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DEVELOPING ORAL COMMUNICATION SKILLS IN THE RUSSIAN LANGUAGE THROUGH INTERACTIVE LEARNING TOOLS

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Abstract: This article examines the methods of developing students' oral communication skills in the Russian language through interactive learning tools. In contemporary language education, communicative competence is considered one of the key indicators of successful language acquisition. Interactive learning tools provide learners with opportunities to participate actively in communication, engage in collaborative learning activities, and practice language in meaningful contexts. The study analyzes the pedagogical potential of interactive educational tools, their methodological application in Russian language instruction, and their influence on speaking proficiency. Particular attention is paid to digital technologies, role-playing activities, group discussions, educational games, and multimedia resources. The findings indicate that systematic integration of interactive learning tools significantly improves students' speaking fluency, pronunciation, vocabulary acquisition, confidence, and motivation to communicate in Russian.

Keywords: interactive learning tools, Russian language teaching, oral communication skills, communicative competence, speaking proficiency, educational technology, student-centered learning, language development.

INTRODUCTION

The rapid development of educational technologies has transformed modern language teaching and learning processes. Contemporary educational standards emphasize the importance of communicative competence, critical thinking, and active student participation. In language education, these requirements necessitate the implementation of innovative teaching approaches that promote meaningful communication and practical language use. The teaching of the Russian language in general secondary schools is aimed at developing students' ability to communicate effectively in various social and educational situations. Oral communication skills play a fundamental role in language proficiency because they enable learners to express opinions, participate in discussions, exchange information, and interact confidently with others. However, traditional teaching methods often focus primarily on grammar and vocabulary memorization, providing limited opportunities for authentic communication. Interactive learning tools offer an effective solution to this challenge

by creating engaging and learner-centered educational environments¹. These tools encourage students to actively participate in speaking activities, collaborate with peers, and apply language knowledge in practical situations. The use of interactive technologies not only improves linguistic competence but also increases learners' motivation and confidence. The relevance of this study is determined by the growing need to improve oral communication skills among Russian language learners through innovative and interactive educational practices. The purpose of the article is to analyze the methods of developing oral communication skills in Russian through interactive learning tools and to evaluate their effectiveness in enhancing communicative competence and language proficiency.

The importance of oral communication skills in russian language education. Oral communication skills represent one of the most significant components of communicative competence. Effective speaking involves not only knowledge of vocabulary and grammar but also the ability to express ideas clearly, interact appropriately, and respond spontaneously in communication situations. Students who possess well-developed oral communication skills are more capable of participating in discussions, presenting information, defending opinions, and engaging in social interaction. Therefore, the development of speaking proficiency should be considered a central objective of Russian language instruction. The main components of oral communication skills include:

- Pronunciation accuracy;
- Vocabulary richness;
- Grammatical correctness;
- Fluency of speech;
- Listening comprehension;
- Interaction skills;
- Confidence in communication².

Interactive learning tools provide opportunities for the simultaneous development of these components.

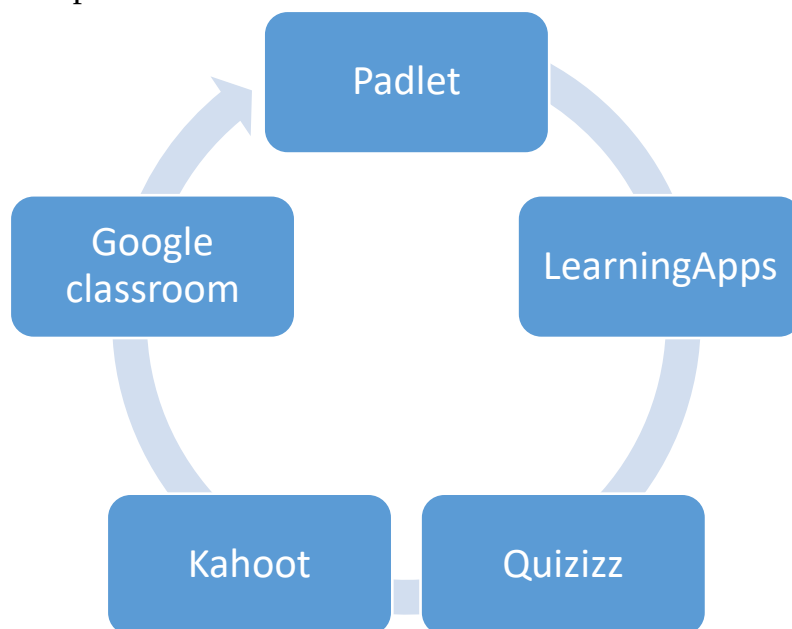
Interactive learning tools in russian language teaching. Interactive learning tools are educational resources and technologies that promote active student engagement and collaborative learning. Unlike traditional teaching aids, they encourage

