_2D_ va _3D_ o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligini solishtirish

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Annotatsiya. 2D o’lchamli p-n-o’tishlarning differensial o’tkazuvchanligini o‘ta yuqori chastotali maydon ta’siri natijasida o’zgarishi, hamda 2D va 3D o’lchamli p-n-o’tishlarning differensial o’tkazuvchanligining o‘ta yuqori chastotali maydon ta’sirida o’zgarishi taqqoslangan.

Kalit so‘zlar: p-n-o’tish, differensial o’tkazuvchanlik, o‘ta yuqori chastotali maydon, 2D o‘lchamli materiallar.

Сравнение дифференциальной проводимости 2D и 3D p-n перехода

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Аннотация. Сравнено изменение дифференциальной проводимости 2D мерный p-n переходов в результате воздействия поля чрезвычайно высокой частоты, так же изменение дифференциальной проводимости 2D мерный и 3D мерный p-n переходов под действием поля сверхвысокой частоты.

Ключевые слова: p-n переход, дифференциальной проводимости, сверх высокочастотний поля, 2 D мерный материалы.

Comparison of differential conductivity of 2D and 3D p-n junction

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Abstract: The change in the differential conductivity of 2D dimensional p-n junctions as a result of exposure to an extremely high frequency field is compared, as

well as the change in the differential conductivity of 2D dimensional and 3D dimensional p-n junctions under the influence of an ultrahigh frequency field.

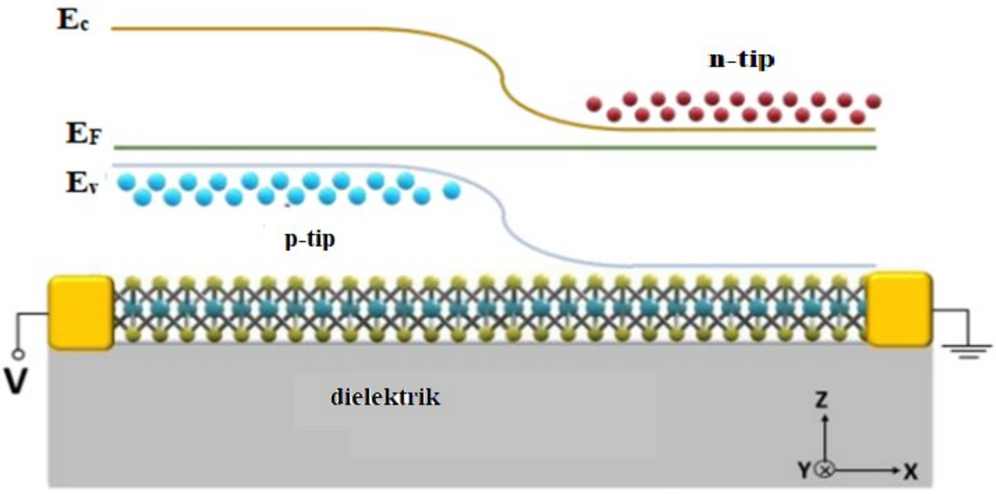
Key words: p-n junction, differential conductivity, super high-frequency fields, 2 D dimensional materials.

Kirish

Ikki turdagi yarimo‘tkazgichdan tashkil topgan p-n-o‘tishli rektifikatorlar [1], fotodetektorlar [1-5], fotovoltaiklar [6-10] va yorug‘lik chiqaradigan diodlar elektron va optoelektronik qurilmalarning [11-12] asosi hisoblanadi. 3D o‘lchamli p-n-o’tishlarini ishlab chiqarishda ionli injeksiyadan kelib chiqqan legirlash yoki sirt o‘zgarishi yarimo‘tkazgichning elektr xususiyatlarini va kristall tuzilishini o‘zgartiradi. Bundan tashqari, yarimo‘tkazgichli qurilmalarning kichrayib borishi natijasida ularda turli kvant effektlari asta-sekin namoyon bo‘lmoqda. Bu esa, klassik qurilma nazariyasining endi qo‘llanish ko‘lami chegaralanib qolishini ko‘rsatadi.

So‘ngi yillarda, atom jixatdan nozik ajoyib xususiyatli ikki o‘lchamli (2D) materiallar katta qiziqish uyg‘otmoqda. Ba’zi, 2D o‘lchamli p-n-o‘tishlar, masalan, WS_2, MoS_2, $MoSe_2$, WSe_2 va qora fosfor (BP) larning elektrostatik maydon xususiyatlari yarimo‘tkazgichlarga yangi imkoniyatlar eshigini ochadi [9,13-19]. Diodlarga tashqi maydon sifatida yorug‘likdan foydalanish ancha qo‘shimcha afzalliklar yaratadi. Masalan, yorug‘likni masofadan turib ham yuborish mumkin. Bu aniq boshqariladigan, tez almashtiriladigan va juda kam energiya sarf qiladigan zamonaviy integral optoelektronik ulanish sxemalari uchun katta ahamiyatga ega [20-26].

