POLIMER ASOSLI LI-ION BATAREYALARINING TARKIBIY QISMLARI VA ULARNI TAYYORLASH TEXNOLOGIYASI

O.O.Mamatkarimov, A.A. Abdukarimov, B.I.Uktamaliyev, R.Mullabayeva, Sh.R.Ne'matjonov, A.U.Soatillayev
Namangan muhandislik texnologiya instituti, katta o'qituvchisi
Tel: +998936700333 e-mail: uktamaliyevb@mail.ru

Annotatsiya: Ma'lumki, yangi tarkibli metall asosli qattiq polimer elektrolitdan tayyorlangan batareyalarni energiyasi va quvvati zichligini yuqoriligi, tannarxi arzonligi, tayyorlash texnologiyasi soddaligi hamda uzoq muddat razryadlanmay tura olishi bilan ajralib turadi. Shuning uchun bu ishda ularni tayyorlash texnologiyasi qarab chiqilgan.

Kalit so'zlar: Li-ion batareya, polimer elektrolit, impedans, ion o'tkazuvchanlik, magniy trifloрometansulfonat.

Kirish. Li-ion batareyalari 1990 yillardan beri juda yaxshi rivojlanib kelmoqda[1-5]. Ular xosil qiladigan kuchlanishi va energiya zichligining yuqoriligi, atrof muhitni ifloslantirmasligi, yengilligi, o'z-o'zidan razryadlanish darajasining pastligi, ishchi holatining barqarorligi kabi afzalliklari tufayli bugungi kunda ixcham quvvat manbai sifatida keng qo'llanib kelinmoqda[6-15].

Xozirgi kunda Li-ion batarekalari millionlab insonlarni kundalik turmushida ko'chma olib yuriladigan texnikalar - noutbuk, uyali telefon, raqamli fotoapparat, videokamera kabi elektron qurulmalarida foydalanib kelinmoqda[16-23]. Ammo bu turdagi batareyalarni kamchiligi mavjud bo'lib bular portlash xavfi mavjudligi, minus temperaturada zaryadlash qiyinligi, ulardan foydalanilmagan xolatda ham ishdan chiqishi kabilardir[24-35]. Tadqiqotlar natijasida Li-ion batareyalariga nisbatan xavfsiz, yengil va ancha ixcham bo'lgan yangi turdagi polimer asosli Li-ion batareyalari yaratildi[36-45]. Bu batareyalar an'anaviy Li-ion, qo'rg'oshin kislotali, nikel-kadmiy batareyalaridan energiya va quvvat zichligini yuqoriligi, tannarxi arzonligi, yengilligi, xajmining kichikligi hamda foydalanilmagan holatda ham uzoq muddat razryadlanmay turaolishi bilan ajralib turadi[46-58].

Polimer elektrolitlar elektrofizik barqaror va yuqori ion o'tkazuvchanlikka ega[1]. Turli xil polimer elektrolit tizimlari ko'plab elektrofizik qurilmalarda o'rganilgan va qo'llanilgan. Suyuq elektrolitlardan foydalanganimizda erituvchini bug'lanish xavfi, elektrokimyoviy korroziya va oqish kabi salbiy oqibatlarini kuzatishimiz mumkin[59-69]. Bu xolatlar polimer elektrolitlarda sezilarli darajada kamayadi. Shuningdek, polimer elektrolitlar suyuq elektrolitlarga juda o'xshash bo'lgan va batareyani ishlash paytida yaxshi elektrod-elektrolitlararo aloqani ushlab tura oladigan xususiyatlarini namoyon etadi[70-89].

