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**Ni-Co-Zr COMPOSITE CATALYSTS FOR PARTIAL OXIDATION OF
NATURAL GAS**

Abstract. Reducing greenhouse gas emissions is one of the most important problems facing humanity at the present stage. New active and selective Ni – Co - Zr catalysts without precious metals were tested in the processes of oxidative conversion of light alkanes into modern synthetic fuel - synthesis gas or hydrogen. Emissions after their use are minimal. Ni – Co - Zr composite catalysts have been prepared by fast, environmentally friendly high temperature synthesis. The morphology of the samples was studied using X-ray phase analysis and electron microscopy. Tests of the oxidative conversion of methane were carried out on an automated flow catalytic unit in a tubular reactor with a fixed catalyst bed at 700 - 900°C. An Agilent 6890 N gas chromatograph with software was used for on-line analysis of raw materials and reaction products. The highest values for target products were obtained on the 47% Ni - 2% Co - 1% Zr - 50% glycine - 36.15% Al - 13.85% Mg catalyst at 900°C. The yield of H₂ was 57.3%, the yield of CO was 19.4% with a selectivity up to 84.2% for H₂ and 57% for CO, the H₂/CO ratio = 2.8 - 2.9. It has been established that Ni-Co-Zr catalysts under experimental conditions contain aluminates and metal alloys.

Key words: methane, catalytic oxidation, synthesis-gas, nickel, cobalt, zirconium.

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ТАБИҒИ ГАЗДЫ КОМПОЗИТТИ Ni-Co-Zr КАТАЛИЗАТОРЛАРЫНДА ПАРЦИАЛДЫ ТОТЫҚТЫРУ

Аннотация. Қазіргі таңда адамзат алдында тұрған маңызды мәселелердің бірі – парниктік газдар шығарындыларын азайту. Жеңіл алкандарды заманауи синтетикалық отын синтез-газға немесе сутекке тотыға айналу үрдісінде жаңа белсенді және селективті бағалы металдарсыз Ni – Co - Zr катализаторлары сыналды. Оларды қолданғаннан кейінгі шығарындылар азайды. Жоғары температуралы синтез арқылы жылдам экологиялық таза Ni – Co - Zr композиттік катализаторлары дайындалды. Үлгілердің морфологиясы рентгендік фазалық талдау және электронды микроскопия арқылы зерттелді. 700-900°C температурада катализатордың қозғалмайтын қабаты бар құбырлы реактордан тұратын автоматтандырылған ағынды катализдік қондырғыда метанның тотығу айналу үрдісі жүргізілді. Бастапқы және реакция өнімдерін on-line талдау үшін n Agilent 6890 N газ бағдарламасымен жабдықталға хроматографында жүргізілді. Максатты өнімдердің ең жоғарғы көрсеткіштерін алу үшін 900°C температурада 47% Ni - 2%Co - 1% Zr - 50% глицин - 36,15% Al - 13,85% Mg катализаторында алынды. $H_2/CO = 2,8 - 2,9$ өзара арақатынасында H_2 шығымы 57,3%, ал CO - 19,4% болса сәйкесінше селективтіліктері H_2 - 84,2% дейін, CO 57%-ды құрады. Алюминий және металл қоспалары Ni – Co - Zr катализаторының құрамында бар екендігі тәжірибе жағдайында анықталды.

Түйін сөздер: метан, катализдік тотығу, синтез-газ, никель, кобальт, цирконий.

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Ni-Co-Zr КОМПОЗИТНЫЕ КАТАЛИЗАТОРЫ ПАРЦИАЛЬНОГО ОКИСЛЕНИЯ ПРИРОДНОГО ГАЗА

