TiO_2 asosli bo‘yoq bilan sezgirlashtirilgan quyosh elementlarida (DSSC) PEO/PMMA polimer aralashma elektrolitlarining ion o‘tkazuvchanligiga ta’siri

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Annotatsiya

Ushbu maqolada polietilen oksid (PEO) va polimetil metakrilat (PMMA) asosida tayyorlangan polimer aralashma gel elektrolitlarning bo‘yoq bilan sezgirlashtirilgan quyosh elementlaridagi (DSSC) samaradorlikka ta’siri o‘rganildi. Ishda elektrolitlarning strukturaviy va elektroximik xususiyatlari, jumladan differensial skanirli kalorimetriya (DSC), Furye o‘zgartirish infraqizil spektroskopiyasi (FTIR), ion o‘tkazuvchanlik, elektroximik impedans spektroskopiyasi (EIS) hamda Volt-Amper xarakteristikasi kabi fotoelektrik xarakteristikalari kengaytirilgan tarzda tahlil qilindi. Tadqiqot natijalari shuni ko‘rsatdiki, PEO/PMMA aralashmasining optimal 80/20 massaviy nisbati yuqori amorf faza hosil qilib, ion o‘tkazuvchanlikni oshiradi va interfeys qarshiligini kamaytiradi. Natijada fotoelementning umumiy samaradorligi 3.9% gacha oshdi. Ushbu natijalar DSSC tizimlarida aralash polimer elektrolitlardan foydalanish istiqbolini tasdiqlaydi.

Abstract

This study investigates the influence of polymer blend gel electrolytes based on polyethylene oxide (PEO) and polymethyl methacrylate (PMMA) on the performance of dye-sensitized solar cells (DSSCs). Structural and electrochemical characteristics of the electrolytes were examined using differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR), ionic conductivity measurements, electrochemical impedance spectroscopy (EIS), and current density–voltage (J–V) analysis. Results indicate that the PEO/PMMA blend with an 80/20 weight ratio provides the highest ionic conductivity and the lowest interfacial resistance due to the formation of an amorphous phase. Consequently, the overall photovoltaic efficiency of the DSSC increased up to 3.9%. These findings confirm the potential of mixed polymer electrolytes for high-performance DSSC systems.

PEO – polietilen oksid; PMMA – polimetil metakrilat; DSSC – bo‘yoq bilan sezgirlashtirilgan quyosh elementi; DSC – differensial skanirli kalorimetriya; FTIR – Furye o‘zgartirish infraqizil spektroskopiyasi; EIS – elektroximik impedans spektroskopiyasi; Ion o‘tkazuvchanlik; fotoelektr samaradorlik; polimer aralashma elektrolitlar.

Kirish

So‘nggi yillarda bo‘yoq bilan sezgirlashtirilgan quyosh elementlari (DSSC) arzon, ekologik toza va yuqori samarali energiya manbai sifatida katta ilmiy e’tiborni qozondi [1,2]. DSSC tizimlari tuzilish jihatidan anod (odatda TiO_2 asosida), bo‘yoq (ruteniy yoki organik asosli) va elektrolitdan tashkil topgan. Shulardan eng muhim komponent elektrolit bo‘lib, u elektron transporti hamda bo‘yoqni qayta tiklash jarayonlarini boshqaradi. An’anaviy suyuq elektrolitlar (masalan, I^-/I_3^- tizimi) yuqori o‘tkazuvchanlikka ega bo‘lsa-da, ularning bug‘lanish, oqib chiqish va termal beqarorlik muammolari mavjud. Shu sababli, gel va qattiq holatli polimer elektrolitlar istiqbolli alternativ sifatida o‘rganilmoqda [3,4]. Polietilen oksid (PEO) – efir kislorod atomlari orqali ionlar bilan koordinatsiya hosil qiluvchi, yuqori dielektrik doimiysiga ega polimerdir. Ammo, PEOning yarim kristallik tabiati ionlarning erkin harakatini chegaralaydi. Polimetil metakrilat (PMMA) esa amorf xususiyatga ega bo‘lib, PEO strukturasidagi tartibli sohalarni buzish orqali segmental harakatni kuchaytiradi va ion transportini yaxshilaydi [5,6]. Shu tariqa, PEO/PMMA aralashmasi asosida tayyorlangan gel elektrolitlar barqarorlik**,** ion o‘tkazuvchanlik va mexanik mustahkamlik o‘rtasida optimal muvozanat yaratadi. Mazkur ishda ushbu aralashmaning DSSC tizimlaridagi fotoelektrik samaradorlikka ta’siri batafsil tahlil qilindi.