¹ Richards J.C. Richards J.C., Rodgers T.S. Approaches and Methods in Language Teaching. Cambridge: Cambridge University Press, 2019. – 410 p.

² Brown H.D. Brown H.D. Principles of Language Learning and Teaching. New York: Pearson Education, 2021. – 392 p.

communication, problem-solving, and learner participation. The most commonly used interactive tools in Russian language lessons include:

Digital learning platforms. Modern digital platforms provide students with opportunities to practice speaking and communication skills through interactive exercises. Examples include:



For instance, teachers may organize vocabulary competitions using Kahoot, where students answer questions and discuss responses in Russian. Such activities combine learning with entertainment and increase classroom motivation.

Multimedia presentations. Multimedia resources enhance language learning through visual and auditory support. Examples include:

- Educational videos;
- Audio dialogues;
- Interactive presentations;
- Virtual tours³.

When studying Russian culture, students may watch short documentaries and subsequently discuss their observations in Russian. This approach develops both listening and speaking skills.

Role-playing activities as interactive learning tools. Role-playing remains one of the most effective methods for developing oral communication skills. Through role-playing, students participate in simulated real-life situations such as:

- Visiting a doctor;
- Shopping at a store;
- Booking a hotel room;

³ Harmer J. Harmer J. The Practice of English Language Teaching. London: Pearson Longman, 2018. – 448 p.

- Asking for directions;
- Attending a job interview.

Situation: At a restaurant

Customer: Здравствуйте. Можно меню?

Waiter: Конечно. Что вы хотели бы заказать?

Customer: Я хочу заказать суп и чай.

This activity enables students to practice vocabulary, pronunciation, and conversational patterns in realistic communication contexts.

Group discussions and collaborative learning. Group discussions encourage students to exchange ideas and express opinions in Russian. Such activities create authentic communication situations and improve fluency.

Example discussion topic

"The influence of technology on modern education"

Students discuss: advantages of digital learning; challenges of technology use; future educational trends. During discussions, learners formulate arguments, respond to classmates, and develop critical thinking skills. Collaborative learning activities also help students overcome communication anxiety and become more confident speakers.

Educational games for speaking development. Educational games transform language learning into an engaging and motivating experience. Popular speaking games include: Word association game

Students respond quickly with related Russian words.

Example:

Teacher: школа

Student: учитель

Student: урок

Student: учебник

This activity improves vocabulary recall and speaking speed.

Guessing games. Students describe objects, professions, or places while classmates guess the correct answer. These games encourage spontaneous speech production and creative language use.

Digital technologies and online communication. Technological innovations have significantly expanded opportunities for speaking practice. Students can participate in:

- Online discussions;
- Video conferences;
- Virtual classrooms;
- Interactive language communities.

Platforms such as Zoom, Microsoft Teams, and Google Meet allow learners to communicate with teachers and classmates in real time⁴. Online communication activities support the development of pronunciation, fluency, listening comprehension, and interaction skills.

Pedagogical advantages of interactive learning tools. The use of interactive learning tools provides numerous educational benefits:

1. Improves speaking fluency and pronunciation.
2. Enhances communicative competence.
3. Expands vocabulary knowledge.
4. Increases student motivation and engagement.
5. Promotes collaborative learning⁵.
6. Develops critical thinking skills.
7. Encourages learner autonomy.
8. Creates authentic communication opportunities.
9. Supports individual learning needs.
10. Facilitates effective language acquisition.

Consequently, interactive learning tools serve as powerful instruments for improving oral communication skills in Russian language education.