Аннотация. Снижение выбросов парниковых газов является одной из важнейших проблем, стоящих на современном этапе перед человечеством. Новые активные и селективные Ni – Co - Zr катализаторы без драгоценных металлов были испытаны в процессах окислительного превращения легких алканов в современное синтетическое топливо – синтез-газ либо водород. Выбросы после их использования минимальны. Ni – Co – Zr композитные катализаторы были приготовлены быстрым, экологически чистым высокотемпературным синтезом. Морфология образцов исследована с помощью рентгенофазового анализа и электронной микроскопии. Испытания окислительного превращения метана проводились на автоматизированной проточной каталитической установке в трубчатом реакторе с неподвижным слоем катализатора при 700 - 900°C. Газовый хроматограф Agilent 6890 N с программным обеспечением был использован для on-line анализов сырья и продуктов реакции. Наиболее высокие показатели по целевым продуктам получены на катализаторе 47% Ni - 2% Co - 1% Zr - 50% глицин - 36,15% Al - 13,85% Mg при 900°C. Выход H₂ составил 57,3%, выход CO - 19,4% при селективности до 84,2% по H₂ и 57% по CO, соотношение H₂/CO = 2,8-2,9. Установлено, что Ni – Co - Zr катализаторы в условиях эксперимента содержат алюминаты и сплавы металлов.

Ключевые слова: метан, каталитическое окисление, синтез-газ, никель, кобальт, цирконий.

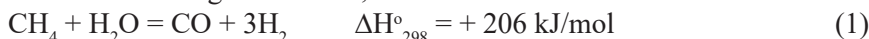
Introduction. In the course of its development, the world economy experienced several energy surges, moving from charcoal and then hard coal to oil. At present, the consumption of natural gas is growing rapidly. Previously, such energy transitions were guided by cost competitiveness, but now the environmental aspects of the choice of energy carriers are becoming important. In the face of the climate crisis, the global oil and gas industry is turning towards a low-carbon future. Now the world community is promoting the idea of decarbonization - the restructuring of economy and energy systems in order to drastically reduce CO₂ emissions, which will reduce the burden

on environment. The current level of technology does not allow abandoning the use of traditional energy sources. However, even now it is possible to improve their efficiency in order to reduce emissions. Natural gas is a promising alternative to oil due to its huge reserves and the rapid development of exploration technologies. Currently, processes for utilizing methane into various products are being actively developed. Obtaining synthesis-gas for its subsequent use in production is an important step in the transformation of natural gas into products.

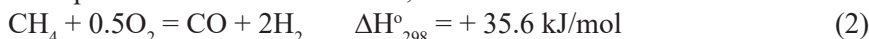
There are three technological directions for processing natural gas into products with increased added value: production of synthesis-gas (Siang, 2017: 6; Jalali, 2020: 15), direct catalytic conversion of methane to ethylene - oxidative condensation of methane (Kassymkan, 2020: 6, Aungaliev, 2021:7), direct catalytic oxidation of methane to oxygen-containing products - alcohols and formaldehyde (Loricera, 2017:11). The catalytic conversion of methane to synthesis gas, a key intermediate for the production of liquid fuels and chemicals, is one of the most important ways to utilize methane. Compared to other sources, natural gas may be one of the cheapest options for hydrogen production.

There are three main methods for producing synthesis gas from methane:

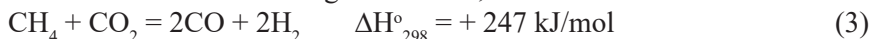
- steam reforming of methane,



- partial oxidation of methane,



- carbon dioxide reforming of methane,



Each of the above methods has its own disadvantages and advantages. However, they all have a common drawback: catalyst deactivation caused by carbon deposition during the reaction. The most active noble metal catalysts for these processes are very expensive. Nickel catalysts, on which high selectivities and yields with respect to target products were also obtained, have been extensively studied in recent years. Regardless of the high catalytic activity, nickel-based samples tend to deactivate due to sintering and coking. Deactivation and sintering of the active metal requires refinement of Ni-based catalysts with improved activity and stability. Despite the high performance in this reaction, catalyst deactivation caused by coke deposition and sintering is still a major problem because carbon formation in nickel catalysts is structure sensitive. Therefore, modifying additives are usually used to reduce the size of the crystallites or increase the interaction with the support. For example, oxides of alkali, rare earth metals, belong to them.

Nickel catalysts have been extensively studied in the past decades (Ali, 2020: 12; Adans, 2017: 10; Estifae, 2014:10), but insufficient research has been done on Co (Horváth, 2017: 8; Özkara-Aydinoğlu 2010: 6; Zhumabek, 2021 a: 16), Ni-Co (Turap, 2020: 11; Wu, 2016: 16; Movasati, 2019: 9; Baizhumanova, 2020: 7) and Mn catalysts (Kim, 2019: 6; Deorsola, 2016: 10; Zhumabek, 2021 b: 8; Kaumenova, 2020: 9). The catalysts described above showed good characteristics in terms of activity and stability. The carbon deposition of the catalysts was negligible even in the unreduced sample. The

structure of fluorite is inherent in MnO_x , which exists in several valence states. (Kim, 2019: 6). The addition of zirconium improves the stability of the catalysts (Bespalko, 2020: 24). It can be assumed that Ni-Co-Zr/Al-Mg catalyst can provide good catalytic performance in reforming of methane to hydrogen and carbon monoxide, as previously reported (Tungatarova, 2021: 6).