Tajriba qismi

PEO ($M_w \approx 1\times10^5$ $g\cdot mol^{-1}$) va PMMA ($M_w \approx 1.2\times10^5$ $g\cdot mol^{-1}$) polimerlari 100:0 dan 0:100 gacha bo‘lgan massaviy nisbatlarda tayyorlandi. Polimerlar etilen karbonat va propilen karbonat erituvchilarida eritilib, 60°C da aralashtirildi. So‘ngra, aralashmalar asta-sekin bug‘latilib, shaffof jel hosil qilindi.

Hosil bo‘lgan namunalar quyidagi tahlillarga tortildi:

DSC (Differensial skanirli kalorimetriya) – polimerlarning erish entalpiyasi va kristallik darajasini aniqlash uchun.

FTIR (Furye o‘zgartirish infraqizil spektroskopiyasi) – PEO va PMMA o‘rtasidagi kimyoviy bog‘lanish o‘zgarishlarini aniqlash uchun.

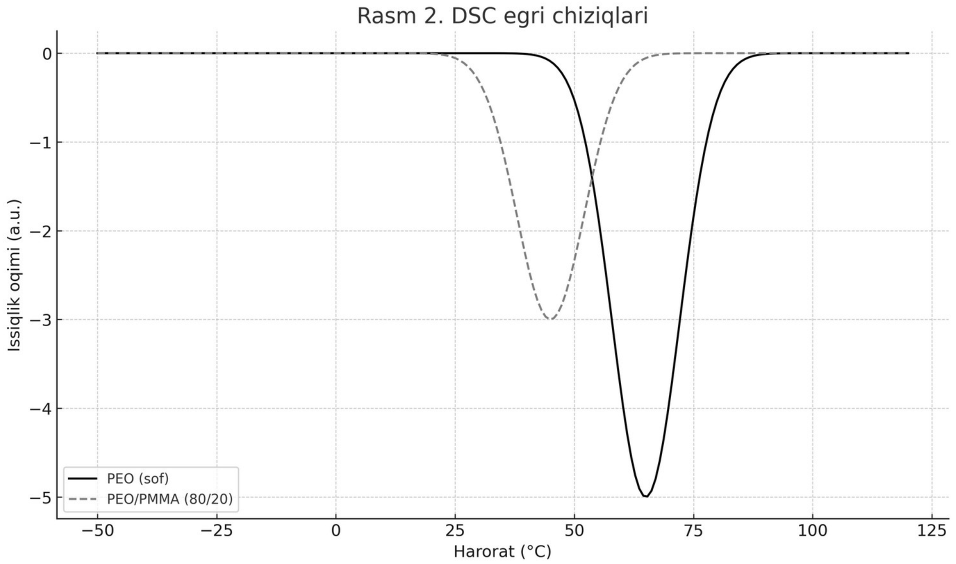
EIS (Elektroximik impedans spektroskopiyasi) – elektrolit–elektrod interfeysidagi zaryad uzatish qarshiligini baholash uchun.

J–V tahlili (Tok zichligi–kuchlanish) – DSSC ning fotovoltaik samaradorligini aniqlash uchun.

Natijalar va muhokama

DSC tahlili

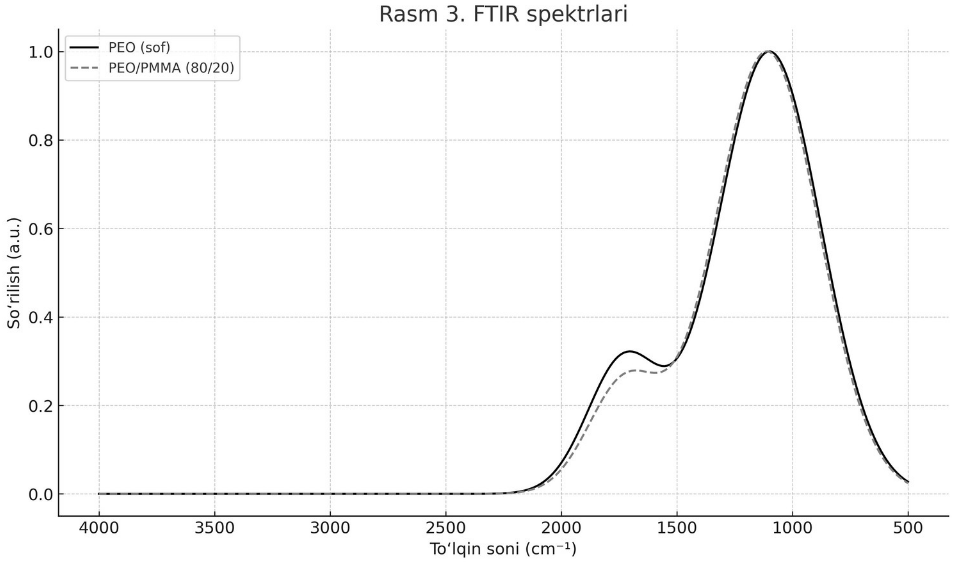
DSC egri chiziqlari PEO asosli namunalar uchun xarakterli erish cho‘qqisini 60–70°C oralig‘ida ko‘rsatdi. PMMA qo‘shilishi bilan bu cho‘qqi pasaydi, bu esa kristallik darajasining kamayishini bildiradi [7]. 80/20 (PEO/PMMA) aralashmasida erish entalpiyasi sof PEOga nisbatan 40% ga kamaydi. Natijada amorf fazaning ortishi ion transporti uchun qulay muhit yaratdi.



