JOURNAL OF TRANSPORT

ISSUE 3, 2026 vol. 3
E-ISSN: 2181-2438
ISSN: 3060-5164

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TOSHKENT DAVLAT TRANSPORT UNIVERSITETI

Tashkent state transport university

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VOLUME 3, ISSUE 3

SEPTEMBER, 2026

jot.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

JOURNAL OF TRANSPORT

SCIENTIFIC-TECHNICAL AND SCIENTIFIC INNOVATION JOURNAL

VOLUME 3, ISSUE 3 SEPTEMBER, 2026

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Received: 30 July 2026 | **Accepted:** 10 September 2026 | **Published:** 30 September 2026

IR spectroscopic study of the formation of functional groups on the surface of polymer materials for packaging under the influence of corona discharge

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Abstract: The article presents the results of an investigation of the surface properties of polypropylene and polyethylene polymer films before and after corona discharge treatment using infrared (IR) spectroscopy. Absorption bands characteristic of the main functional groups of the polymers were identified. After corona discharge treatment, the spectra of BOPP and PE films exhibited new absorption bands in the 1700–1750 cm^{-1} region, indicating the formation of oxygen-containing functional groups on the polymer surfaces, particularly carbonyl (C=O) groups. The results demonstrate that corona discharge treatment increases the polarity and surface energy of the polymers, as well as improving their wettability and adhesion properties. The findings provide a basis for substantiating the effectiveness of corona treatment of polymer films in enhancing their adhesion to printing inks and improving print quality.

Keywords: polymer film, polypropylene, polyethylene, BOPP, IR spectroscopy, corona discharge, surface energy, functional group, adhesion, printing ink

Qadoqlar uchun polimer materiallar yuzasida tojli razryad ta’sirida funksional guruhlarning shakllanishini iq-spektroskopik tadqiqi

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Annotatsiya: Maqolada polipropilen va polietilen polimer plyonkalarning tojli razryad bilan ishlov berishdan oldingi va keyingi sirt xususiyatlarini infraqizil (IQ) spektroskopiya usulida tadqiq qilish natijalari keltirilgan. Polimerlarning asosiy funksional guruhlariga xos yutilish polosalari aniqlandi. Tojli razryad bilan ishlov berilgandan keyin BOPP va PE plyonkalar spektrlarida 1700–1750 sm^{-1} sohada yangi yutilish polosalarining paydo bo‘lishi polimer sirtida kislorod saqlovchi funksional guruhlar, xususan, karbonil (C=O) guruhlari shakllanganligini ko‘rsatdi. Natijalar tojli razryad ta’sirida polimer sirtining qutbliligi va sirt energiyasi ortishi, namlanish hamda adgezion xususiyatlar yaxshilanishini ko‘rsatdi. Olingan natijalar polimer plyonkalarning bosma bo‘yoqlari bilan adgezion o‘zaro ta’sirini oshirish va bosma sifatini yaxshilashda tojli razryadli ishlov berishning samaradorligini asoslash imkonini beradi.

Kalit so‘zlar: polimer plyonka, polipropilen, polietilen, BOPP, IQ-spektroskopiya, tojli razryad, sirt energiyasi, funksional guruh, adgeziya, bosma bo‘yoq

1. Kirish

Polimer materiallar zamonaviy bosma va qadoqlash sanoatida keng qo‘llaniladigan materiallardan biri bo‘lib, ularning funksional va ekspluatatsion xususiyatlari nafaqat polimerning hajmiy tuzilishi, balki sirt qatlamining fizik-kimyoviy holati bilan ham belgilanadi. Ayniqsa, polietilen (PE) va polipropilen (PP), jumladan, biaksial yo‘naltirilgan polipropilen (BOPP) plyonkalar yuqori mexanik mustahkamligi, kimyoviy barqarorligi, namlikka chidamliligi va texnologik qulayligi tufayli qadoqlash materiallari hamda bosma mahsulotlar ishlab chiqarishda keng qo‘llaniladi.

Shu bilan birga, polietilen va polipropilen kabi polimerlarning sirt energiyasi nisbatan past bo‘lganligi sababli ularni bosma bo‘yoqlari bilan namlash va mustahkam adgezion bog‘lanish hosil qilishda muayyan texnologik qiyinchiliklar yuzaga keladi. Polimer sirtining past qutbliligi bo‘yoqning sirtga bir tekis tarqalishi, namlanishi va mustahkam birikishini cheklaydi. Shu munosabat bilan polimer plyonkalar sirtini bosma jarayoniga tayyorlash va uning adgezion xususiyatlarini yaxshilash muhim ilmiy-amaliy vazifalardan biri hisoblanadi.