Catalyst preparation. Ni-Co-Zr/Al-Mg catalysts were synthesized by SCS method. A series of samples was prepared with varying content of Ni, Co, and Zr in the composition of the catalysts. Certain amounts of nitrate salts: $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Zr}(\text{NO}_3)_4 \cdot 5\text{H}_2\text{O}$, $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$, $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ and glycine ($\text{H}_2\text{NCH}_2\text{COOH}$) are weighed for the preparation of catalysts. These salts are first ground in an agate mortar and then mixed in a porcelain cup. Then 10 ml of distilled water is gradually added to this mixture of salts. The resulting mixture is stirred in air for several minutes until complete dissolution. The muffle furnace is preliminarily switched on up to 500°C . The prepared mixture is transferred from a porcelain cup into a heat-resistant glass beaker and placed in a heated muffle furnace. After 2-3 minutes, when the door of the muffle furnace is not fully opened, combustion in the solution can be visually observed, in which this mixture rises along the walls of the glass during rapid boiling. Glycine is added to SCS catalysts to improve the combustion process. The presence of glycine in the composition of the catalyst contributes to a change in the color of the solution to brown during combustion. Then the glass is cooled in air and the finished catalyst is placed in a glass bottle. Structures with a high concentration of defects in intermediate and nonstoichiometric compounds are formed, which are one of the reasons for the high activity of SCS catalysts. General view of the catalyst prepared by the SCS method is shown in Figure 1.

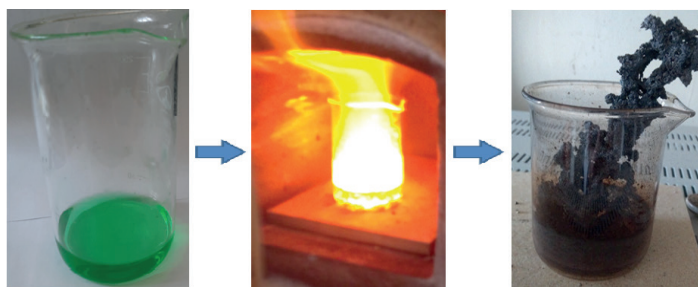


Figure 1. General view of the catalyst prepared by the SCS method

Ni-Co-Zr/Al-Mg catalysts were also prepared by the impregnation method. Titrated solutions of nitrates $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Zr}(\text{NO}_3)_4 \cdot 5\text{H}_2\text{O}$, and $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ were preliminarily prepared. Certain amounts of prepared solutions are mixed in a porcelain cup. A pre-calculated amount of alumina carrier is added there. The prepared mixture is thoroughly mixed in air, placed in a water bath and kept under constant stirring for 5-6 h. The air-dry mixture is then transferred to a clean porcelain cup and placed in an oven for 2 h at 250°C and then calcined for 2 h at 500°C . The catalysts were characterized by X-ray diffraction (XRD) using $\text{CuK}\alpha_1$ radiation on a Siemens Spellman DF3 spectrometer, scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Catalytic activity studies. The tests of the synthesized catalysts were carried out in an automated flow catalytic unit in a tubular quartz reactor with a fixed catalyst bed with on-line analysis. The studies were conducted using the reaction mixture containing CH_4 , O_2 , and Ar to study the oxidative conversion of methane into synthesis gas at 700 - 900°C and atmospheric pressure. The composition of the initial reaction mixture ($\text{CH}_4 : \text{O}_2 : \text{Ar} = 34\% : 17\% : 49\%$) and the products were studied by the chromatographic method. The initial mixture and reaction products were analyzed using a Chromos GC-1000 chromatograph with the Chromos software. Chromatographic peaks were calculated using calibration curves constructed for the corresponding products using the Chromos software for pure substances.