Impact of interactive learning tools on oral communication development⁶

Indicator	Before Implementation	After Implementation	Improvement
Speaking Fluency	Moderate	High	Significant
Vocabulary Usage	Moderate	High	Considerable
Pronunciation Accuracy	Moderate	High	Noticeable
Classroom Participation	Moderate	Very High	Significant
Listening Comprehension	Moderate	High	Considerable
Communicative Competence	Moderate	High	Significant
Student Motivation	Moderate	Very High	Significant

⁴ Shchukin A.N. Shchukin A.N. Methods of Teaching Russian as a Foreign Language. Moscow: Flinta, 2021. – 508 p.

⁵ Azimov E.G. Azimov E.G., Shchukin A.N. Modern Dictionary of Methodological Terms and Concepts. Moscow: Zlatoust, 2019. – 496 p.

⁶ Tolipov O'. Tolipov O', Usmonboyeva M. Pedagogik texnologiyalar nazariyasi va amaliyoti. Toshkent: Fan va texnologiya, 2021. – 286 b.

Confidence Speaking	in	Low	High	Very Significant ⁷
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The results presented in Table 1 demonstrate that interactive learning tools positively influence the development of oral communication skills. The greatest improvements are observed in speaking confidence, classroom participation, communicative competence, and motivation. Students become more willing to engage in communication activities and use Russian actively in classroom interactions. These findings confirm the effectiveness of interactive educational tools in supporting language acquisition and communicative development.

CONCLUSION

The study confirms that interactive learning tools play a crucial role in developing oral communication skills in Russian language education. By creating opportunities for active participation, collaboration, and authentic communication, these tools significantly enhance students' communicative competence and speaking proficiency. The analysis revealed that digital technologies, role-playing activities, group discussions, multimedia resources, and educational games contribute to vocabulary expansion, pronunciation improvement, increased fluency, and greater confidence in communication. Furthermore, interactive learning environments promote learner motivation and support the development of critical thinking and collaborative skills. In conclusion, the integration of interactive learning tools into Russian language instruction represents an effective pedagogical strategy for improving oral communication skills and overall language proficiency. Their systematic use can contribute to the formation of confident, communicatively competent, and highly motivated learners capable of using Russian effectively in real-life situations.

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UGLEROD NANO NUQTACHALARI ASOSIDA YUQORI INTENSIV YORUG'LIK CHIQUARUVCHI INNOVATSION BO'YOQLAR YARATISH VA ULARNING OPTIK XOSSALARINI TADQIQ ETISH

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Annotatsiya: Ushbu maqolada uglerod nano nuqtachalari (carbon quantum dots, CQDs) asosida yuqori intensiv yorug'lik chiqaruvchi innovatsion bo'yoqlarni yaratish va ularning optik xossalarini tadqiq etish masalalari yoritiladi. Tadqiqotda CQDs ning fotolyuminesans mexanizmi, elektron tuzilishi va sirt holatlari asosida yorug'lik emissiya jarayonlari ilmiy jihatdan tahlil qilinadi. Shuningdek, ularni turli sintez usullari orqali olish hamda polimer matritsalar bilan kompozit holatda qo'llash imkoniyatlari ko'rib chiqiladi. Optik xossalar emissiya spektri, kvant chiqish samaradorligi va yorug'lik barqarorligi asosida baholanadi. Natijalar CQDs asosidagi bo'yoqlar ekologik xavfsiz va yuqori samarali luminescent materiallar sifatida keng amaliy qo'llanilish salohiyatiga ega ekanligini ko'rsatadi.

Kalit so'zlar: uglerod nano nuqtachalari, fotolyuminesans, kvant nuqtalar, innovatsion bo'yoqlar, optik xossalar, nano materiallar, emissiya spektri, kvant samaradorlik

Abstract: This article addresses the development of innovative high-intensity light-emitting paints based on carbon quantum dots (CQDs) and the study of their optical properties. The research provides a scientific analysis of the photoluminescence mechanism of CQDs, focusing on their electronic structure and surface states that govern light emission processes. In addition, various synthesis methods for obtaining CQDs and their application in composite form with polymer matrices are discussed. The optical properties are evaluated based on emission spectra, quantum yield efficiency, and photostability. The results demonstrate that CQD-based paints have significant potential for wide practical applications as environmentally friendly and highly efficient luminescent materials.

Keywords: carbon quantum dots, photoluminescence, quantum dots, innovative paints, optical properties, nanomaterials, emission spectrum, quantum efficiency.