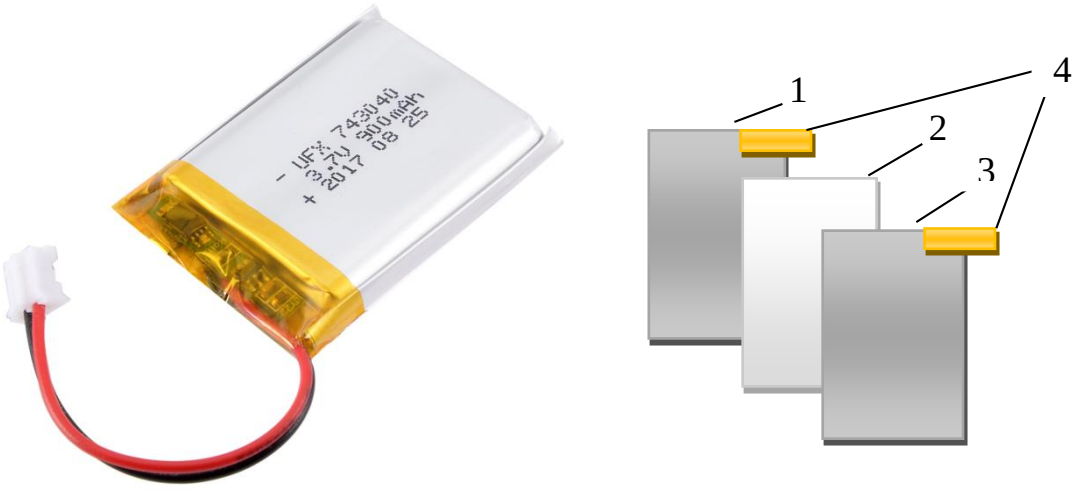
Polimer elektrolitlarni ham o'z navbatida 3 ta turga bo'linadi: qattiq polimer elektrolit (SPE)[90-110], Gel polimer elektrolit (GPE)[111-125], Suyuq polimer elektrolit (LPE). Suyuq polimer elektrolitlar organik erituvchida litiy tuzi va elektrodlarning qisqa tutashuvini oldini oladigan separatordan iborat. Gel-polimer

elektrolitlar - erituvchi, past molekulyar birikmali polimer va litiy tuzidan iborat. Polimer elektrolitlarda aralashma sifatida asosan polimetilmetakrilat (PMMA), poliakrilonitril (PAN), propilin karbonat (PC), polietilen oksid (PEO)[126-145], polivinilidenftorid (PVDF), polivinilbutiral (PVB), polipropilyen oksid foydalaniladi[146-158].

Asosiy qism

Polimer elektrolitni tayyorlashda ishlatiladigan materiallar Elektrolitlarni tayyorlashda quyidagi kimyoviy moddalar va eritmalardan foydalanildi. AQSH da (Sigma Aldrich firmasi) ishlab chiqilgan: polimetilmetakrilat (PMMA), polietilenoksid PEO, litiy trifloрometansulfonat ($LiTf_2$), etilen karbonat (EC), propilen karbonat (PC), tetragidrofuran (THF). Litiy permanganat ($LiMnO_4$), uglerod, polivinilidenftorid (PVDF), N-metilpirrolidon (NMP). Agar bu davlatlarda ishlab chiqilgan materiallar bo‘lmasa, O‘zbekistonda ishlab chiqarilgan materiallardan foydalanish mumkin[160-165].

Polimer asosli Li-ion batareyalarining umumiy ko‘rinishi 1- a rasmda, tarkibiy qismlari esa 1-b rasmda keltirilgan. Unga ko‘ra bu turdagi batareyalar katod, polimer elektrolit (seperator) va anoddan iborat. Biz ushbu ishda batareya tarkibiy qismlarining tayyorlanish texnologiyasi va ishlash prinsipini ko‘rib chiqamiz[166-171].



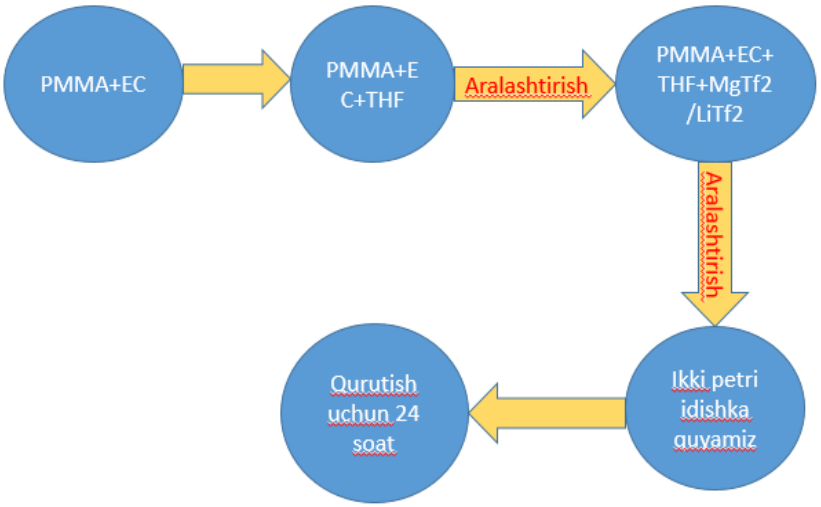
a) b)

1-rasm. a) Polimer asosli Li-ion batarekalarining umumiy ko‘rinishi, b) polimer asosli Li-ion batareyalarining tarkibiy qismlari. 1-anod, 2-elektrolit(seperator), 3-katod, 4- kontakt.