Results and Discussion. Investigation of the activity of catalysts based on the initial mixture 47% Ni - 2% Co - 1% Zr - 50% glycine - 36.15% Al - 13.85% Mg, obtained in the process of solution combustion synthesis (SCS), was carried out in the reaction of oxidative conversion of methane. A mixture of gases 34% CH_4 , 17% O_2 , and 50% ($\text{Ar} \pm \text{H}_2\text{O}$), $\text{CH}_4 : \text{O}_2 = 2 : 1$, in the temperature range 750 - 900°C was used to study the oxidation of methane to synthesis gas. The results on the yield of hydrogen and CO, as well as the selectivity for target products for these catalysts depending on the space velocity (500 - 8500 h^{-1}) at different temperatures (850 - 900°C) are shown in Figures 2a and 2b.

The yields of hydrogen and CO, their selectivity, as well as the H_2/CO ratio, which plays an important role in the further synthesis of alcohols and hydrocarbons, were determined on this catalyst by varying the temperature and space velocities from 500 to 8500 h^{-1} . It was shown that it is possible to obtain the highest rates of yield and selectivity for target products at space velocities from 1000 to 2500 h^{-1} . For example, up to 55 - 57.3% H_2 , 19 - 19.4% CO were obtained with a selectivity of up to 84.2% for hydrogen and 57% for CO, the ratio $\text{H}_2/\text{CO} = 2.8 - 2.9$ at GHSV = 2500 h^{-1} . Similar results were also obtained at a space velocity of 1000 h^{-1} . It should be noted that the H_2/CO ratio is more optimal and corresponds to a value of 2.3 - 2.4. A further increase of the space velocity or decrease leads to a decrease in process performance.

As a result of temperature variation, it was found that carrying out the process at 900°C allows achieving the highest values of both the yield and selectivity for H_2 and CO. However, the H_2/CO ratio slightly increases from 2.3 - 2.5 ($T = 700 - 800^\circ\text{C}$) up to 2.8 - 2.9 ($T = 900^\circ\text{C}$) at GHSV = 2500 h^{-1} , Figure 3.

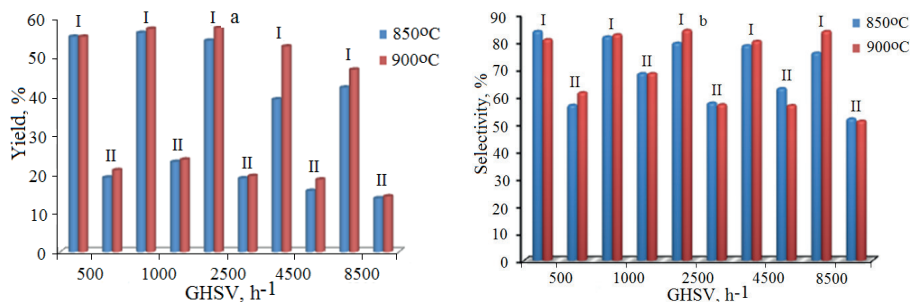


Figure 2. Effect of varying the space velocity on the yield and selectivity by H_2 and CO at different temperatures on the 47% Ni - 2% Co - 1% Zr - 50% glycine - 36.15% Al - 13.85% Mg catalyst: a - yield of I - H_2 , II - CO; b - selectivity for I - H_2 , II - CO

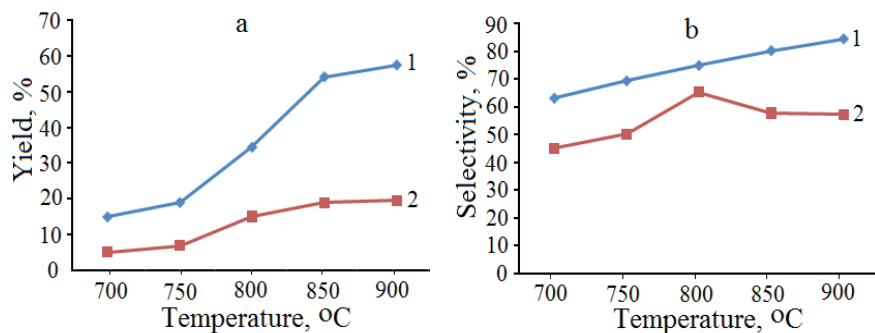


Figure 3. Influence of the temperature of the process of oxidative conversion of methane on the yield and selectivity by H₂ and CO: a - H₂ and CO yield, b - H₂ and CO selectivity. 1 - H₂, 2 - CO