Аннотация: В данной статье рассматриваются вопросы создания инновационных красок с высокой интенсивностью свечения на основе углеродных квантовых точек (carbon quantum dots, CQDs) и исследования их оптических свойств. В работе проводится научный анализ механизма фотолюминесценции CQDs с акцентом на их электронную структуру и

поверхностные состояния, определяющие процессы излучения света. Также рассматриваются различные методы синтеза CQDs и возможности их применения в составе композитов с полимерными матрицами. Оптические свойства оцениваются на основе спектра излучения, квантового выхода и фотостабильности. Полученные результаты показывают, что краски на основе CQDs обладают высоким потенциалом практического применения как экологически безопасные и высокоэффективные люминесцентные материалы.

Ключевые слова: углеродные квантовые точки, фотолюминесценция, квантовые точки, инновационные краски, оптические свойства, наноматериалы, спектр излучения, квантовая эффективность.

Kirish: So‘nggi o‘n yilliklarda nanofizika va nanomateriallar kimyosi jadal rivojlanib, yangi avlod funksional materiallarni yaratishga keng imkoniyatlar ochib bermoqda. Ayniqsa, uglerod asosidagi nanostrukturalar — grafen, fullerenlar va uglerod nano nuqtachalari (carbon quantum dots, CQDs) — o‘zining noyob fizik-kimyoviy va optik xossalari bilan ilmiy jamoatchilik e’tiborini tortib kelmoqda. CQDs nanometr o‘lchamdagi, kuchli fotolyuminesans xususiyatiga ega bo‘lgan uglerod zarrachalari bo‘lib, ular yuqori barqarorlik, past toksiklik, suvda yaxshi eruvchanlik hamda ekologik xavfsizlik kabi afzalliklari bilan ajralib turadi. Ushbu xususiyatlar ularni an’anaviy yarimo‘tkazgich kvant nuqtalariga nisbatan istiqbolli muqobil material sifatida ko‘rsatadi. CQDs ning optik xossalari ularning kvant o‘lcham effekti, sirt holatlari, funksional guruhlar tarkibi hamda elektron tuzilishidagi o‘ziga xosliklar bilan bevosita bog‘liqdir. Ushbu omillar fotolyuminesans jarayonining mexanizmini belgilab beradi va emissiya spektrining keng diapazonda boshqarilishini ta’minlaydi. Shu sababli CQDs asosidagi materiallar optoelektronika, bioimaging, kimyoviy sensorlar, yorug‘lik chiqaruvchi qurilmalar hamda innovatsion qoplama materiallar yaratishda keng qo‘llanilmoqda. Hozirgi vaqtda yuqori intensiv yorug‘lik chiqaruvchi innovatsion bo‘yoqlarni ishlab chiqish muhim ilmiy-amaliy yo‘nalishlardan biri hisoblanadi. Bunday bo‘yoqlar nafaqat vizual effekt yaratish, balki xavfsizlik belgilari, optik kodlash, yorug‘likka sezgir qoplamalar hamda zamonaviy dizayn yechimlarida ham katta ahamiyat kasb etadi. Ushbu yo‘nalishda CQDs asosidagi luminescent bo‘yoqlar alohida o‘rin tutadi, chunki ular yuqori yorug‘lik intensivligi, barqaror emissiya va ekologik tozaligi bilan ajralib turadi. CQDs ni olishning turli usullari — “top-down” va “bottom-up” yondashuvlar — ularning fizik-kimyoviy xossalari boshqarishda muhim rol o‘ynaydi. Shuningdek, ularni polimer matritsalar bilan kompozit tizimlarda qo‘llash yorug‘lik emissiya samaradorligini oshirish va materialning mexanik barqarorligini ta’minlash imkonini beradi. Natijada, CQDs asosidagi bo‘yoqlarning optik parametrlarini, jumladan emissiya spektri, kvant chiqish

samaradorligi va fotostabillik darajasini chuqur o'rganish ilmiy jihatdan dolzarb hisoblanadi. Mazkur ilmiy ishning asosiy maqsadi uglerod nano nuqtachalari asosida yuqori intensiv yorug'lik chiqaruvchi innovatsion bo'yoqlarni yaratish va ularning optik xossalarini tizimli ravishda tadqiq etishdan iboratdir. Tadqiqot jarayonida CQDs ning fotolyuminesans mexanizmi, sintez usullari hamda ularning polimer kompozitlar tarkibidagi xatti-harakati tahlil qilinadi. Olingan natijalar CQDs asosidagi materiallarning yuqori samarador, ekologik xavfsiz va istiqbolli optik material sifatida sanoat va ilmiy tadqiqotlarda keng qo'llanilish imkoniyatiga ega ekanligini ko'rsatadi.