Polimer sirtini modifikatsiyalashning samarali usullaridan biri tojli razryad bilan ishlov berish hisoblanadi. Ushbu jarayon ta’sirida polimer sirtida fizik va kimyoviy o‘zgarishlar sodir bo‘lib, sirt energiyasi va qutblilikning ortishi, namlanish qobiliyatining yaxshilanishi hamda yangi funksional guruhlarning shakllanishi kuzatiladi. Natijada polimer sirtining bosma bo‘yoqlari bilan adgezion o‘zaro

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ta’siri kuchayadi. Polimer materiallarning sirt va hajmiy tuzilishini, makromolekulyar zanjirlardagi funksional guruhlarni hamda tashqi ta’sirlar natijasida yuzaga keladigan struktur o‘zgarishlarni aniqlashda infraqizil (IQ) ahisoblanadi. IQ-spektroskopiya yordamida polimer tarkibidagi funksional guruhlarga xos yutilish polosalarini aniqlash va spektral xarakteristikalardagi o‘zgarishlar asosida materialning kimyoviy tuzilishida sodir bo‘lgan o‘zgarishlarni baholash mumkin [1]. Shu nuqtai nazardan, tojli razryad bilan ishlov berilgan polimer plyonkalarning sirt qatlamida yuzaga keladigan kimyoviy o‘zgarishlarni IQ-spektroskopiya usulida o‘rganish mazkur ishning dolzarbligini belgilaydi.

2. Tadqiqot metodologiyasi

Polimer materiallarni sirt modifikatsiyalash va ularning adgezion xususiyatlarini yaxshilash masalalari bo‘yicha olib borilgan tadqiqotlarda tojli razryadli ishlov berish usuliga alohida e’tibor qaratilgan. Tadqiqotlar shuni ko‘rsatadiki, yuqori kuchlanishli tojli razryad ta’sirida polimer sirtida erkin radikal markazlar hosil bo‘lib, ular atmosfera tarkibidagi kislorod va namlik bilan o‘zaro ta’sirga kirishadi. Bu jarayon natijasida sirtda kislorod saqlovchi qutbli funksional guruhlar shakllanadi [2–4].

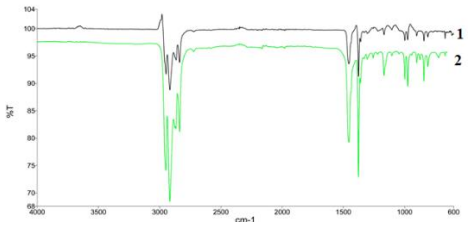
Polipropilen va polietilen plyonkalarning sirt xususiyatlarini o‘rganishga bag‘ishlangan ilmiy ishlar tahlili tojli razryad ta’sirida sirt energiyasining ortishi va kontakt burchagining kamayishini ko‘rsatgan. Bunday o‘zgarishlar polimer sirtining namlanish qobiliyati yaxshilanishi bilan bog‘liq bo‘lib, keyingi bosqichda bo‘yoq, lak va boshqa qoplama materiallarining sirtga adgeziyasini oshirish imkonini beradi.

IQ-spektroskopiya polimerlarning kimyoviy tarkibi va funksional guruhlarini identifikatsiya qilishda keng qo‘llaniladigan analitik usullardan biri hisoblanadi. Mazkur usulda molekulalarning infraqizil nurlanishni yutishi ulardagi kimyoviy bog‘larning valent va deformatsion tebranishlari bilan bog‘liq. Shu sababli ma’lum to‘lqin sonlaridagi yutilish polosalari polimer tarkibidagi C–H, C–C, C=C, C=O va O–H kabi funksional guruhlarni aniqlash imkonini beradi. Polipropilenning IQ-spektrida 3000–2800 sm^{-1} sohada C–H bog‘larining valent tebranishlari, 1500–1300 sm^{-1} sohada esa C–H va C–C bog‘larining deformatsion tebranishlari xarakterli hisoblanadi. Polimer sirti oksidlanganda esa 1700–1750 sm^{-1} sohada C=O bog‘iga xos yangi yutilish polosalarining paydo bo‘lishi kuzatilishi mumkin. Mazkur spektral o‘zgarishlar polimer sirtida kislorod saqlovchi funksional guruhlarning shakllanganligidan dalolat beradi.