It is known that the addition of water vapor to the reaction mixture in the processes of oxidative conversion of methane often plays a positive role, softening the conditions of the process, increasing the selectivity, and reducing the carbonization of the samples. The addition of water vapor to the initial reaction mixture and variation of the CH₄ : H₂O ratio (1 : 0, 1 : 1, 1 : 0.5, 1 : 0.3) were studied on the indicated catalyst compositions. It was found that the addition of water vapor is insignificant, but reduces the production of synthesis gas, while increasing the yield of carbon dioxide from 0.1% to 1.1%, Figure 4. The H₂/CO ratio also increases from 2.8 to 3.3.

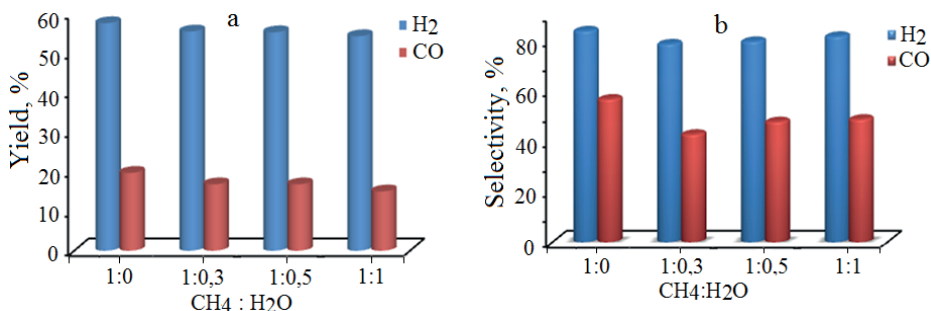


Figure 4. Influence of water vapor content in the reaction mixture on the yield and selectivity of the process by H₂ and CO: a - H₂ and CO yield, b - H₂ and CO selectivity; GHSV = 2500 h⁻¹

In the next series of experiments, the composition of the catalyst was studied. The following catalysts were tested, Figure 5:

- 1 - 47% Ni - 2% Co - 1% Zr - 50% глицин - 36.15% Al - 13.85% Mg,
- 2 - 35% Ni - 10% Co - 5% Zr - 50% глицин - 36.15% Al - 13.85% Mg,
- 3 - 20% Ni - 20% Co - 10% Zr - 50% глицин - 36.15% Al - 13.85% Mg,
- 4 - 16.7% Ni - 16.7% Co - 16.7% Zr - 50% глицин - 36.15% Al - 13.85% Mg.

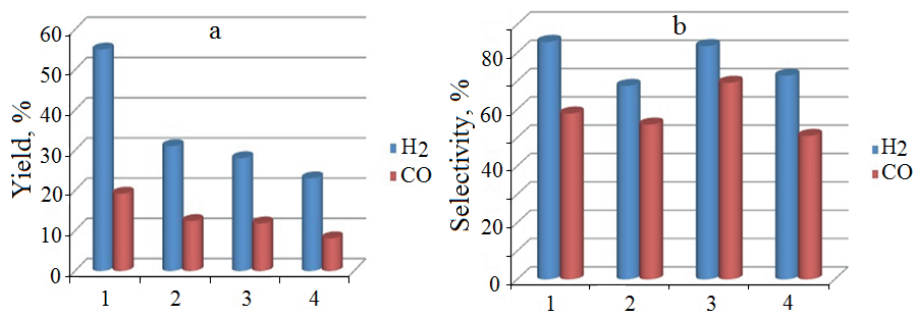


Figure 5. Influence of the composition of catalysts on the yield and selectivity for H₂ and CO: a - H₂ and CO yield, b - H₂ and CO selectivity. 1 - 47% Ni - 2% Co - 1% Zr - 50% glycine - 36.15% Al - 13.85% Mg, 2 - 35% Ni - 10% Co - 5% Zr - 50% glycine - 36.15% Al - 13.85% Mg, 3 - 20% Ni - 20% Co - 10% Zr - 50% glycine - 36.15% Al - 13.85% Mg, 4 - 16.7% Ni - 16.7% Co - 16.7% Zr - 50% glycine - 36.15% Al - 13.85% Mg; GHSV = 2500 h⁻¹

It is shown that the compositions with the highest nickel contents give the highest results in terms of synthesis gas. Nevertheless, the selectivities for the target products are quite high and the H₂/CO ratio is the most optimal in comparison with the other sample compositions (2.3 instead of 2.8 - 2.9) at 20% Ni content in the catalyst composition.