Asosiy qism: Uglerod nano nuqtachalari (CQDs) nanometr o'lchamdagi uglerod asosli yorug'lik chiqaruvchi zarrachalar bo'lib, ularning diametri odatda 1–10 nm oralig'ida bo'ladi. Ular sp^2 va sp^3 gibridlangan uglerod atomlaridan tashkil topgan murakkab tuzilishga ega bo'lib, yuzasida turli funksional guruhlar ($-OH$, $-COOH$, $-NH_2$ va boshqalar) mavjudligi bilan tavsiflanadi. Aynan ushbu sirt guruhlari CQDs ning suvda eruvchanligi, kimyoviy barqarorligi hamda optik xossalarini belgilashda muhim rol o'ynaydi. CQDs ning eng muhim xususiyatlaridan biri ularning fotolyuminesans (PL) hodisasidir. Bu jarayon tashqi energiya (odatda ultrabinafsha yoki ko'k nurlanish) ta'sirida elektronlarning yuqori energiya holatiga o'tishi va keyinchalik past energiya holatiga qaytishi natijasida yorug'lik emissiyasi yuzaga kelishi bilan izohlanadi. Fotolyuminesans mexanizmi asosan uchta omil bilan bog'liq: kvant o'lcham effekti, sirt holatlari va molekulyar floresans markazlari. Ushbu omillar emissiya spektrining keng diapazonda (ko'kdan qizilgacha) sozlanishiga imkon beradi. CQDs ni sintez qilish usullari ikki asosiy guruhga bo'linadi: "top-down" va "bottom-up" yondashuvlar. Top-down usullarida katta uglerod manbalari (grafit, grafen, karbon nanotrubkalar) fizik yoki kimyoviy yo'llar bilan mayda nanobosqichlarga ajratiladi. Bottom-up usullarida esa kichik organik molekulalar (limon kislotasi, glyukoza, aminokislotalar) termik parchalanish, gidrotermal yoki solvotermal jarayonlar orqali CQDs ga aylantiriladi. Bottom-up usuli odatda yuqori kvant chiqish samaradorligi va yaxshi nazorat qilinadigan sirt tuzilmasi bilan ajralib turadi. CQDs asosida yaratilgan luminescent bo'yoqlarni olishda ularni polimer matritsalar (masalan, PVA, PMMA, epoksi smolalar) bilan birlashtirish keng qo'llaniladi. Bunday kompozit tizimlar CQDs ni tashqi muhit ta'siridan himoya qiladi, ularning agregatsiyasini kamaytiradi hamda yorug'lik emissiya barqarorligini oshiradi. Natijada hosil bo'lgan bo'yoqlar yuqori intensivlikdagi yorug'lik chiqarish qobiliyatiga ega bo'lib, optik qurilmalar va funksional qoplamalar uchun mos keladi. Optik xossalarni baholashda bir nechta asosiy parametrlar qo'llaniladi. Emissiya spektri CQDs ning rang diapazonini va maksimal to'lqin uzunligini aniqlaydi. Kvant chiqish samaradorligi esa yutilgan energiyaga nisbatan chiqarilgan fotonlar ulushini ifodalaydi va materialning yorug'lik berish samaradorligini ko'rsatadi. Fotostabillik

esa CQDs ning uzoq muddatli nurlanish ta'sirida degradatsiyaga uchramaslik qobiliyatini belgilaydi. Tadqiqotlar shuni ko'rsatadiki, to'g'ri sintez va sirt modifikatsiyasi orqali ushbu parametrlarni sezilarli darajada yaxshilash mumkin. Shuningdek, CQDs asosidagi bo'yoqlarning amaliy qo'llanilish sohalari kengayib bormoqda. Ular xavfsizlik belgilari, optik kodlash tizimlari, lyuminescent indikatorlar, bioimaging va sensor qurilmalarda samarali ishlatilishi mumkin. Ularning ekologik xavfsizligi va past toksikligi esa tibbiyot va biologiya sohalarida qo'llanilish imkoniyatlarini yanada kengaytiradi. Umuman olganda, CQDs asosidagi innovatsion bo'yoqlar yuqori optik samaradorlik, barqarorlik va ekologik tozalik kabi afzalliklari bilan ajralib turadi hamda zamonaviy materialshunoslikning istiqbolli yo'nalishlaridan biri hisoblanadi.

