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YUPQA PARDALI FOTOTERMOBATAREYALAR ISHLAB CHIQISHDAGI ASOSIY NOQULAYLIKLAR

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Annotatsiya: Fototermobatareyalarni ishlab chiqarish xarajatlari yuqori bo‘lib, ularning ommaviy ishlab chiqarishni xozircha imkoni yo‘q. Toksik elementlardan foydalanish esa qo‘shimcha ekologik standartlar va qayta ishlash texnologiyalarini talab qiladi, bu esa FTBni yanada qimmatlashishiga olib keladi. Hozirgi kunda fototermobatareyalar sohasida qator yechilmagan masalalar mavjud. Masalan: qatlamlar interfeysi (orasi)dagi rekombinatsiya jarayonlari, uzoq muddatli barqarorlikni ta’minlash, hamda foto va termo elementlarning optimal integratsiya sxemasini aniqlash shular jumlasidandir. Bu yo‘nalishdagi tadqiqotlardan olinadigan natijalar kelgusida fototermobatareyalar samaradorligini oshirish va ularni amaliyotga keng joriy etish imkonini beradi.

Kalit so‘zlar: Fotobatareya (CdTe), termobatareya (Bi_2Te_3, Sb_2Te_3), integratsiya sxemasi, samaradorlik, yupqa qatlamli fototermobatareya.

Аннотация: Стоимость производства фототермоэлементов высока, и их массовое производство в настоящее время невозможно. Использование токсичных элементов требует дополнительных экологических стандартов и технологий переработки, что дополнительно увеличивает стоимость ФТБ. В настоящее время в области фототермоэлементов существует ряд нерешенных вопросов. Например, рекомбинационные процессы на границе раздела слоев, обеспечение долговременной стабильности и определение оптимальной схемы интеграции фото- и термоэлементов. Результаты исследований в этой области позволят в будущем повысить эффективность фототермоэлементов и широко внедрить их в практику.

Ключевые слова: Фотоэлемент (CdTe), термоэлемент (Bi_2Te_3, Sb_2Te_3), схема интеграции, эффективность, тонкопленочный фототермоэлемент.

Abstract: The production costs of photothermocells are high, and their mass production is currently not possible. The use of toxic elements requires additional environmental standards and processing technologies, which further increases the cost of FTB. Currently, there are a number of unresolved issues in the field of photothermocells. For example, recombination processes at the interface (between) layers, ensuring long-term stability, and determining the optimal integration scheme of photo and thermal elements. The results of research in this area will

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allow in the future to increase the efficiency of photothermocells and widely introduce them into practice.

Keywords: Photocell (CdTe), thermal cell (Bi_2Te_3, Sb_2Te_3), integration scheme, efficiency, thin-film photothermocell.

Kirish

Materiallar va uslublar:

Harorat oshishi bilan fotoelektrik samaradorlik pasayishni boshlaydi, bu esa fototermobatareya ishlab chiqishda tabiiy muammoga aylanib qolmoqda [1].

Termoelementlar ortiqcha issiqlikdan energiya olsa-da, ularning η odatda 5–8% dan oshmaydi. Qatlamlar interfeysi (orasi)da elektron va fononlarning rekombinatsiyasi yo‘qotishlarga olib keladi [2-3].

Optimal integratsiya sxemasida, qaysi tartibda qo‘shish (Glass/EVA/PV/EVA/TE/Tedler) samaraliroq ekanini aniqlash orqali amalga oshiriladi [4]. Yupqa pardali fotoelektrik elementlar (CdTe) va termoelementlar (Bi_2Te_3, Sb_2Te_3) birlashtirilganda fototermobatareya hosil bo‘ladi. CdTe yupqa pardali elementlari odatda $\eta = 17-22\%$ samaradorlikka ega (yoqori laboratoriya namunasi $\eta \approx 22.2\%$ [5-7].

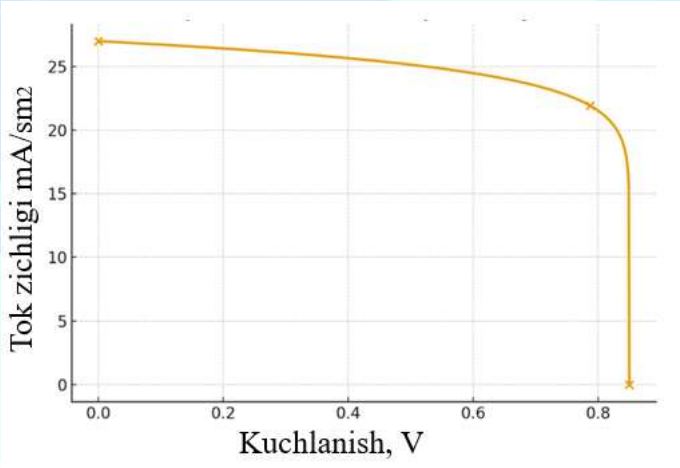
Bi_2Te_3 va Sb_2Te_3 asosidagi termoelementlarda samaradorlik ($ZT \approx 1–1.2$), elektrga aylanishi $\eta \approx 5–8\%$ ni tashkil qiladi [8-10].

Ortiqcha issiqlik (CdTe da foton energiyasining bir qismi issiqlikka aylanadi) termoelement orqali qo‘shimcha elektr ishlab chiqish hususiyatiga egadir [11-14]. Olimlar hisoblariga ko‘ra erishiladigan samaradorlik, oddiy CdTe paneli: $\eta \sim 18-20\%$, gibrid tizimda esa, CdTe + Bi_2Te_3/Sb_2Te_3 qo‘shimcha $\eta \approx 2-4\%$ qo‘shilishi mumkin. Umumiy olganda $\eta \approx 23–26\%$ ga atrofida bo‘lishi mumkin [15].