A decrease in the dilution of the reaction mixture (as a result of a decrease in the argon content) reduces the yields for H₂ and CO, but significantly increases the selectivity for products (for H₂ - up to 97-98%, for CO - 58-60%). The most optimal composition of the catalyst, tested for 120 h, did not reduce its activity in terms of the main indicators, Figure 6.

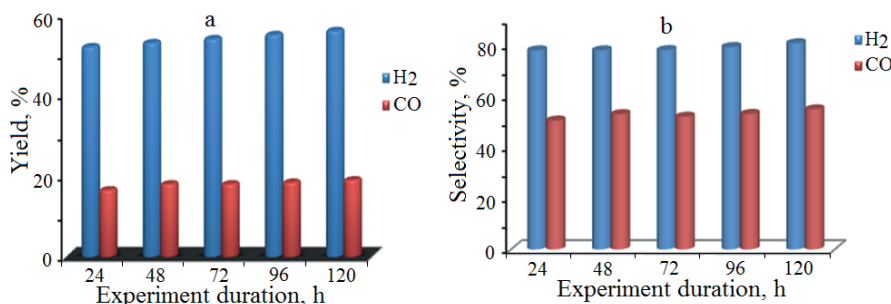


Figure 6. Effect of the duration of experiment on the yield and selectivity by H₂ and CO: a - H₂ and CO yield, b - H₂ and CO selectivity; GHSV = 2500 h⁻¹

Comparison of data on the oxidative conversion of CH₄ on catalysts with the composition 47% Ni - 2% Co - 1% Zr - 50% glycine - 36.15% Al - 13.85% Mg prepared by SCS and impregnation methods shows that the values of the process parameters are close. However, in terms of commercial use, the catalyst prepared by the SCS method has a greater advantage due to lower energy costs. The process of impregnation, drying and calcination requires many hours of thermal procedures, which leads to an increase in the cost of the catalyst.

X-ray diffraction studies have shown that all diffraction patterns are almost identical. Reflexes 2.03; 1.76; 1.24 refer to Ni (ASTM 4-850), and the X-ray amorphous component of the structural elements related to Co, Mg, Zr, Al was not detected. Figure

7a shows films contaminated with particles ranging in size from 8 - 10 to 15 nm. The microdiffraction pattern is represented by rings and reflections and can be attributed to a mixture of phases: $ZrO_{0.35}$ (JCPDS, 17-385), ZrH_2 (JCPDS, 17-1424), $CoAl_2O_4$ (JCPDS, 10-459), possibly Zr (JCPDS, 5- 665). Figure 7b shows a dense aggregate, along the edge of which there are particles 5–8 nm in size. The microdiffraction pattern is represented by diffuse rings and can be attributed to Ni_3Zr (JCPDS, 4-835), $MgNiO_2$ (JCPDS, 24-712), and to a lesser extent MgO_2 (JCPDS, 19-771). Images of highly dispersed samples are presented in Figure 7c.

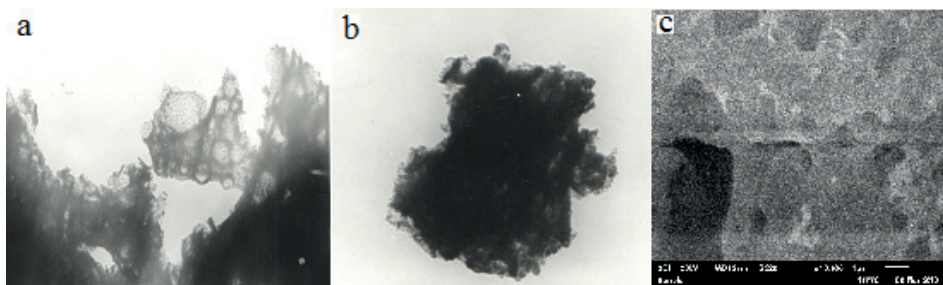


Figure 7. TEM (a, b) and SEM (c) images of Ni - Co - Zr - glycine - Al - Mg catalysts