Qattiq polimer elektrolitni tayyorlash: Dastlab 2 gr polimetilmetakrilat (PMMA) moddasi, 1 gr etilen karbonat (EC), 0,75 gr litiy trifloрometansulfonat ($LiTf_2$) moddasidan olib menzurkaga solamiz va bunga erituvchi sifatida tetragidrofuran (THF) moddasidan 40 ml qo‘shamiz. Bu aralashmani 24 soat davomida xona xaroratida IKA C-MAG apparatida birjinsli holatga kelgunicha aralashtiramiz undan so‘ng diametri 8 smli petri chashkaga quyib olamiz. Petri idishdagi namunani 24 soat qurutish uchun yopiq idishda, qorong‘u joyga qo‘yamiz (2-rasm).

Tayyorlangan namunalarning o‘lchamlari va tarkibi quyidagi jadvalda keltirilgan:

Namuna nomi	Namuna qalinligi (sm)	PMMA (gr)	EC (gr)	$LiTf_2$ (gr)	THF (ml)
N1	0.0246	2	1	0.75	40
N2	0.0233	2	1	0.75	40
N3	0.028	2	1	0.75	40
N4	0.0287	2	1	0.75	40
N5	0.0203	2	1	0.75	40



2-rasm. Qattiq elektrolitni tayyorlanish bosqichlari

Polimer asosli Li-ion batareyalarining elektrodlarini tayyorlash. Elektrodlarning tarkibi quyidagi materiallardan tashkil topgan: Litiy permanganat ($LiMnO_4$), uglerod, polivinilidenftorid (PVDF), N-metilpirrolidon (NMP). Dastlab 0.8 mg litiy permanganat ($LiMnO_4$), 0,1 mg uglerod (S), 0,1 mg polivinilidenftorid (PVDF) tortib olamiz, 80°S temperaturada vakuum sharoitida $LiMnO_4$ hamda uglerod aralashmasini 5 daqiqa vaqt davomida qizdiramiz, so‘ng PVDF qo‘shib aralashtiramiz. Aralashma birjinsli xolatga kelganidan so‘ng unga NMP erituvchisidan 3-4 tomchi tomizamiz va aralashmani bir sutka davomida xona haroratida aralashtiramiz. Tayyor bo‘lgan namunalardan sendvich usulida quyidagi ketma-ketlikda batareyani yig‘amiz $LiMnO_4$/SPE/ Li metalli 1-b rasm.

Hulosa. An’anaviy Li-ion batareyalariga nisbatan xavfsiz, yengil va ancha ixcham bo‘lgan polimer asosli Li-ion batareyalari energiya va quvvat zichligini yuqoriligi, tannarxi arzonligi, tayyorlash texnologiyasi soddaligi hamda uzoq muddat razryadlanmay turaolishi bilan ajralib turadi. Bu batareyalarni respublikamizda ishlab chiqarishga tavsiya etamiz.

Foydalanilgan adabiyotlar

1. Bozorov, Kh N., O. O. Mamatkarimov, and B. T. Abdulazizov. "Electric and ionic conductivity of potassium antimony tungstate with addition of alkali metals." *«Узбекский физический журнал»* 24.2 (2022): 129-132.
2. Uktamaliyev, B. I., et al. "Determination of transport properties for polymer electrolytes containing LiTf and MgTf2 salts." *Molecular Crystals and Liquid Crystals* 763.1 (2023): 17-27.
3. Mamatkarimov, O. O., R. Khamidov, and A. Abdukarimov. "The relative current change, concentration, and carrier mobility in silicon samples doped nickel and at pulse hydrostatic pressure." *Materials Today: Proceedings* 17 (2019): 442-445.