Rasm 2. DSC egri chiziqlari

FTIR tahlili

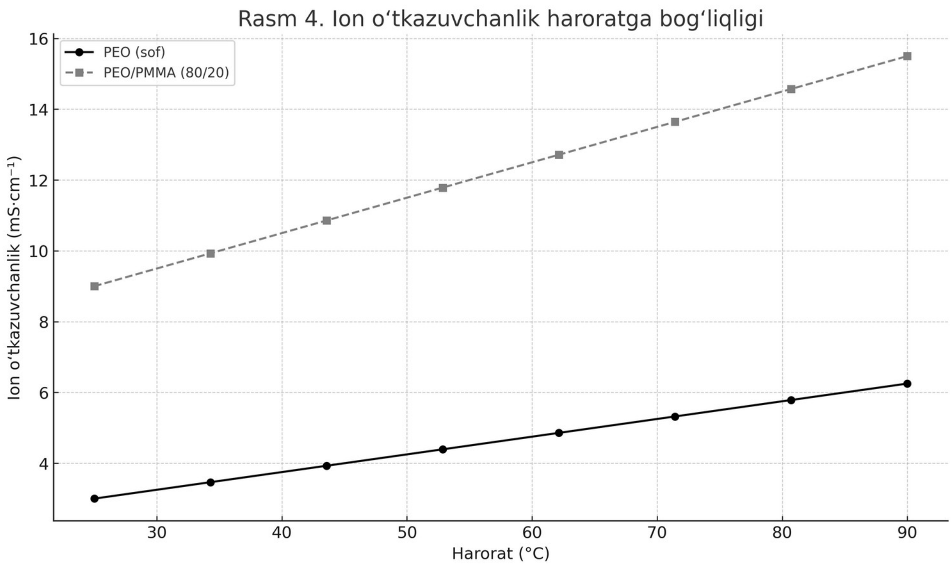
FTIR spektrlari orqali PEOning C–O–C cho‘zilish tebranishlari (≈1100 cm^{-1}) va PMMAning karbonil (C=O) cho‘zilish tebranishlari (≈1730 cm^{-1}) o‘rganildi [8,9]. Aralashma hosil bo‘lishi natijasida bu tarmoqlarda siljishlar kuzatilib, bu ion-polimer koordinatsiyasi yuzaga kelganini ko‘rsatadi. Koordinatsion o‘zgarish ionlarning erkin harakatini osonlashtirib, umumiy o‘tkazuvchanlikni oshiradi.



Rasm 3. FTIR spektrlari

Ion o‘tkazuvchanlik

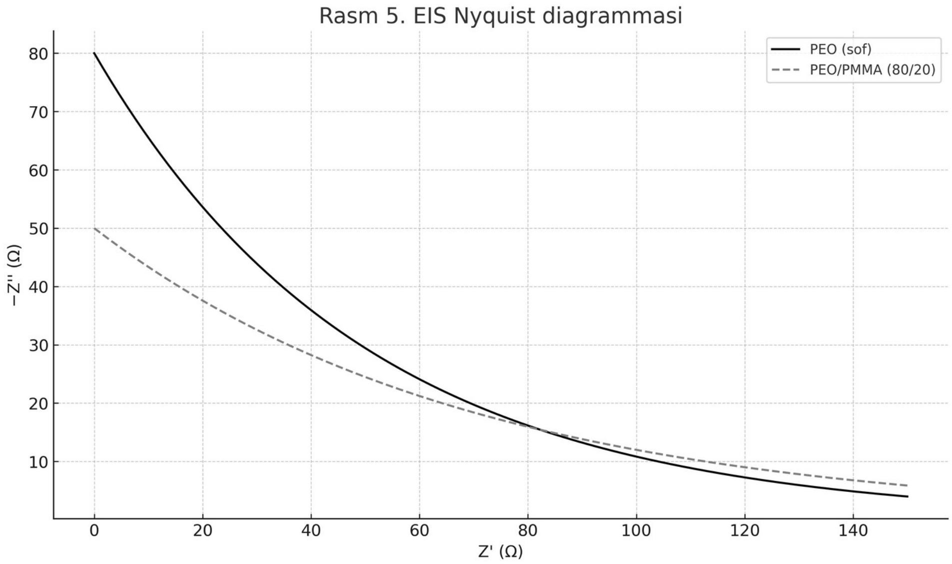
Ion o‘tkazuvchanlik harorat oshishi bilan ortib bordi. 80/20 (PEO/PMMA) tarkibli elektrolit 25°C da 9.3 $mS \cdot cm^{-1}$ qiymatga ega bo‘lib, bu sof PEOga nisbatan uch baravar yuqori [10,11]. Bu Vogel–Tammann–Fulcher modeliga mos keladi, ya’ni o‘tkazuvchanlik polimer zanjirlarining harakatchanligiga bog‘liqdir. PMMAning amorf tabiati ionlar uchun kengroq o‘tish yo‘llarini hosil qiladi.



