GRAFEN OKSID BILAN MODIFIKATSIYALANGAN PVA–CS/LAB$_6$ NANOTOLALARINING DIELEKTRIK XARAKTERISTIKALARI VA SIRT ENERGIYASINING NAZORAT OSTIDA SOZLANISHI

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Annotatsiya Ushbu tadqiqotda, PVA-CS/LaB$_6$ asosli elektrospinning usulida olingan nanotolalar grafen oksid (GO) qo'shimchasi (%1, %2 va %4) bilan modifikatsiya qilindi va ularning dielektrik va sirt xususiyatlari sistematik ravishda o'rganildi. FTIR tahlillari PVA va xitozanga xos bo'lgan funksional guruhlarning saqlanib qolganligini va GO qo'shilishi bilan kislorod saqlovchi funksional guruhlarga bog'liq bo'lgan chiziqlar intensivligining ortganligini ko'rsatdi. SEM tasvirlari barcha namunalarda tolali strukturaning saqlanganligini va GO qo'shilishi tola morfologiyasida sezilarli o'zgarishlarga olib kelmaganligini aniqladi. Dielektrik o'lchovlar barcha namunalarda dielektrik doimiylikning chastota ortishi bilan kamayganligini va yuqori chastotali sohada plato holatini namoyon etganligini ko'rsatdi. Sof PVA-CS/LaB$_6$ nanotolalari past chastotada taxminan $\varepsilon' \approx 8.0$ qiymatiga ega bo'lsa, %4 GO saqlovchi namunada bu qiymat ≈ 4.3 darajasiga tushdi. Xuddi shunday, dielektrik yo'qotish va AC o'tkazuvchanlik qiymatlari GO miqdori ortishi bilan pasaygan. Kontakt burchagi o'lchovlari GO qo'shilishi bilan suv kontakt burchagining ~26.9° dan ~44.3° ga ko'tarilganligini, ammo sirtning nazorat ostidagi gidrofilik xarakterini saqlab qolganligini ko'rsatdi. Olingan natijalar GO qo'shimchasi dielektrik yo'qotishlarni kamaytiradigan va sirt energiyasini sozlash imkonini beradigan samarali modifikatsiya vositasi ekanligini ko'rsatmoqda.

Kalit so'zlar: Elektrospinning usulida olingan nanotolalar, Dielektrik xususiyatlar, Grafen oksid, Sirt erkin energiyasi, Kontakt burchagi

Abstract In this study, PVA-CS/LaB$_6$-based electrospun nanofibers were modified with graphene oxide (GO) additives (1%, 2%, and 4%) and systematically investigated in terms of their dielectric and surface properties. FTIR analyses showed that the characteristic functional groups of PVA and chitosan were preserved, and with the addition of GO, there was an increase in the band intensities associated with oxygen-containing functional groups. SEM images revealed that the fibrous structure was maintained in all samples and that the addition of GO did not lead to significant deterioration in fiber morphology. Dielectric measurements indicated that the dielectric constant of all samples decreased with increasing

frequency and exhibited plateau behavior in the high-frequency region. While pure PVA-CS/LaB_6 nanofibers had a value of approximately $\varepsilon' \approx 8.0$ at low frequency, this value decreased to ≈ 4.3 in the sample containing 4% GO. Similarly, the dielectric loss and AC conductivity values were suppressed as the GO ratio increased. Contact angle measurements showed that with the addition of GO, the water contact angle increased from ~26.9° to ~44.3°, while the surface maintained its controlled hydrophilic character. The results obtained demonstrate that GO additive is an effective modification tool that reduces dielectric losses and makes the surface energy adjustable.

Keywords: Electrospun nanofibers, Dielectric properties, Graphene oxide, Surface free energy, Contact angle

Kirish (Introduction)

