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ZnSb ASOSLI TERMOELEKTRIK MATERIALNI TAYYORLASH USULI**СПОСОБ ПОЛУЧЕНИЯ ТЕРМОЭЛЕКТРИЧЕСКОГО МАТЕРИАЛА НА ОСНОВЕ ZnSb****METHOD FOR MANUFACTURING ZnSb-BASED THERMOELECTRIC MATERIAL****Olimov Lutfiddin Omanovich¹** ¹University of economics and pedagogy fizika-matematika fanlari doktori, professor**Axmadaliyev Utkirbek Akramjonovich²**²Andijon davlat texnika instituti katta o'qituvchisi**Anotatsiya**

Ushba maqolada kukunsimon holatga yetguncha tortilgan yarimo'tkazgichli ZnSb zarrachalarining 70 % etil spirti yordamidagi qorishmasi tayyorlanadi va ular ichki diametri 1 millimetr bo'lgan issiqqa bardosh masalan, keramik trubka taglikka solinib, uning ikki tomonidan Omik kontakt vazifasini bajaruvchi metal sterjenlar bilan bir-biriga bosiladi, so'ngra, ZnSb birikmaning erish temperaturasiga yaqin, $T=400-600$ °C temperaturalarda zarrachalarni qizdirib birlashtirish orqali diametri 1 millimetr bo'lgan sterjen shaklidagi ZnSbning polikristali hosil qilinadi. Polikristal tuzilishdagi yarimo'tkazgichli ZnSb sterjen qarshiligi $R \leq 1$ kOm bo'lib, uning donadorliklararo chegara sohasida tunnelli kontaktlar hamda lokal energetik sathlar hosil kilinadi, bunda energetik sathlar elektronlarning rezonansli tunnellashtirilishini ta'minlaydi.

Аннотация

В данной статье смесь полупроводниковых частиц ZnSb, измельченных до порошкообразного состояния, готовится с использованием 70% этилового спирта, и они помещаются на термостойкую подложку, например, керамическую трубку с внутренним диаметром 1 миллиметр, и сжимаются с двух сторон металлическими стержнями, действующими как омические контакты. Затем путем нагрева и соединения частиц при температурах, близких к температуре плавления соединения ZnSb, $T=400-600$ °C, формируется поликристалл ZnSb в форме стержня диаметром 1 миллиметр. Полупроводник ZnSb в поликристаллической структуре имеет сопротивление $R \leq 1$ кОм, а в его межзеренных граничных областях образуются туннельные контакты и локальные энергетические уровни, где энергетические уровни обеспечивают резонансное туннелирование электронов.

Abstract

In this article, a mixture of ZnSb semiconductor particles, ground to a powder state, is prepared using 70% ethyl alcohol, and they are placed on a heat-resistant substrate with an internal diameter of 1 mm, for example, a ceramic tube, and pressed together on both sides with metal rods acting as ohmic contacts. Then, by heating and bonding the particles at temperatures close to the melting temperature of the ZnSb compound, $T=400-600$ °C, a rod-shaped ZnSb polycrystal with a diameter of 1 mm is formed. The rod resistance of the ZnSb semiconductor in a polycrystalline structure is $R \leq 1$ kOhm, and tunnel contacts and local energy levels are formed in its intergranular boundary regions, in which energy levels ensure resonant tunneling of electrons.

Kalit so'zlar: Omik kontakt, termoelektrik, intermetal birikma, kristal panjara, sterjen, zarracha.**Ключевые слова:** Омический контакт, термоэлектрик, интерметаллическое соединение, кристаллическая решетка, стержень, частица.**Key words:** Ohmic contact, thermoelectric, intermetallic compound, crystal lattice, rod, particle.**KIRISH**