Conclusion. In the present work, Ni - Co - Zr - glycine - Al - Mg catalysts prepared by solution combustion synthesis and impregnation methods were active in the reaction of partial conversion of methane into synthesis-gas. The optimal conditions for the maximum operation of this catalyst are: 34% CH_4 , 17% O_2 , 49% ($Ar \pm H_2O$), space velocity – $2500\ h^{-1}$ at the temperature of $900^\circ C$. 57.3% of H_2 , 19.4% of CO with selectivity up to 84.2% for H_2 and 57% for CO, H_2/CO ratio = 2.8 - 2.9 were obtained as a result of the research. Reducing the dilution of the reaction mixture led to an increase in the selectivity for hydrogen up to 97 - 98%, and for CO - up to 58 - 60%.

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REFERENCES

Adans Y.F., Ballarini A.D., Martins A.R., Coelho R.E., Carvalho L.S. (2017). Performance of nickel supported on γ -alumina obtained by aluminum recycling for methane dry reforming, *Catalysis Letters*, 147:2057-2066. <https://doi.org/10.1007/s10562-017-2088-3> (in Eng.).

Ali S., Khader M.M., Almarri M.J., Abdelmoneim A.G. (2020). Ni-based nano-catalysts for the dry reforming of methane, *Catalysis Today*, 343:26-37. <https://doi.org/10.1016/j.cattod.2019.04.066> (in Eng.).

Augaliev D.B., Erkiabaeva M.K., Aidarova A.O., Tungatarova S.A., Baizhumanova T.S. (2021). Oxidative dimerization of methane to C2 hydrocarbons, *News of the National Academy of Sciences of the Republic of Kazakhstan. Series Chemistry and Technology*, 3:18-24. <https://doi.org/10.32014/2021.2518-1491.44> (in Eng.).

Baizhumanova T.S., Zhang X., Murzin D.Y., Tungatarova S.A. (2020). Catalytic conversion of biogas into synthesis gas on Ni, Co and Ni-Co catalysts, *News of the National Academy of Sciences of the Republic of Kazakhstan. Series Chemistry and Technology*, 5:14-20. <https://doi.org/10.32014/2020.2518-1491.75> (in Eng.).

Bespalko Yu., Smal E., Simonov M., Valeev K., Fedorova V., Krieger T., Cherepanova S., Ishchenko A., Rogov V., Sadykov V. (2020). Novel Ni/Ce(Ti)ZrO₂ catalysts for methane dry reforming prepared in supercritical alcohol media, *Energies*, 13: 3365-3389. DOI: 10.3390/en13133365 (in Eng.).

Deorsola F.A., Andreoli S., Armandi M., Bonelli B., Pirone R. (2016). Unsupported nanostructured Mn oxides obtained by Solution Combustion Synthesis: Textural and surface properties, and catalytic performance in NO_x SCR at low temperature, *Applied Catalysis A: General*, 522:120-129. <https://doi.org/10.1016/j.apcata.2016.05.002> (in Eng.).

Estifae P., Haghighi M., Babaluo A.A., Rahemi N., Jafari M.F. (2014). The beneficial use of non-thermal plasma in synthesis of Ni/Al₂O₃-MgO nano-catalyst used in hydrogen production from reforming of CH₄/CO₂ greenhouse gases, *Journal of Power Sources*, 257:364-373. <https://doi.org/10.1016/j.jpowsour.2014.01.128> (in Eng.).

Horváth É., Baán K., Varga E., Oszkó A., Vágó Á., Törő M., Erdőhelyi A. (2017). Dry reforming of CH₄ on Co/Al₂O₃ catalysts reduced at different temperatures, *Catalysis Today*, 281:233-240. <https://doi.org/10.1016/j.cattod.2016.04.007> (in Eng.).

Jalali R., Rezaei M., Nematollahi B., Baghalha M. (2020). Preparation of Ni/MeAl₂O₄-MgAl₂O₄ (Me=Fe, Co, Ni, Cu, Zn, Mg) nanocatalysts for the syngas production via combined dry reforming and partial oxidation of methane, *Renewable Energy*, 149:1053-1067. <https://doi.org/10.1016/j.renene.2019.10.111> (in Eng.).