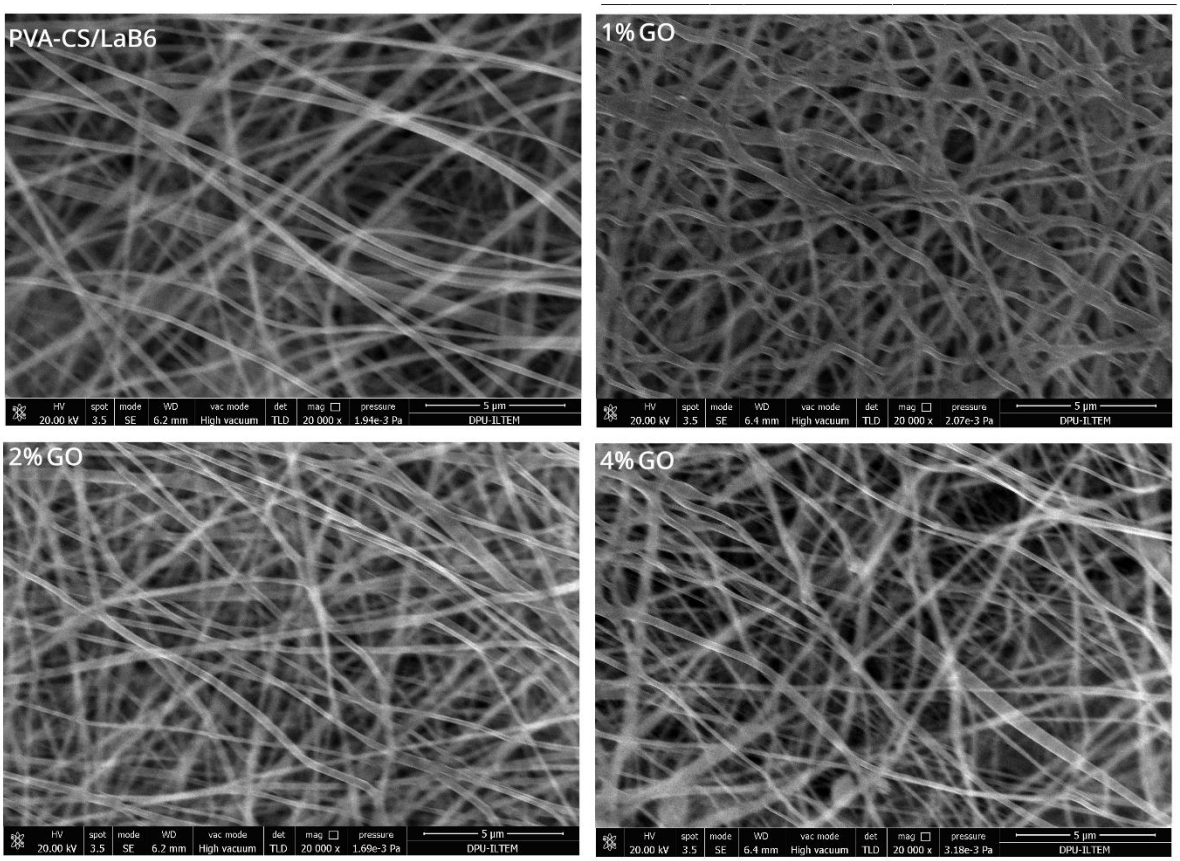
Polimer asosli nanokompozitlar, maqsadga mos sozlanuvchan dielektrik xususiyatlari, yengilligi va qayta ishlash qulayligi tufayli egiluvchan elektronika, sensorlar va energiya saqlash tizimlari kabi sohalarda katta qiziqish uyg‘otmoqda. Elektrospinning usulida olingan polimer nanotolalar yuqori solishtirma sirt maydoni va g‘ovakli morfologiyasi bilan ajralib turadi. Polivinil spirti (PVA) va xitozan (CS) aralashmasi bio-asosli tabiati tufayli jozibador matritsa hisoblansa-da, ularning yakka holdagi cheklangan termal barqarorligi va zaif elektr funksionalligi ilg‘or dasturlar uchun yetarli emas. Shu maqsadda, noorganik to‘ldiruvchilar, xususan, lantan geksaborid (LaB_6) va grafen oksidi (GO) bilan modifikatsiya qilish orqali gibrid tizimlarni yaratish istiqbolli yondashuv hisoblanadi. Ushbu tadqiqotning asosiy maqsadi – PVA-CS/LaB_6 gibrid nanotola platformasiga turli nisbatlarda GO qo‘shib, olingan nanokompozitlarning dielektrik (ε', ε'', $\tan\delta$, AC o‘tkazuvchanlik) va sirt xossalariga (kontakt burchagi va sirt erkin energiyasi) ta’sirini sistematik ravishda o‘rganishdan iborat.

Material va Metodlar (Materials and Methods)

Tadqiqotda polivinil spirti (PVA), past molekulyar massali xitozan (CS), laboratoriya sharoitida sintez qilingan lantan geksaborid (LaB_6) nanozarrachalari va tijoriy grafen oksidi (GO) ishlatildi. PVA–CS/LaB_6 asosli va turli nisbatlarda (%1, %2 va %4) GO saqlovchi nanotolalar eritma tayyorlash va undan keyingi gorizontal konfiguratsiyali elektrospinning jarayoni orqali olindi. Olingan nanotolalarning kimyoviy tuzilishi infraqizil (IQ) spektroskopiyasi, sirt morfologiyasi skanerlovchi elektron mikroskop (SEM) yordamida tahlil qilindi. Dielektrik xususiyatlar impedans analizatori yordamida 1 kHz – 1 MHz chastota oralig‘ida, sirt namlanuvchanligi esa kontakt burchagi qurilmasi yordamida Ouens–Vendt–Kaelble modeli asosida o‘lchandi.