Adabiyotlar tahlili shuni ko‘rsatadiki, tojli razryad bilan ishlov berishning polimer sirtidagi funksional guruhlar tarkibiga ta’siri yetarlicha o‘rganilgan bo‘lsa-da, BOPP va PE plyonkalarda spektral o‘zgarishlarning bosma bo‘yoqlari bilan adgezion o‘zaro ta’sirga ta’sirini kompleks baholash masalasi qo‘shimcha tadqiqotlarni talab etadi. Shu sababli mazkur tadqiqotda BOPP va PE plyonkalarning tojli razryaddan keyingi IQ-spektrlarini o‘rganish orqali sirtda shakllangan funksional guruhlarni aniqlash va ushbu o‘zgarishlarni polimerning adgezion xususiyatlari bilan bog‘lashga alohida e’tibor qaratildi.

Mazkur tadqiqotning maqsadi tojli razryad ta’sirida ishlov berilgan polimer plyonkalarning IQ-spektroskopik xususiyatlarini o‘rganish, makromolekulyar zanjirlarning yo‘nalganligi va uzunligi, shuningdek, polimer sirtida hosil bo‘luvchi funksional guruhlarning spektral yutilish intensivligiga ta’sirini aniqlashdan iborat.

Tadqiqot obekti sifatida qalinligi 20 mkm bo‘lgan biaksial yo‘naltirilgan polipropilen (BOPP) va polietilen (PE) polimer plyonkalaridan foydalanildi. Namunalarning IQ-spektroskopik tahlili PerkinElmer Spectrum Two spektrofotometrida 4200–600 sm^{-1} to‘lqin sonlari diapazonida amalga oshirildi. Olingan eksperimental spektrlar Aldrich-IChem IQ-spektrlar kutubxonasi ma’lumotlari bilan taqqoslanib, polimerlarning funksional guruhlari va ularga mos yutilish sohalari identifikatsiya qilindi(1-rasm).

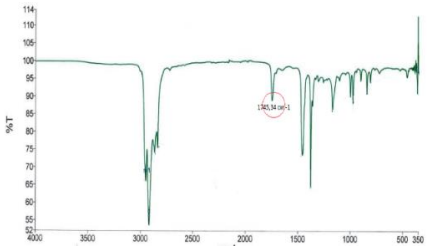


1-rasm. 1–BOPP ning tojli razryadli ishlov beriogandan oldingi IQ-spektri; 2–Aldrich-IChem IQ-spektr kutubxona baza dasturidagi spektri

Tadqiqot natijalari shuni ko‘rsatdiki, tojli razryad bilan ishlov berilmagan BOPP plyonkaning IQ-spektri polipropilenga xos bo‘lgan yutilish polosalari bilan tavsiflanadi (1-rasm). Xususan, 2949–2918 sm^{-1} sohada to‘yingan C–H bog‘larining simmetrik valent tebranishlari, 2867–2838 sm^{-1} sohada esa C–H bog‘larining asimmetrik valent tebranishlariga mos yutilish polosalari qayd etildi. 1456–1375 sm^{-1} diapazonida C–C va C–H bog‘lariga xos deformatsion va valent tebranishlar kuzatildi. Shuningdek, 1167, 997, 972 va 840 sm^{-1} sohalarda polipropilen makromolekulalaridagi C–H va C–C bog‘lariga xos tebranishlar aniqlandi.

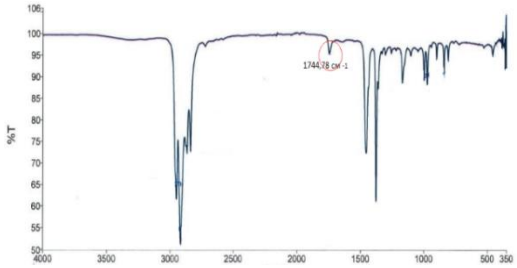
Tojli razryad bilan ishlov berilgan polimer plyonkalarning IQ-spektrlarida ishlov berilmagan namunalarga nisbatan yangi yutilish polosalarining paydo bo‘lishi va ayrim polosalar intensivligining o‘zgarishi kuzatildi. Ayniqsa, 1700–1750 sm^{-1} sohasida yangi intensiv yutilish polosasining shakllanishi polimer sirtida kislorod saqlovchi funksional guruhlar hosil bo‘lganligini ko‘rsatadi. BOPP plyonkada 1745,34 sm^{-1}, PE plyonkada esa 1744,78 sm^{-1} sohalarda kuzatilgan yutilish minimumlari C=O karbonil guruhlariga xos tebranishlar bilan bog‘liq.