Kassymkan K., Zhang X., Sarsenova R.O., Zheksenbaeva Z.T., Tungatarova S.A., Baizhumanova T.S. (2020). Catalytic processing of natural gas into olefins, *Chemical Engineering Transactions*, 81:1057-1062. DOI: 10.3303/CET2081177 (in Eng.).

Kaumenova G.N., Xanthopoulou G., Sovetbek Y.K., Baizhumanova T.S., Tungatarova S.A., Kotov S.O. (2020). Co-Mg-Mn composite catalysts for partial oxidation of natural gas, *News of the National Academy of Sciences of the Republic of Kazakhstan. Series Chemistry and Technology*, 4:64-72. <https://doi.org/10.32014/2020.2518-1491.66> (in Eng.).

Kim W.Y., Jang J.S., Ra E.C., Kim K.Y., Kim E.H., Lee J.S. (2019). Reduced perovskite LaNiO_3 catalysts modified with Co and Mn for low coke formation in dry reforming of methane, *Applied Catalysis, A: General*, 575:198-203. <https://doi.org/10.1016/j.apcata.2019.02.029> (in Eng.).

Loricera C.V., Alvarez-Galvan M.C., Guil-Lopez R., Ismail A.A., Al-Sayari S.A., Fierro J.L.G. (2017). Structure and reactivity of sol-gel V/SiO_2 catalysts for the direct conversion of methane to formaldehyde, *Topics in Catalysis*, 60:1129-1139. <https://doi.org/10.1007/s11244-017-0809-x> (in Eng.).

Movasati A., Alavi S.M., Mazloom G. (2019). Dry reforming of methane over $\text{CeO}_2\text{-ZnAl}_2\text{O}_4$ supported Ni and Ni-Co nano-catalysts, *Fuel*, 236:1254-1262. <https://doi.org/10.1016/j.fuel.2018.09.069> (in Eng.).

Özkara-Aydinoğlu S., Aksoylu A.E. (2010). Carbon dioxide reforming of methane over Co-X/ ZrO_2 catalysts (X=La, Ce, Mn, Mg, K), *Catalysis Communications*, 11:1165-1170. <https://doi.org/10.1016/j.catcom.2010.07.001> (in Eng.).

Siang T.J., Danh H.T., Singh S., Truong Q.D., Setiabudi H.D., Vo D.V.N. (2017). Syngas production from combined steam and carbon dioxide reforming of methane over Ce-modified silica-supported nickel catalysts, *Chemical Engineering Transactions*, 56:1129-1134. DOI: 10.3303/CET1756189 (in Eng.).

Tungatarova S.A., Xanthopoulou G., Vekinis G., Baizhumanova T.S., Zhumabek M., Kotov S.O., Manabayeva A. (2021). Production of hydrogen-containing clean fuel from biogas, *Chemical Engineering Transactions*, 88:1093-1098. DOI: 10.3303/CET2188182.k (in Eng.).

Turap Y., Wang I., Fu T., Wu Y., Wang Y., Wang W. (2020). Co-Ni alloy supported on CeO_2 as a bimetallic catalyst for dry reforming of methane, *International Journal of Hydrogen Energy*, 45:6538-6548. <https://doi.org/10.1016/j.ijhydene.2019.12.223> (in Eng.).

Wu H., Liu H., Yang W., He D. (2016). Synergetic effect of Ni and Co in Ni-Co/SBA-15-CD catalysts and their catalytic performance in carbon dioxide reforming of methane to syngas, *Catalysis Science and Technology*, 6:5631-5646. <https://doi.org/10.1039/C6CY00202A> (in Eng.).

Zhumabek M., Xanthopoulou G., Tungatarova S.A., Baizhumanova T.S., Vekinis G., Murzin D. (2021). Biogas reforming over Al-Co catalyst prepared by solution combustion synthesis method, *Catalysts*, 11:274-289. <https://doi.org/10.3390/catal11020274>. (in Eng.).

Zhumabek M., Kaumenova G.N., Manabayeva A., Sarsenova R.O., Kotov S.O. (2021). Ni-Al-Mg-Mn composite catalysts for partial oxidation of natural gas, *News of the National Academy of Sciences of the Republic of Kazakhstan. Series Chemistry and Technology*, 4:19-26. <https://doi.org/10.32014/2021.2518-1491.62> (in Eng.).

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