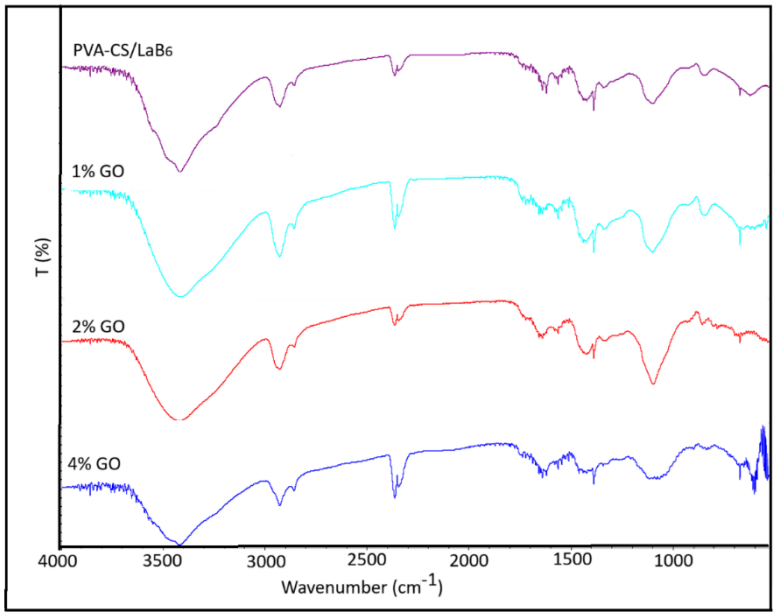
Natijalar (Results)

FTIR tahlillari (2-rasm) GO qo‘shilishi bilan polimer zanjirlari orasidagi vodorod bog‘lanish tarmog‘ining kuchayganligini ko‘rsatdi. SEM tasvirlari (1-rasm) barcha



1. Rasm PVA-CS/LaB6-GO fiber nanokompozitlarning SEM natijalari

namunalarda uzluksiz va boncuksiz nanotola tarmoq tuzilmasi saqlanib qolganligini, GO qo‘shilishi esa tola morfologiyasida sezilarli buzilishlarga olib kelmaganligini tasdiqladi.



2-Rasm. PVA-CS/LaB6-GO fiber nanokompozitlarning FTIR spektrumi

Dielektrik o‘lchovlar natijasida GO miqdori ortishi bilan dielektrik doimiylik (ε′), dielektrik yo‘qotish (ε″) va AC o‘tkuvchanlik (σac) qiymatlarining sistematik ravishda kamayganligi aniqlandi. Masalan, 10^6 Hz chastotada sof sistema uchun ~1.3×10^{-5} S/cm bo‘lgan AC

o‘tkazuvchanlik, %4 GO saqlovchi namunada ~7.0×10^{-6} S/cm darajasiga tushdi. Kontakt burchagi o‘lchovlari GO qo‘shilishi bilan suv kontakt burchagining ~26.9° dan ~44.3° gacha ortganligini, biroq sirtning gidrofilik xarakteri saqlanib qolganligini ko‘rsatdi. Umumiy sirt erkin energiyasi esa PVA-CS/LaB_6 uchun 69.79 mN/m dan %4 GO saqlovchi namunada 63.95 mN/m gacha pasaydi.

Muhokama va Xulosa (Discussion and Conclusion)

Olingan natijalar shuni ko‘rsatadiki, grafen oksidi (GO) qo‘shimchasi PVA-CS/LaB_6 nanotola tizimining dielektrik va sirt xususiyatlarini samarali nazorat qilish imkonini beruvchi modifikatsiya vositasidir. GO miqdorining ortishi dielektrik yo‘qotishlarni kamaytirib, tizimning elektr xususiyatlarini yuqori chastotali sohalarda yanada barqaror qildi. Bu holat GO ning oraliq sirt qutblanishini cheklab, zaryad tashish mexanizmlarini bostirishi bilan izohlanadi. Sirt xususiyatlarining tahlili shuni ko‘rsatdiki, GO sirt energiyasini haddan tashqari o‘zgartirmasdan, muvozanatli tarzda pasaytirib, qutbli va dispersiv komponentlarning birgalikda sozlanishiga imkon berdi. Ushbu xususiyatlar majmuasi ishlab chiqilgan nanotola tizimlarini past yo‘qotishli dielektrik oraliq qatlamlar, sirtga sezgir funksional qoplamalar va sozlanuvchan sirt o‘zaro ta’siri talab qiladigan membrana qo‘llanmalari uchun istiqbolli material platformasi sifatida baholashga asos bo‘ladi. Xulosa qilib aytganda, PVA-CS/LaB_6/GO asosli gibrid nanotolalar ham elektr, ham sirt xususiyatlarini birgalikda optimallashtirish mumkin bo‘lgan ko‘p tomonlama tizimdir.

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