Shu nuqtai nazardan, tojli razryad ta’sirida polimer sirtining kimyoviy tarkibida ma’lum darajada oksidlanish jarayoni sodir bo‘lishi va natijada kislorod saqlovchi funksional guruhlar miqdorining ortishi haqida xulosa qilish mumkin. Bunday o‘zgarishlar polimer sirtining qutbliligini oshiradi hamda uning adgezion xususiyatlarini yaxshilaydi.



2-rasm. Tajribaviy BOPP polimer plyonkaning IQ-spektroskopik tahlili

Polietilen plyonkaning IQ-spektroskopik tahlilida ham tojli razryadli ishlovdan keyin spektral o‘zgarishlar aniqlandi (2-rasm). PE uchun xarakterli bo‘lgan C–H bog‘lariga tegishli yutilish polosalari bilan bir qatorda ishlov berilgan namuna spektrida kislorod saqlovchi funksional guruhlarga xos qo‘shimcha polosalar shakllanganligi kuzatildi.



3-rasm. Tajribaviy PE polimer plyonkaning IQ-spektroskopik tahlili

Olingan spektroskopik natijalar tojli razryad bilan ishlov berish polimer materiallar sirtining kimyoviy holatiga ta’sir ko‘rsatishini tasdiqlaydi. Ishlov berish jarayonida yuqori energiyali razryad ta’sirida polimer makromolekulalaridagi ayrim C–H va C–C bog‘larining faollashishi natijasida sirtda erkin radikal markazlar hosil bo‘ladi. Ushbu faol markazlarning atmosfera tarkibidagi kislorod va namlik bilan o‘zaro ta’siri natijasida gidroksil (–OH), karbonil (>C=O), karboksil (–COOH) va gidroperoksid (–OOH) kabi kislorod saqlovchi funksional guruhlar shakllanishi mumkin.

Shakllangan qutbli funksional guruhlar polimer sirtining sirt energiyasini oshiradi, namlanish qobiliyatini yaxshilaydi va bosma bo‘yoqlari bilan o‘zaro ta’sirini kuchaytiradi. Natijada polimer sirtida bo‘yoq komponentlarining adgeziyasi yaxshilanib, bosma qatlamining material bilan bog‘lanish mustahkamligi ortadi. Shu sababli tojli razryad bilan ishlov berish polipropilen va polietilen kabi past sirt energiyasiga ega polimer plyonkalarni bosma jarayoniga tayyorlashning samarali usullaridan biri hisoblanadi [5].

IQ-spektroskopik tahlil natijalari shuni ko‘rsatadiki, tojli razryad ta’sirida polimer sirtida yuzaga kelgan struktura-viy va kimyoviy o‘zgarishlar, avvalo, kislorod saqlovchi funksional guruhlarning hosil bo‘lishi bilan namoyon bo‘ladi. 1745,34 sm^{-1} (BOPP) va 1744,78 sm^{-1} (PE) sohalardagi yangi yutilish polosalari C=O bog‘larining mavjudligini tasdiqlaydi. Ushbu o‘zgarishlar polimer sirtining qutbliligini oshirib, sirt energiyasining ortishi va adgezion xususiyatlarning yaxshilanishiga olib keladi.

3. Xulosa

Shunday qilib, IQ-spektroskopik tadqiqot natijalari tojli razryad bilan ishlov berish BOPP va PE polimer plyonkalar sirtida sezilarli fizik-kimyoviy o‘zgarishlarni yuzaga keltirishini ko‘rsatdi. Tojli razryad ta’sirida C=O, –OH, –COOH va –OOH kabi qutbli funksional guruhlarning shakllanishi polimer sirtining sirt energiyasi va namlanish qobiliyatini oshiradi. Bu esa polimer materiallarning bosma bo‘yoqlari bilan adgezion o‘zaro ta’sirini kuchaytiradi va bosma sifati barqarorligini ta’minlashga xizmat qiladi. Olingan natijalar polimer plyonkalarni chuqur bosma va boshqa bosma usullarida ishlatishdan oldin tojli razryad bilan sirtga ishlov berishning texnologik samaradorligini asoslaydi.

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