4. Uktamaliyev, B. I., et al. "Determination of transport properties for polymer electrolytes containing LiTf and MgTf2 salts." *Molecular Crystals and Liquid Crystals* 763.1 (2023): 17-27.
5. Mamatkarimov, O., B. Uktamaliyev, and A. Abdukarimov. "Temperature dependence of active and reactive impedances of PMMA-EC-LITF2 solid polymer electrolytes." *НАУЧНЫЕ ОСНОВЫ ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ НОВОГО УРОВНЯ И СОВРЕМЕННЫЕ ПРОБЛЕМЫ АВТОМАТИЗАЦИИ* (2022): 366.
6. Manjuladevi, R., et al. "Preparation and characterization of blend polymer electrolyte film based on poly (vinyl alcohol)-poly (acrylonitrile)/MgCl 2 for energy storage devices." *Ionics* 24 (2018): 1083-1095.
7. Mamatkarimov, O., A. Abdukarimov, and B. Uktamaliev. "ABOUT THE CHARACTERISTICS OF MULTILAYER THIN-FILM STRUCTURES WITH DYES BASED ON TITANIUM DIOXIDE." *Euroasian Journal of Semiconductors Science and Engineering* 3.40 (2021): 26-29.
8. Odiljon, Mamatkarimov, Uktamaliyev Bekzod, and Abdullaziz Abdukarimov. "Determination of ionic conductivity of polymer electrolytes in li-ion batteries using electrochemical impedance spectroscopy." *ACADEMICIA: An International Multidisciplinary Research Journal* 11.7 (2021): 141-146.
9. Ikramov, R. G., et al. "Calculation of the interband absorption spectra of amorphous semiconductors using the Kubo-Greenwood formula." *Journal of Applied Science and Engineering* 25.5 (2021): 919-924.
10. Ikramov, Rustamjon G., et al. "Calculation of the Density of the Distribution of Electronic States in the Conduction Band from the Fundamental Absorption Spectra of Amorphous Semiconductors." *East European Journal of Physics* 4 (2023): 153-158.
11. Ikramov, Rustamjon G., et al. "Dangerous Bonds Individual of Hydrogenated Amorphous Silicon and Defect Absorption Spectra." *East European Journal of Physics* 4 (2023): 244-250.
12. Абдулазизов, Б. Т., et al. "Дефекты, характерные для гидрогенизированных аморф-ных полупроводников, и спектры дефектного поглощения." *«Узбекский физический журнал»* 25.3 (2023).
13. Ikramov, R. G., et al. "Kubo-greenwood Formula For The Exponential Absorption Region Of Amorphous Semiconductors And Distribution Of The Density Of Electronic States In The Tail Of The Conduction Band." *Journal of Applied Science and Engineering* 26.8 (2022): 1167-1171.
14. Абдулазизов, Б. Т., et al. "Область экспоненциального поглощения аморфных полупроводников." *«Узбекский физический журнал»* 24.2 (2022): 96-99. Икрамов, Рустамжон, et al. "СПЕКТРЫ КОЭФФИЦИЕНТА ДЕФЕКТНОГО ПОГЛОЩЕНИЯ АМОРФНЫХ ПОЛУПРОВОДНИКОВ." *Scientific Collection «InterConf»* 107 (2022): 409-420.
