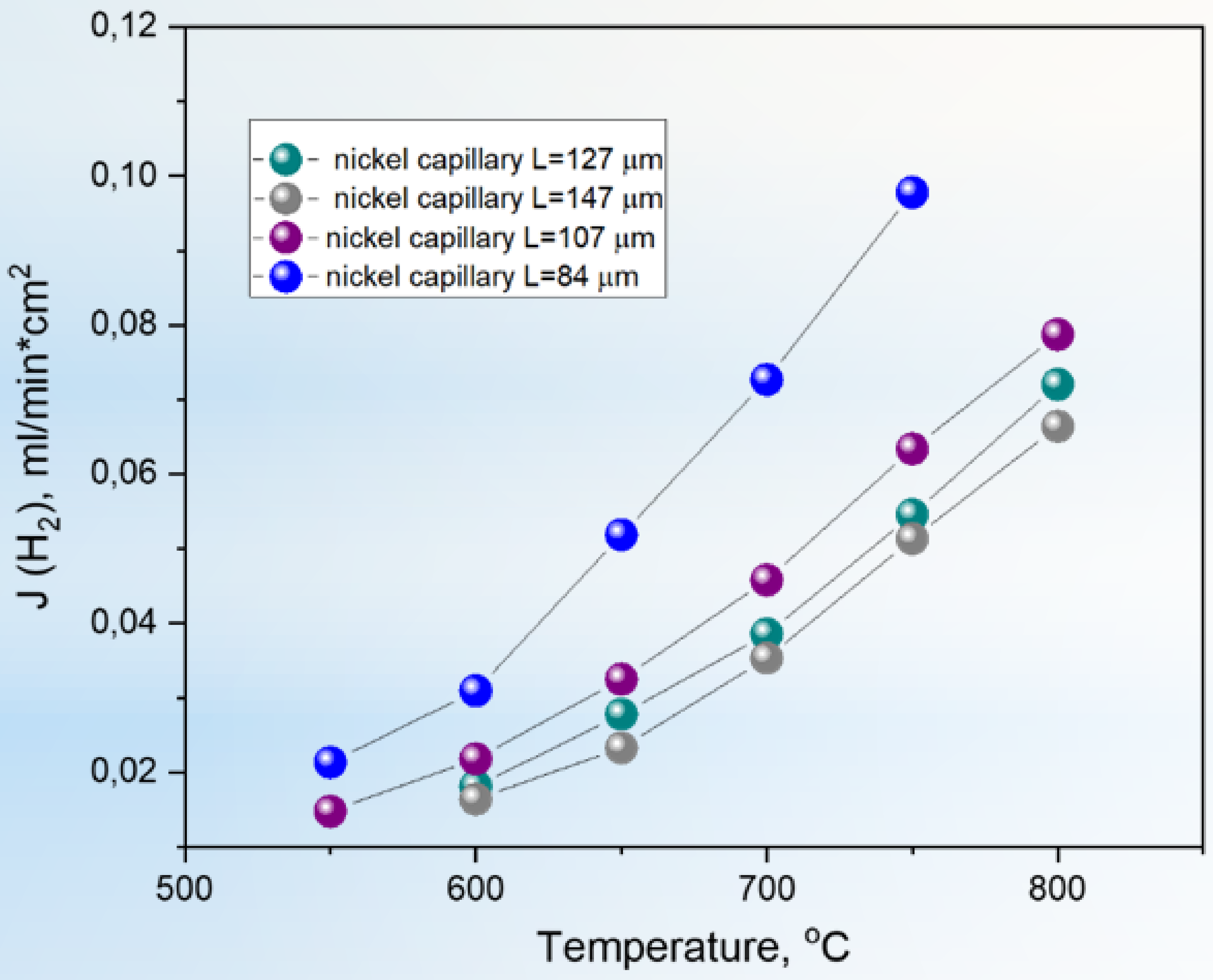


SEM micrograph of original capillaries and microphotograph of a thin section of the longitudinal section of the capillary after mechanical polishing, wall thickness 107±2 µm



X-ray patterns of nickel capillaries before and after measurements of hydrogen permeability