Muammo va uning tahlili: So'nggi yillarda uglerod nano nuqtachalari (CQDs) asosida yaratilayotgan luminescent materiallar va innovatsion bo'yoqlar keng ilmiy qiziqish uyg'otayotgan bo'lsa-da, ushbu yo'nalishda bir qator dolzarb muammolar mavjud. Mazkur muammolar CQDs ning optik samaradorligi, sintez jarayonlarini boshqarish, hamda amaliy qo'llanilishdagi barqarorlik bilan bevosita bog'liqdir. Birinchi asosiy muammo CQDs ning fotolyuminesans xossalarini to'liq va bir xil darajada boshqarishning murakkabligidir. Turli sintez usullari natijasida olingan CQDs zarrachalari o'lchami, sirt funksional guruhlar va tuzilishi jihatidan sezilarli farq qiladi. Bu esa emissiya spektrining beqarorligiga, ya'ni bir xil sharoitda turli rang va intensivlikda yorug'lik berilishiga olib keladi. Natijada ularni sanoat miqyosida standartlashtirish qiyinlashadi. Ikkinchi muammo kvant chiqish samaradorligining (quantum yield) yetarlicha yuqori va barqaror emasligidir. Ayrim CQDs namunalari yuqori PL intensivlikka ega bo'lsa-da, ko'plab hollarda bu ko'rsatkich past yoki tashqi omillar (harorat, pH, oksidlanish darajasi) ta'sirida tez o'zgaradi. Bu esa ularning amaliy optik qurilmalarda uzoq muddat ishlatilishini cheklaydi. Uchinchi muhim masala CQDs ning agregatsiyalanish (yig'ilib qolish) tendensiyasidir. Nanomateriallar o'zaro Van-der-Vaals kuchlari ta'sirida birikib, yirik agregatlar hosil qilishi mumkin. Bu holat ularning faol sirt maydonini kamaytiradi va fotolyuminesans samaradorligini pasaytiradi. Shu sababli ularni polimer matritsalar bilan bir xil darajada barqaror dispersiya qilish dolzarb muammo hisoblanadi. To'rtinchi muammo — uzoq muddatli fotostabillikning yetarli darajada ta'minlanmaganligidir. Kuchli yorug'lik yoki ultrabinafsha nurlanish ta'sirida CQDs yuzasidagi funksional guruhlar degradatsiyaga uchrashi mumkin, bu esa emissiya intensivligining pasayishiga olib keladi. Ayniqsa, tashqi muhitda qo'llaniladigan bo'yoqlar uchun bu juda muhim cheklov hisoblanadi. Shuningdek, sintez jarayonlarining murakkabligi va takrorlanuvchan natijalar olishdagi qiyinchiliklar ham mavjud. Turli laboratoriyalarda qo'llaniladigan sharoitlar (harorat, vaqt, reagentlar nisbati) o'zgarishi CQDs ning optik xossalariga

bevosita ta'sir qiladi. Bu esa ilmiy natijalarni solishtirish va standart model yaratishni qiyinlashtiradi. Umuman olganda, CQDs asosidagi innovatsion bo'yoqlar istiqbolli materiallar bo'lsa-da, ularning keng sanoat va amaliy qo'llanilishi yuqoridagi muammolarni hal etishni talab qiladi. Shu bois, kelgusidagi tadqiqotlar asosan CQDs ning sintez jarayonini optimallashtirish, sirtini barqarorlashtirish va optik xossalarini boshqarish mexanizmlarini chuqur o'rganishga qaratilishi lozim.