15. Муминов, Х. А., Б. Султонов, and О. Т. Холмирзаев. "РАСЧЕТ РАСПРЕДЕЛЕНИЕ ПЛОТНОСТИ ЭЛЕКТРОННЫХ СОСТОЯНИЙ В ВАЛЕНТНОЙ ЗОНЕ ИЗ СПЕКТРА МЕЖЗОННОГО ПОГЛОЩЕНИЯ АМОРФНЫХ ПОЛУПРОВОДНИКОВ." *EDITOR COORDINATOR* (2021): 384.
16. Икрамов, Рустамжон, et al. "СПЕКТРЫ КОЭФФИЦИЕНТА ДЕФЕКТНОГО ПОГЛОЩЕНИЯ АМОРФНЫХ ПОЛУПРОВОДНИКОВ." *Scientific Collection «InterConf»* 107 (2022): 409-420.
17. Maxmudovich, To‘xliyev Mansur. "PAST POTENSIALLI QUYOSH QURITGICHLARNI SAMARADORLIGINI OSHIRISH." *Educational Research in Universal Sciences* 1.6 (2022): 79-86.
18. Yusupov, Elmurod Kuchkarboyevich. "STUDYING PROPERTIES OF ROTATIONAL STATES 156Gd."
19. Байматов, П. Ж., et al. "ВЛИЯНИЕ ИЗМЕНЕНИЯ ХИМИЧЕСКОГО ПОТЕНЦИАЛА НА ТЕПЛОЕМКОСТЬ КВАЗИДВУМЕРНОГО ЭЛЕКТРОННОГО ГАЗА." *«Узбекский физический журнал»* 20.6 (2018).
20. Ravshanjon o’g, G‘aybullayev Dostonbek. "QUYOSH ENERGIYASI VA UNDAN FOYDALANISH." *O'ZBEKISTONDA FANLARARO INNOVATSIYALAR VA ILMIY TADQIQOTLAR JURNALI* 2.19 (2023): 1574-1576.
21. Ikramov, Rustamjon G., et al. "Calculation of the Density of the Distribution of Electronic States in the Conduction Band from the Fundamental Absorption Spectra of Amorphous Semiconductors." *East European Journal of Physics* 4 (2023): 153-158.
22. Ikramov, Rustamjon G., et al. "Dangerous Bonds Individual of Hydrogenated Amorphous Silicon and Defect Absorption Spectra." *East European Journal of Physics* 4 (2023): 244-250.
23. Ikramov, R. G., et al. "Kubo-greenwood Formula For The Exponential Absorption Region Of Amorphous Semiconductors And Distribution Of The Density Of Electronic States In The Tail Of The Conduction Band." *Journal of Applied Science and Engineering* 26.8 (2022): 1167-1171.
24. Ikramov, Rustamzhon Gulomzhonovich, Mashkhura Anvarbekovna Nuriddinova, and Xurshid Adhamjon Muminov. "A new method for determining the density distribution of electronic states on the tail of the valence band of amorphous semiconductors Se _x S _1-x." *Optics and spectroscopy* 129.11 (2021): 1382-1386.
25. Икрамов, Р. Г., М. А. Нуриддинова, and Х. А. Муминов. "Вычисление плотности электронных состояний в валентной зоне из экспериментального спектра межзонного поглощения аморфных полупроводников." *Журнал прикладной спектроскопии* 88.3 (2021): 378-382.
26. Икрамов, Рустамжон Гуломжонович, Машхура Анварбековна Нуриддинова, and Хуршид Адхамжон уғли Муминов. "Новый метод определения распределения плотности электронных состояний в хвосте валентной зоны аморфных твердых растворов Se _x S _1-x." *Оптика и спектроскопия* 129.11 (2021): 1382-1386.
27. Ikramov, Rustam, et al. "Temperature Dependence of Urbach Energy in Non-Crystalline Semiconductors." *Optics and Photonics Journal* 10.9 (2020): 211-218.