Study of hydrogen permeability



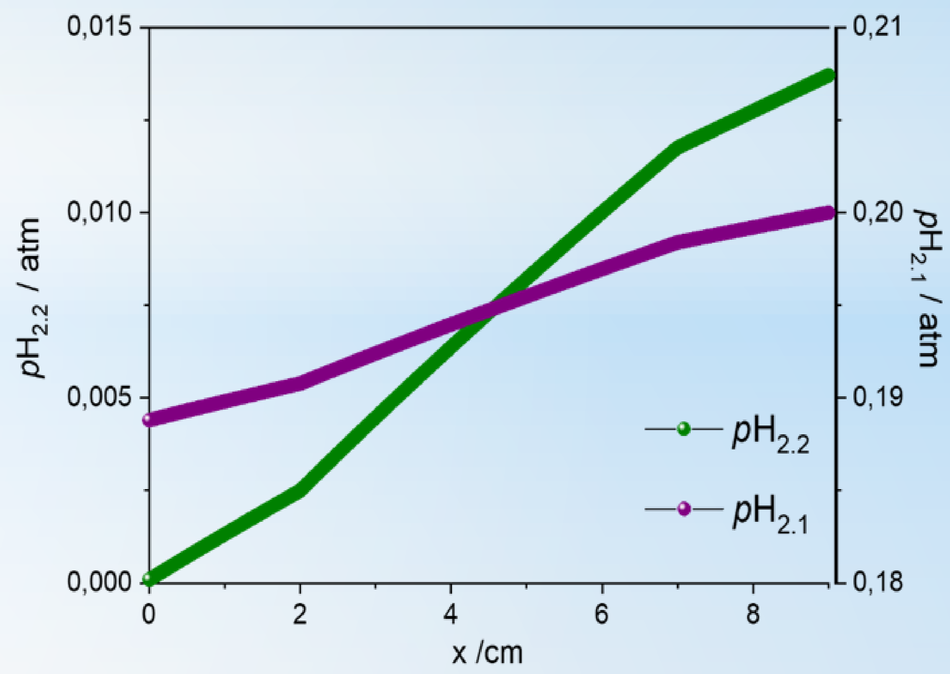
Fluxes of hydrogen through nickel capillaries

A one-dimensional mathematical model describing the transport of hydrogen through a nickel capillary is based on the assumptions, namely:

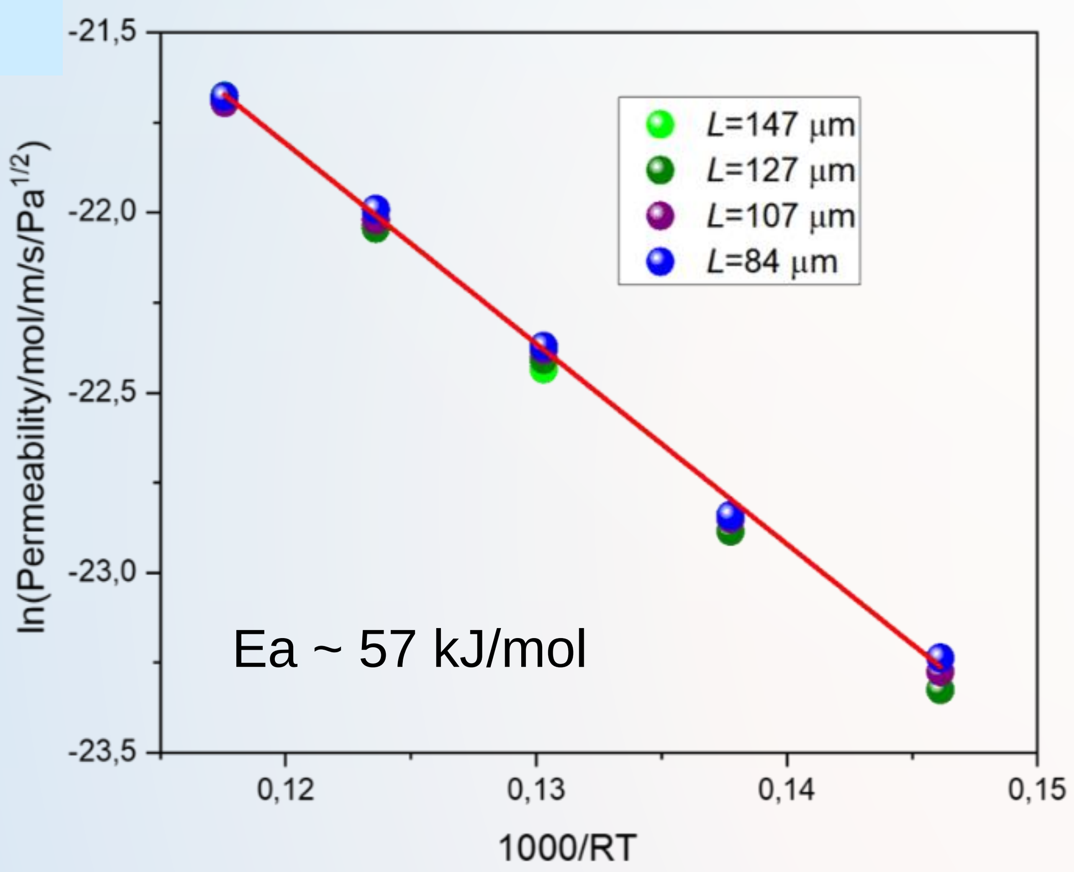
1. Nickel capillary operates under steady state isothermal conditions.
2. Diffusion of hydrogen in gas flows is not a limiting stage. The radial inhomogeneity of the composition in gases is insignificant.
3. The partial pressures of hydrogen on the outer and inner surfaces of the capillary are the same as in the gas phase.
4. It is assumed that the case in the plug-flow reactor is considered.5. The ideal gas law applies to a gas mixture.6. The total pressure in gases is maintained at atmospheric pressure.