Natija va munozara: CdTe elementlari va Bi_2Te_3 asosidagi termoelektrik modul qo‘shilganda, $\eta \approx 30\%$ ga yaqin yaxshilanishi qayd etilgan (Zhang va boshqalar., *Journal of Materiomics*, 2019) [3, 16].

Ushbu natijani quyidagi 1-grafik orqali ko‘rishimiz mumkin.

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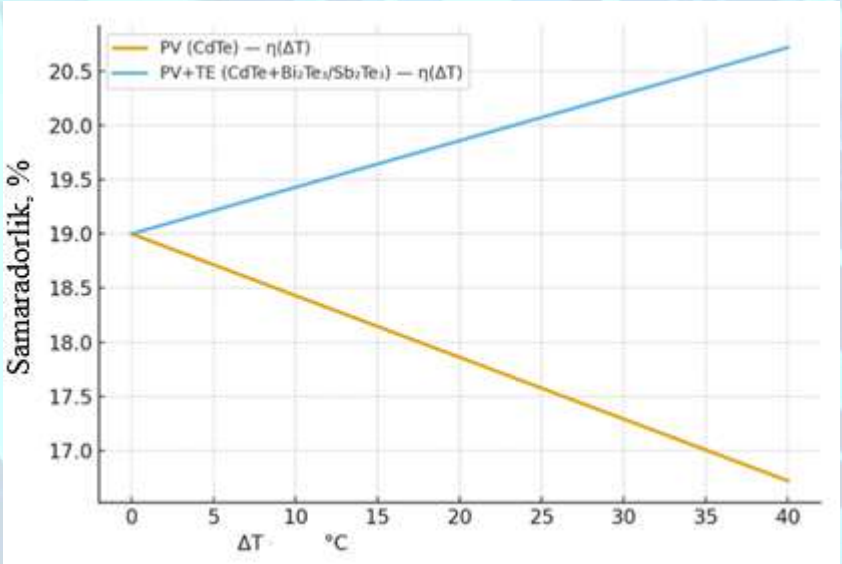
1-grafik. Yupqa pardali CdTe fotobatareyaning tok-kuchlanish grafigi.

Ushbu grafikda CdTe JV ning qiyosiy representative parametrlarda (Voc≈0.85 V, Jsc≈27 mA/cm², FF≈0.75) bazaviy η≈**17.3%** chiqdi.

Bu yerda yupqa pardali FTB elementning tok–kuchlanish **qiyasi, gorizontal o‘q (V)** va kuchlanish (volt) egri chiziqlari keltirilgan. Bunda, qiyos nol kuchlanishda (V=0) **eng katta tok JSC ≈ 27 mA/sm²**ni ko‘rsatadi. Kuchlanish maksimal nuqtaga yetganda ya’ni Voc≈0.85 V bo‘lganda, tok nolga tushadi.

MPP (Maximum Power Point) nuqtada; Vm≈0.6 V, Jm≈27 mA/sm² dan kamroq shu yerda maksimal elektr quvvati olinadi va hisoblangan samaradorlik η≈**17.3%** bo‘ldi.

2-grafikda esa samaradorlik η va ΔT — konseptual modeli keltirilgan. Bunda, PV (CdTe) ni harorat oshganda pasayishi va gibrid **PV (CdTe)+TE (Bi_2Te_3/Sb_2Te_3)** ni qo‘shilgandagi hissasi (ΔT=40 °C da ~+4% absolyut) ko‘rsatilgan. Bu grafikda CdTe paneli va gibrid (CdTe+Bi_2Te_3/Sb_2Te_3) fototermobatareyasi taqqoslangan.



2-grafik. Gibrid PV (CdTe)+TE (Bi_2Te_3/Sb_2Te_3) ning samaradorlikka bog‘liqligi grafigi keltirilgan.

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Masalan, **ΔT=25 °C** da PV≈**17.6%**, PV+TE≈**20.1%** (≈**+2.5% - punkt** qo‘shimcha). **η va ΔT** samaradorlik haroratga bog‘liq.

Gorizontal o‘q (ΔT) – panelning standart test sharoiti (STC)ga nisbatan harorati qancha ko‘tarilgani (°C). **Vertikal o‘q (η)** – samaradorlik (%). PV (CdTe) chizig‘i keltirilgan.

Bunda, harorat ortishi bilan samaradorlik pasayadi. Masalan, ΔT=25 °C da η≈**17.6%**. PV+TE (CdTe+Bi_2Te_3/Sb_2Te_3) chizig‘i

Bu holda CdTe ning fotoelektrik samaradorligi pasaysa-da, ortiqcha issiqlik termoelementlar orqali elektrga aylanadi.

ΔT=25 °C da gibrid η≈**20.1%**, ya’ni oddiy CdTe dan ≈**+2.5%** yuqori ekanligini ko‘rishimiz mumkin.

ΔT=40 °C ga yetganda qo‘shimcha η≈**22.3 %**, ~4% η ortishi mumkin.

Xulosa: Gibrid tizim harorat oshgan sharoitda ham yuqoriroq samaradorlikni saqlab qoladi va CdTening «issiqlikdan yo‘qotish» muammosini qisman hal qiladi. Yupqa pardali CdTe elementlari va termoelementlar (Bi_2Te_3/Sb_2Te_3) ini birlashtirish orqali samaradorlikni 2–4% ga oshirish mumkin ekan. Bu katta qiymat emasdek tuyulishi mumkin, ammo sanoat miqyosida bir necha foiz η o‘sishi juda katta iqtisodiy va energetik samara berishi mumkin ekanligi aniqlandi.

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