[27] ishda 2D o‘lchamdagi p-n-o‘tish uchun Puasson tenglamasi drift-diffuziya va uzluksizlik tenglamalari bilan birlashtirilgan va ideal VAX uchun Shokli tenglamasi taklif qilingan. 1-rasmda 2D o‘lchamli p-n-o’tishning geometrik sxemasi keltirilgan. Bu struktura p va n tiplarning $x=0$ da birlashishidan hosil bo‘ladi va $z=0$ tekislikda yotadi, y o‘qi bo‘ylab struktura keraklicha katta, shuning uchun bu yo‘nalishni xususiyatlarga ta’sirini ko‘rib o‘tilgan.



1-rasm. 2D o‘lchamli p-n-o’tishning geometrik sxemasi [27].

Biroq, yuqorida keltirilgan tadqiqotlarda, 2D o’lchamli p-n-o’tishlarning differensial o’tkazuvchanligini tashqi ta’sirlar natijasida o’zgarishi yetarli darajada o’rganilmagan, hamda 3D va 2D o’lchamli p-n-o’tishlarning differensial o’tkazuvchanligining tashqi ta’sirlar natijasida o’zgarish grafiklari solishtirilmagan.

Ishning maqsadi, 2D va 3D o‘lchamli p-n-o‘tishlarning differensial o‘tkazuvchanligini tashqi ta‘sirlar natijasida o‘zgarishini tahlil qilishdan iborat.

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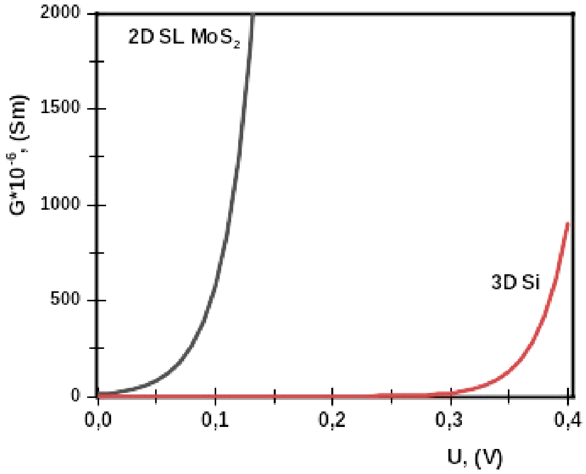
3D o‘lchamdagi p-n-o‘tishning differensial o‘tkazuvchanligi G quyidagi munosabat bilan aniqlanadi [28-36]:

$$G=\frac{eI_s}{kT}\exp\left(\frac{eU}{kT}\right) \tag{3}$$

2D o‘lchamdagi p-n-o‘tishning differensial o‘tkazuvchanligi [27] ishda keltirilgan ifodalardan foydalangan holda quyidagi formulaga ega bo‘lamiz:

$$G=\frac{q^2 n_i^2}{kTN_d}\left(\frac{D_p}{L_p}+\frac{D_n}{L_n}\right)\exp\left(\frac{qU}{kT}\right), \tag{4}$$

bu yerda, $n_i=g_{2D}kT\exp\left(-\frac{E_g}{2kT}\right)$, $L_n=L_p=\sqrt{D_{n(p)}\tau_{n(p)}}$, $D_{n(p)}=\frac{kT\mu_{n(p)}}{q}$, $E_g=1.8eV$ $\mu_n=\mu_p=50\frac{sm^2}{Vs}$, $\tau_n=\tau_p=3\cdot10^{-10}s$, $n_i=9.9\cdot10^{-3}sm^{-2}$ ga teng. (3) va (4) ifodalardan foydalanib, 2D va 3D o‘lchamdagi p-n-o‘tish differensial o‘tkazuvchanliklarini solishtirildi (2- rasm).



2-rasm. 2D va 3D o‘lchamdagi p-n-o’tish differensial o‘tkazuvchanligining kuchlanishga bog‘liqligi.

2 - rasmda 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligining kuchlanishga bog‘liqligi ko‘rsatilgan. Olingan natijalardan ko‘rinadiki, 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligi 2D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligiga nisbatan kichik bo‘lar ekan. Bu esa 2D o‘lchamli p-n-o‘tish 3D o‘lchamli p-n-o‘tishga nisbatan samarali ekanligini ko‘rsatadi.

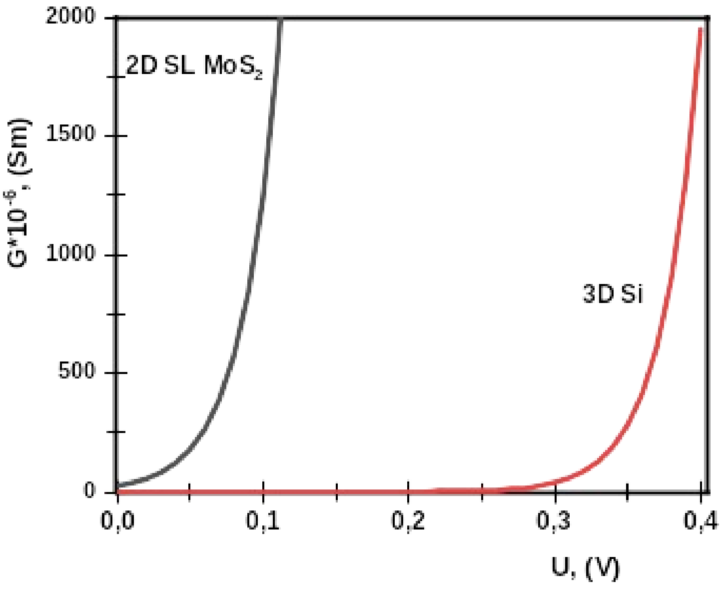
Kuchsiz O‘YuCh maydon ta’sirida 3D o’lchamli p-n-o‘tishdagi elektron va kovaklar qizimagan, faqat potensial to‘siq balandligining g‘alayonlanishi hisobga olinganda p-n-o‘tishning differensial o‘tkazuvchanligi uchun quyidagi ifodaga ega bo’lamiz [29]:

$$G=\frac{eI_s}{kT}e^{-\frac{e(U+U_1-\phi_0)}{kT}} \quad . \qquad (5)$$

Kuchsiz O‘YuCh maydon ta’sirida 2D o‘lchamli p-n-o‘tishning differensial o‘tkazuvchanligi uchun quyidagi ifodaga ega bo‘lamiz:

$$G=\frac{q^2 n_i^2}{kTN_d}\left(\frac{D_p}{L_p}+\frac{D_n}{L_n}\right)\exp\left(\frac{q\left(U+U_1-\phi\right)}{kT}\right)\qquad (6)$$

(5) va (6) ifodalardan foydalanib, kuchsiz O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanliklarini solishtirish mumkin (3-rasm).



3-rasm. Kuchsiz O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligining qo‘yilgan kuchlanishga bog‘liqligi

3 - rasmda kuchsiz O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligining kuchlanishga bog‘liqligi ko‘rsatilgan.

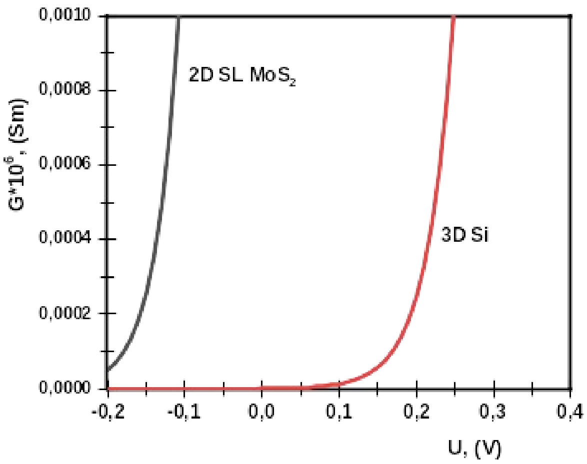
Kuchli O‘YuCh maydon ta’sirida 3D o‘lchamli p-n-o‘tishning differensial o‘tkazuvchanligi uchun quyidagi ifodaga ega bo‘lamiz:

$$G=\left(\frac{kT}{eI_e}\sqrt{\frac{T}{T_e}}\,e^{\left(\frac{e(\phi_0-U-U_1)}{kT_e}-\frac{e\phi_0}{kT}\right)}+\frac{kT}{eI_h}\sqrt{\frac{T}{T_h}}\,e^{\left(\frac{e(\phi_0-U-U_2)}{kT_h}-\frac{e\phi_0}{kT}\right)}\right)^{-1}\qquad (7)$$

Kuchli O‘YuCh maydon ta’sirida 2D o‘lchamli p-n-o‘tishning differensial o‘tkazuvchanligi uchun quyidagi ifodaga ega bo‘lamiz:

$$G=\frac{q^2 n_i^2}{kTN_d}\left(\frac{D_p}{L_p}+\frac{D_n}{L_n}\right)\left(\sqrt{\frac{T}{T_e}}\exp\left(\frac{q(\phi-U-U_1)}{kT_e}-\frac{q\phi}{kT}\right)+\sqrt{\frac{T}{T_h}}\exp\left(\frac{q(\phi-U-U_2)}{kT_h}-\frac{q\phi}{kT}\right)\right)^{-1} \quad (8)$$

(7) va (8) ifodadan foydalanib, kuchli O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanliklarini solishtirish mumkin (4-rasm).



4-rasm. Kuchli O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligining qo‘yilgan kuchlanishga bog‘liqligi

4 - rasmda kuchli O‘YuCh maydonda joylashgan 2D va 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligining kuchlanishga bog‘liqligi ko‘rsatilgan.

Xulosa

- 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligi 2D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligiga nisbatan kichik bo‘ladi.
- Kuchsiz va kuchli O‘YuCh maydonda joylashgan 3D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligi 2D o‘lchamli p-n-o‘tish differensial o‘tkazuvchanligiga nisbatan kichik bo‘ladi. Bu esa, kuchsiz va kuchli O‘YuCh maydonda joylashgan 2D o‘lchamli p-n-o‘tish 3D o‘lchamli p-n-o‘tishga nisbatan samarali ekanligini ko‘rsatadi.

MINNATDORCHILIK

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