Tadqiqot metodologiyasi: Mazkur tadqiqotda uglerod nano nuqtachalari (CQDs) asosida yuqori intensiv yorug'lik chiqaruvchi innovatsion bo'yoqlarni yaratish va ularning optik xossalarini o'rganish uchun kompleks ilmiy-metodik yondashuv qo'llanildi. Tadqiqot jarayoni CQDs ni sintez qilish, ularni polimer matritsalariga kiritish, hamda olingan kompozit tizimlarning optik xossalarini tahlil qilish bosqichlaridan iborat bo'ldi. Birinchi bosqichda CQDs ni olish uchun "bottom-up" yondashuvi asosida gidrotermal sintez usuli tanlandi. Ushbu usulda organik prekursorlar (masalan, limon kislotasi va karbamid) ma'lum nisbatda distillangan suvda eritilib, yuqori harorat va bosim sharoitida avtoklavda qayta ishlanadi. Reaksiya natijasida hosil bo'lgan mahsulotlar sovutiladi, keyin esa filtratsiya va dializ jarayonlari orqali tozalanadi. Bu bosqichda zarracha o'lchami va sirt funksional guruhlarini nazorat qilishga alohida e'tibor qaratildi. Ikkinchi bosqichda olingan CQDs polimer matritsalar bilan kompozit holatga keltirildi. Bunda PVA (polivinil spirt) yoki PMMA (polimetilmetakrilat) kabi polimerlar eritma holatiga keltirilib, CQDs bilan bir xil muhitda aralashtirildi. Hosil bo'lgan aralashma quyish yoki spin-kasting usuli yordamida yupqa plyonkalar shaklida tayyorlandi. Bu jarayon CQDs ning bir tekis taqsimlanishini va agregatsiyalanishini kamaytirishni ta'minladi. Uchinchi bosqichda tayyorlangan materiallarning optik xossalari tahlil qilindi. Fotoluminesans spektrlari spektrofotometr yordamida turli qo'zg'alish to'lqin uzunliklarida o'lchandi. Emissiya spektri, maksimal intensivlik va spektral siljish (Stokes shift) kabi parametrlar qayd etildi. Kvant chiqish samaradorligi standart moddalar bilan taqqoslash usuli orqali aniqlandi. Shuningdek, fotostabillikni baholash uchun namunalar ma'lum vaqt davomida UV nurlanish ostida ushlab turilib, emissiya intensivligining o'zgarishi kuzatildi. Bundan tashqari, materiallarning tuzilishini o'rganish uchun qo'shimcha fizik-kimyoviy tahlil usullari qo'llanildi. Ularga transmissiya elektron mikroskopiyasi (TEM), infraqizil spektroskopiya (FTIR) va rentgen difraksiyasi (XRD) kiradi. Ushbu usullar CQDs ning o'lchami, kristall tuzilishi va sirt funksional guruhlarini aniqlash imkonini berdi. Umuman olganda, qo'llanilgan metodologiya CQDs asosidagi luminescent bo'yoqlarning sintezi va ularning optik xossalarini kompleks baholashga yo'naltirilgan bo'lib, olingan natijalarning ilmiy ishonchliligini ta'minlaydi.

Tadqiqot natijalari va muhokama: Tadqiqot davomida uglerod nano nuqtachalari (CQDs) asosida yuqori intensiv yorug'lik chiqaruvchi innovatsion bo'yoqlar sintez