28. Абдулазизов, Б. Т., et al. "Расчет распределения плотности электронных состояний в хвосте зоны проводимости аморфных полупроводников." *«Узбекский физический журнал»* 22.6 (2020): 344-349.
29. IKRAMOV, RUSTAM GULOMJONOVICH, MASHXURA ANVARBEKOVNA NURIDDINOVA, and KHURSHID ADHAMJON UGLI MUMINOV. "Parameters defining the interzonal absorption coefficient in amorphous semiconductors." *Journal of Applied Physical Science International* 12.1 (2021): 36-40.
30. Ikramov, R. G., M. A. Nuriddinova, and R. M. Jalalov. "Density of defect states and spectra of defect absorption in a-Si: H." *Ukrainian journal of physics* 64.4 (2019): 315-315.
31. Ikramov, R. G., M. A. Nuriddinova, and A. Muminov Kh. "Spectra of the coefficient of defect absorption and the energy position of defects in amorphous hydrogenated silicon." *International Journal of Multidisplinary Trends* 1.1 (2019): 12.
32. Zaynobidinov, S., et al. "Infra-red absorption spectra of amorphous semiconductors." *Uzbekiston Fizika Zhurnali* 21.2 (2019): 88-92.
33. Ikramov, R. G., M. A. Nuriddinova, and A. Muminov Kh. "Spectra of the coefficient of defect absorption and the energy position of defects in amorphous hydrogenated silicon." *International Journal of Multidisplinary Trends* 1.1 (2019): 12.
34. ZAYNOBIDINOV, S., et al. "Spectra of interband absorption and optical gap of amorphous semiconductors; Spektry mezhzonnogo pogloshcheniya i opticheskaya shchel'amorfnykh poluprovodnikov." *Uzbekiston Fizika Zhurnali* 15 (2013).
35. Zainobidinov, S., et al. "Distribution of electron density of states in allowed bands and interband absorption in amorphous semiconductors." *Optics and spectroscopy* 110 (2011): 762-766.
36. Zajnobidinov, S., et al. "Dependence of the Urbach energy on the Fermi level in A-Si: H films; Zavisimost'ehnergii Urbakha ot urovnya Fermi v plenkakh a-Si: H." *Ukrayins' kij Fyizichnij Zhurnal (Kyiv)* 53 (2008).
37. Zajnovidinov, S., et al. "Temperature effect in absorption spectra of amorphous semiconductors; Temperaturnyj ehffekt v spektrakh pogloshcheniya amorfnykh poluprovodnikov." *Ukrayins' kij Fyizichnij Zhurnal (Kyiv)* 53 (2008).
38. Qo'chqarov, B. X., A. Nishonov, and X. O. Qochqarov. "Scientific bulletin of Namangan State University,"." *The effect of tunneling gurrent on the spedd surface generation of charge garries* 1.7 (2020): 3-6.
39. Qo'chqarov, Bekzod Xoshimjonovich, Azizbek Nishonov, and Xoshimjon Ortiqovich Qo'chqarov. "The effect of tunneling current on the speed surface generation of charge carriers." *Scientific Bulletin of Namangan State University 2019y* 1.7 (2009): 3-6.
40. Usmanov, P. N., A. I. Vdovin, and A. N. Nishonov. "Investigating the Energies and Electrical Characteristics of the Negative Parity States of the 156Gd Nucleus." *Bulletin of the Russian Academy of Sciences: Physics* 86.8 (2022): 918-923.
41. Усманов, П. Н., et al. "Энергия и структура октупольных состояний ядра 238U." *«Узбекский физический журнал»* 24.2 (2022): 90-95.
42. Arof, A. K., et al. "Investigation on morphology of composite poly (ethylene oxide)-cellulose nanofibers." *Materials Today: Proceedings* 17 (2019): 388-393.
43. Abdukarimov, Abdullaziz, et al. "Characteristics of dye-sensitized solar cells (DSSCs) using liquid and gel polymer electrolytes with tetrapropylammonium salt." *Optical and Quantum Electronics* 52 (2020): 1-15.
44. Abdukarimov, Abdullaziz, et al. "Influence of charge carrier density, mobility and diffusivity on conductivity–temperature dependence in polyethylene oxide–based gel polymer electrolytes." *High Performance Polymers* 34.2 (2022): 232-241.
45. Kuchkarov, B. H., et al. "Influence of all-round compression on formation of the mobile charge in lead-borosilicate glass structure." *American Institute of Physics Conference Series*. Vol. 2432. No. 1. 2022.
46. Uktamaliyev, B. I., et al. "Determination of transport properties for polymer electrolytes containing LiTf and MgTf2 salts." *Molecular Crystals and Liquid Crystals* 763.1 (2023): 17-27.
47. Mamatkarimov, O. O., R. Khamidov, and A. Abdukarimov. "The relative current change, concentration, and carrier mobility in silicon samples doped nickel and at pulse hydrostatic pressure." *Materials Today: Proceedings* 17 (2019): 442-445.
48. Uktamaliyev, B. I., et al. "Determination of transport properties for polymer electrolytes containing LiTf and MgTf2 salts." *Molecular Crystals and Liquid Crystals* 763.1 (2023): 17-27.
49. Abdukarimov, A. A., et al. "Dependence of the characteristics of dye-sensitized solar cells on amount tetrapropylammonium iodide." *«Узбекский физический журнал»* 22.4 (2020): 250-253.
50. Sultanov, A. M., A. A. Abdukarimov, and M. Z. Kufian. "Development of technology for creating high-voltage p0–n0 junctions based on GaAs." *Bulletin of the Karaganda University" Physics Series"* 112.4 (2023): 50-56
51. Abdukarimov, A. A., et al. "Characteristics of natural dye sensitized solar cells." *Molecular Crystals and Liquid Crystals* 767.1 (2023): 98-105.
52. Mamatkarimov, O., B. Uktamaliyev, and A. Abdukarimov. "Temperature dependence of active and reactive impedances of PMMA-EC-LITF2 solid polymer electrolytes." *НАУЧНЫЕ ОСНОВЫ ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ НОВОГО УРОВНЯ И СОВРЕМЕННЫЕ ПРОБЛЕМЫ АВТОМАТИЗАЦИИ* (2022): 366.
53. Manjuladevi, R., et al. "Preparation and characterization of blend polymer electrolyte film based on poly (vinyl alcohol)-poly (acrylonitrile)/MgCl 2 for energy storage devices." *Ionics* 24 (2018): 1083-1095.