$$J_{H_2} = \frac{P_H}{L}\left[pH_{2.1}^{0.5} - pH_{2.2}^{0.5}\right]$$

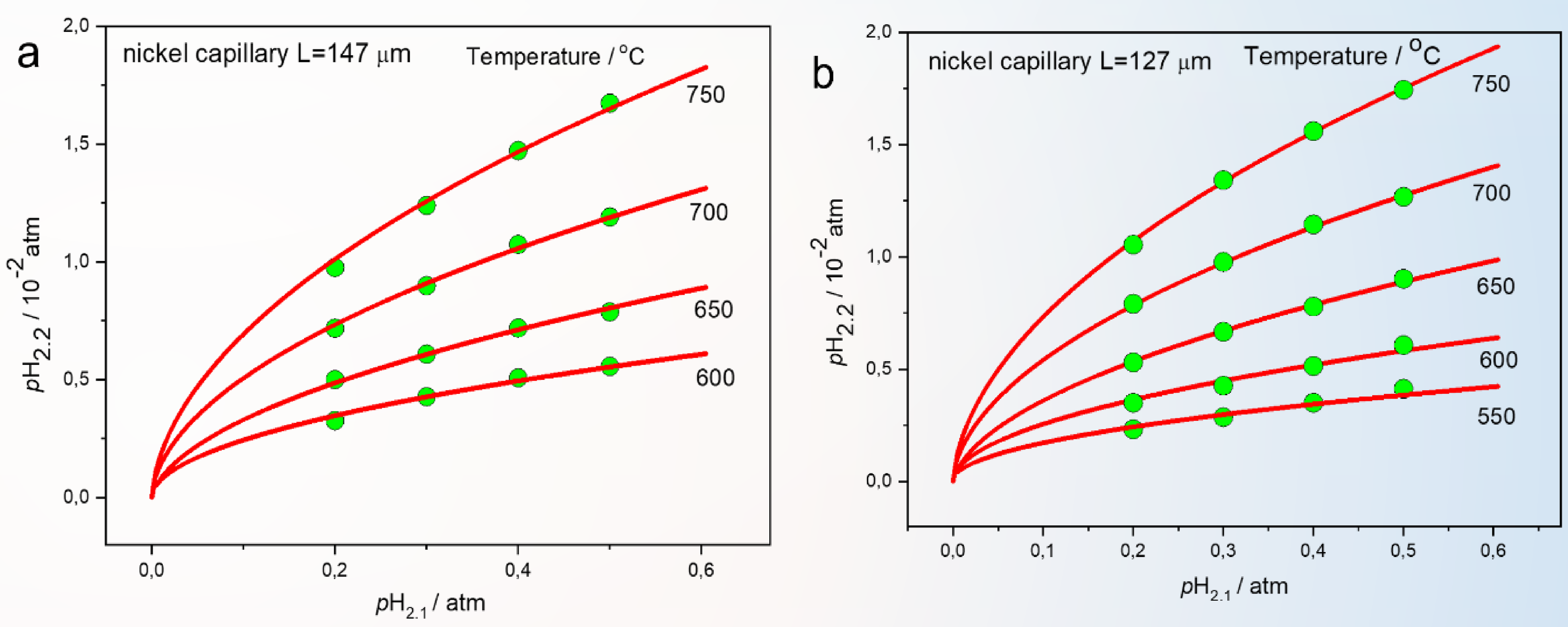
$$F_{H_2}(x, x+dx) = J_{H_2} dS = \gamma(T)\left(pH_{2.1}^{n}(x) - pH_{2.2}^{n}(x)\right)dS$$



Pressure distribution along the length of the capillary



Calculated dependence of F_{H2} on temperature in Arrhenius coordinates for different L



The experimental dependence of $pH_{2.2}$ as function of $pH_{2.1}(0)$ (points) and that one calculated by using of model (lines) for nickel capillary with a) L=147 µm; b) L=127 µm

Conclusion

In this paper, experimental and simulation results are presented in the form of a dependence of the hydrogen flux on the difference in the square root of the hydrogen partial pressure. Using the previously developed mathematical model, Ea and the pre-exponential factor (diffusion coefficient) were calculated for nickel capillaries with different wall thicknesses. The obtained data confirm the reliability of the model.

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