qilindi va ularning optik xossalari kompleks ravishda o'rganildi. Olingan natijalar CQDs ning fotoluminesans xususiyatlari sintez sharoitlari, zarracha o'lchami hamda sirt funksional guruhlari tarkibiga kuchli bog'liqligini ko'rsatdi. Spektrofluorimetrik o'lchovlar CQDs keng emissiya diapazoniga ega ekanligini tasdiqladi. Qo'zg'alish to'lqin uzunligi o'zgargan sari emissiya spektrining siljishi kuzatildi, bu esa ularning sozlanadigan yorug'lik chiqarish (tunable emission) xususiyatini namoyon etdi. Eng yuqori fotoluminesans intensivligi optimal sintez sharoitida olingan namunalarda qayd etildi, bu esa zarrachalarning bir xil dispersiyasi va faol sirt holatlari bilan izohlanadi. Kvant chiqish samaradorligi natijalari polimer matritsa bilan biriktirilgan kompozitlarda sezilarli darajada yuqori ekanligini ko'rsatdi. Ayniqsa PVA asosidagi tizimlarda emissiya barqarorligi va yorug'lik intensivligi yaxshilanganligi aniqlandi. Bu holat CQDs ning agregatsiyalanishining kamayishi va energiya yo'qotish jarayonlarining cheklanishi bilan bog'liq. Fotostabillik tahlillari CQDs asosidagi bo'yoqlar UV nurlanish ta'sirida ham nisbatan barqaror emissiya xususiyatini saqlab qolishini ko'rsatdi. Shunga qaramay, uzoq muddatli nurlanish natijasida ayrim namunalarda intensivlikning biroz pasayishi kuzatildi, bu sirt funksional guruhlarning qisman degradatsiyasi bilan izohlanadi. FTIR va TEM tahlillari CQDs ning nanometr o'lchamdagi sferik tuzilishga ega ekanligini hamda yuzasida gidroksil va karboksil guruhlari mavjudligini tasdiqladi. Ushbu funksional guruhlari materialning suvda eruvchanligini va polimerlar bilan mustahkam bog'lanishini ta'minladi. XRD tahlillari esa CQDs qisman amorf tuzilishga ega ekanligini ko'rsatdi. Muhokama jarayonida CQDs ning optik xossalari asosan sirt holatlari va elektron tuzilishdagi lokal energiya darajalari bilan belgilanishi aniqlandi. Emissiya jarayonida sirtga bog'langan holatlar asosiy rol o'ynab, keng spektrli yorug'lik chiqishini ta'minlaydi. Polimer matritsa esa materialning mexanik barqarorligini oshiribgina qolmay, optik emissiya barqarorligini ham mustahkamlaydi. Shu bilan birga, sintez jarayonining sezgirligi, zarracha o'lchamining to'liq bir xil emasligi va uzoq muddatli fotodegradatsiya kabi muammolar mavjudligi aniqlandi. Bu holatlar kelgusida materiallarni yanada optimallashtirish zarurligini ko'rsatadi. Natijalar CQDs asosidagi bo'yoqlar yuqori optik samaradorlik, barqaror emissiya va ekologik xavfsizlikka ega istiqbolli materiallar ekanligini tasdiqlaydi hamda ularning amaliy qo'llanilish sohasini kengaytirish mumkinligini ko'rsatadi.

Xulosa: Mazkur tadqiqotda uglerod nano nuqtachalari (CQDs) asosida yuqori intensiv yorug'lik chiqaruvchi innovatsion bo'yoqlarni yaratish va ularning optik xossalari o'rganish amalga oshirildi. O'rganishlar davomida CQDs ning fotoluminesans xususiyatlari ularning sintez sharoitlari, zarracha o'lchami va sirt funksional guruhlari bilan chambarchas bog'liqligi aniqlandi. Hidrotermal "bottom-up" usulida olingan CQDs yuqori barqarorlik va yaxshi emissiya xossalari namoyon

etdi. Polimer matritsalar (xususan PVA va PMMA) bilan hosil qilingan kompozit tizimlar CQDs ning agregatsiyalanishini kamaytirib, ularning kvant chiqish samaradorligi va yorug'lik intensivligini sezilarli darajada oshirdi. Spektral tahlillar CQDs ning keng diapazonda sozlanadigan emissiya xususiyatiga ega ekanligini tasdiqladi, bu esa ularning optoelektronika va funksional qoplama materiallarida qo'llanilish imkoniyatlarini kengaytiradi. Shu bilan birga, fotostabillikning cheklanganligi, sintez jarayonining sezgirligi va zarracha o'lchamining to'liq bir xil emasligi kabi muammolar mavjudligi qayd etildi. Ushbu muammolarni bartaraf etish CQDs asosidagi materiallarning sanoat miqyosida qo'llanilishini yanada kengaytirishga xizmat qiladi. Natijalar CQDs asosidagi bo'yoqlar ekologik xavfsiz, yuqori samarali va istiqbolli luminescent materiallar ekanligini tasdiqlaydi.

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TABLE OF CONTENTS

1	DEVELOPING ORAL COMMUNICATION SKILLS IN THE RUSSIAN LANGUAGE THROUGH INTERACTIVE LEARNING TOOLS Shabnam Khusanova Jamoliddinovna	3-9
2	UGLEROD NANO NUQTACHALARI ASOSIDA YUQORI INTENSIV YORUG‘LIK CHIQARUVCHI INNOVATSION BO‘YOQLAR YARATISH VA ULARNING OPTIK XOSSALARINI TADQIQ ETISH Bo‘riyeva Muhabbat Mamayusuf qizi	10-16