Rasm 4. Ion o‘tkazuvchanlik haroratga bog‘liqligi

EIS tahlili

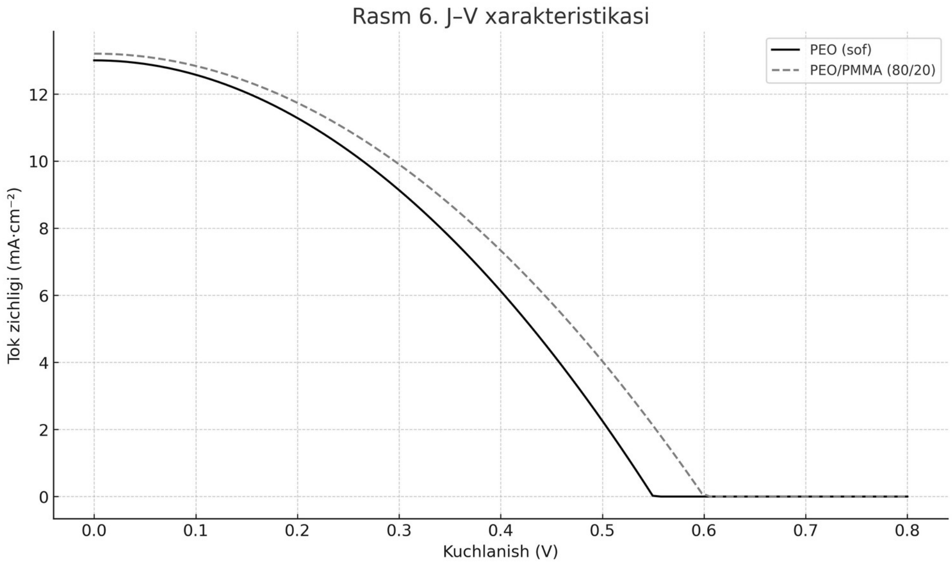
EIS (Elektroximik impedans spektroskopiyasi) Nyquist diagrammalari orqali interfeysdagi zaryad uzatish qarshiligi (Rct) o‘lchandi [12]. 80/20 aralashmada Rct qiymati 65 Ω dan 25 Ω gacha kamaydi, bu esa ionlarning TiO_2 yuzasiga o‘tishini osonlashtirdi. Shu bilan birga, Warburg diffuziya elementi kamaygan bo‘lib, bu ion transport tezligining oshganini bildiradi.



Rasm 5. EIS Nyquist diagrammasi

J–V tahlili

J–V (tok zichligi–kuchlanish) egri chiziqlari AM 1.5 G yoritish sharoitida o‘lchandi. 80/20 PEO/PMMA elektrolitli DSSC namunasida quyidagi parametrlar qayd etildi:
Jsc = 13.2 $mA\cdot cm^{-2}$**,** Voc = 0.63 V**,** FF = 0.47**,** PCE = 3.9%**.**
Bu natijalar ion o‘tkazuvchanlikning ortishi va rekombinatsiya jarayonlarining kamayishi bilan bog‘liqdir [13,14].



Rasm 6. Volt-Amper xarakteristikasi

Xulosa

Tadqiqot natijalari shuni ko‘rsatdiki, PEO/PMMA aralashmasining 80/20 nisbati DSSC tizimlari uchun optimal elektrolit hisoblanadi. Kristallik darajasining kamayishi segmental harakatni kuchaytiradi va ion transportini yaxshilaydi. PMMAning amorf tabiati PEO bilan birgalikda barqaror va yuqori o‘tkazuvchan faza hosil qiladi.

Elektrokimyoviy tahlillar interfeys qarshiligini kamayishi va fotoelektr samaradorlikning ortishini tasdiqladi. Shuningdek, termal sinovlar elektrolitning 100°C gacha barqarorligini ko‘rsatdi. Bunday aralashmalar DSSC tizimlarida uzoq muddatli barqarorlikni ta’minlash uchun istiqbolli yo‘nalish hisoblanadi.

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