54. Mamatkarimov, O., A. Abdukarimov, and B. Uktamaliev. "ABOUT THE CHARACTERISTICS OF MULTILAYER THIN-FILM STRUCTURES WITH DYES BASED ON TITANIUM DIOXIDE." *Euroasian Journal of Semiconductors Science and Engineering* 3.40 (2021): 26-29.
55. Yakubbaev, A. A., A. Abdukarimov, and S. H. Nazarov. "Application of pincents of spinal leaf (chlorophylle) as a natural die for paint sensitive sun element (DSSC)." *ACADEMICIA: An International Multidisciplinary Research Journal* 11.8 (2021): 185-188.
56. Odiljon, Mamatkarimov, Uktamaliyev Bekzod, and Abdullaziz Abdukarimov. "Determination of ionic conductivity of polymer electrolytes in li-ion batteries using electrochemical impedance spectroscopy." *ACADEMICIA: An International Multidisciplinary Research Journal* 11.7 (2021): 141-146.
57. Mamatkarimov, O., and A. Abdukarimov. "ABOUT THE CHARACTERISTICS OF MULTILAYER THIN-FILM STRUCTURES WITH DYES BASED ON TITANIUM DIOXIDE." *Euroasian Journal of Semiconductors Science and Engineering* 2.3 (2020): 28.
58. Abdukarimov, A. A. "UDK: 621.315. 592 MAIN ELECTROPHYSICAL CHARACTERISTICS OF DYE-SENSITIZED SOLAR CELLS (DSSCS)." *атты V Халықаралық ғылыми-тәжірибелік конференция*.
59. Корольков, В. И., and Александр Владимирович Рожков. "Исследование стабильности переключения высоковольтных субнаносекундных фотонно-инжекционных коммутаторов." *Письма в Журнал технической физики* 18.10 (1992): 26-31.
60. Sultanov, A. M., E. K. Yusupov, and R. G. Rakhimov. "Investigation of the Influence of Technological Factors on High-Voltage p0–n0 Junctions Based on GaAs." (2024).
61. Avrutin, E. A., Korol'Kov, V. I., ORLOV, B., Rozhkov, A. V., & Sultanov, A. M. (1992). Dynamic characteristics of high-power pulses generated in GaAs/AlGaAs superluminescent diodes. *Soviet physics. Semiconductors*, *26*(4), 403-406.
62. Sultanov, A. M., & Mirzarayimov, J. Z. (2024). MAIN TECHNOLOGICAL FACTORS AFFECTING THE PROPERTIES OF LOW-DOPED LAYERS AND TRANSISTOR n+-p0–n0 STRUCTURES. *European Journal of Emerging Technology and Discoveries*, *2*(3), 41-47.
63. Султанов, А. М., and Ж. З. Мирзарайимов. "ОСОБЕННОСТИ И ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ ФОТОННОЕ–ИНЖЕКЦИОННЫХ ИМПУЛЬСНЫХ ТИРИСТОРОВ ДЛЯ МОДУЛЯЦИИ УСИЛЕНИЯ ПОЛУПРОВОДНИКОВЫХ ГЕТЕРО ЛАЗЕРОВ." *Multidisciplinary Journal of Science and Technology* 4.3 (2024): 577-583.
64. Рожков, А. В., А. М. Султанов, and Х. Бозоров. "ГЕТЕРОПЕРЕХОДЫ МИКРОЭЛЕКТРОНИКЕ." *И ПРИКЛАДНЫЕ ПРОБЛЕМЫ СОВРЕМЕННОЙ ФИЗИКИ FUNDAMENTAL AND APPLIED PROBLEMS OF MODERN PHYSICS* (2023): 115.