Hozirgi kunda ZnSb asosli termoelektrik materiallar tayyorlashning bir necha usullari mavjud bo'lib, umumiy holda, ular vakuumda yoki inert gaz bilan himoyalangan muhitda dastlabki qotishmani eritish, toblash, legirlash preslash kabi texnologiyalarga asoslangan [1-13]. Jumladan, termik ishlov berish termoelektrik samaradorlik (ZT)ning ortishiga [1], legirlash jarayoni Zeebek koeffitsienti (α)ning ortishi va issiqlik o'tkazuvchanlik (λ)ning keskin kamayishiga bu esa o'z navbatida ZTning qiymatini ortishiga [2, 3], issiqlayin preslash esa ZnSb ning donadorligini ortishiga [4] olib keladi. Shuningdek, kristal panjara tuzilishini o'zgartirish orqali ZnSb asosli

termoelektrik materialning asosiy xarakteristikalarini yaxshilashga erishish mumkin [5-9]. Usullarning asosiy hususiyati ZnSb asosli yarimo'tkazgichlar taqiqlangan zonasida turli energetik sathlar hosil qilishdir. Ularning bunday xususiyati termoelementlar yaratishda keng tarqalgan. Biroq, usullarning umumiy kamchiliklari murakkab texnologiya va kimyoviy jarayonlar qo'llanilishi, bularga bog'liq holda termoelektrik materialning asosiy parametrlari solishtirma termoelektr yurituvchi kuchi (α) va o'tkazuvchanlik (σ)ning bir me'yorda o'sishi, issiqlik o'tkazuvchanlikning (λ) kamayishi va boshqa bir qator asosiy xarakteristikalarini boshqarib bo'lmastir.

ADABIYOTLAR TAHLILI VA METODOLOGIYA

ZnSb asosli termoelektrik material tayyorlash usullaridan yana biri [3, 4] analog) bo'lib, u dastlabki $R(\text{Zn}_{2-x}\text{T}_x)_2(\text{Sb}_{2-y}\text{M}_y)_2$ (bu yerda, R – Yb, Eu yoki Ca; T – In, Mn yoki Cd hamda M – Si, Ge yoki As guruh elementlari) [3] yoki $(\text{Zn}_{4-x}\text{T}_x)_4(\text{Sb}_{3-y}\text{M}_y)_3$ (bu yerda, T – In, Cd, Mg yoki Pb; M – Te, Sn yoki In guruh elementlari) [4] kimyoviy birikmali hom ashyoni yuqori temperaturalarda eritish, qizdirish, razryadli plazma yordamida toblash kabi texnologiyalarga asoslangan. Buning uchun maxsus issiqqabardosh idishga joylashtirilgan hom ashyo $T \sim 750-1000$ °C temperaturalarda 2-20 soat davomida qizdirib toblanadi va yakunda $R(\text{Zn}_{2-x}\text{T}_x)_2(\text{Sb}_{2-y}\text{M}_y)_2$ birikma hosil qilinadi [3]. So'ngra, $R(\text{Zn}_{2-x}\text{T}_x)_2(\text{Sb}_{2-y}\text{M}_y)_2$ birikma kukun holatigacha maydalaniladi. Kukunlarning rux fazasida qayta kristallanishi jarayonida piroelektrik material hosil bo'ladi. Ushbu usul 20-200 nm o'lchamda Zn va Sb asosidagi p-tipli termoelektrik material tayyorlash imkonini beradi. [4] usulda esa maxsus issiqqabardosh idishga joylashtirilgan hosh ashyo $T \sim 600-750$ °C temperaturalarda 0,3-3 soat davomida qizdirib toblanib $(\text{Zn}_{4-x}\text{T}_x)_4(\text{Sb}_{3-y}\text{M}_y)_3$ birikma hosil qilinadi. Bunda ham $(\text{Zn}_{4-x}\text{T}_x)_4(\text{Sb}_{3-y}\text{M}_y)_3$ birikma kukun holatigacha maydalanadi. So'ngra, razryadli plazmada qizdirib biriktirish orqali kristallanadi. Yakunda Zn_4Sb_3 asosidagi p-tipli termoelektrik material hosil bo'ladi.

[3, 4] analoglarning asosiy kamchiligi dastlabki hom ashyoni yuqori temperaturalarda eritish, vakuum yoki inert gaz bilan himoyalangan muhitda dastlabki qotishmani qizdirib biriktirish bilan toblash uchun hamda razryadli plazma kabi murakkab texnologiyalar qo'llanilishi olingan termoelektrik materialning tannarxini ortishiga olib keladi. Bundan tashqari, $R(\text{Zn}_{2-x}\text{T}_x)_2(\text{Sb}_{2-y}\text{M}_y)_2$ (bu yerda, R – Yb, Eu yoki Ca; T – In, Mn yoki Cd hamda M – Si, Ge yoki As guruh elementlari) [3] yoki $(\text{Zn}_{4-x}\text{T}_x)_4(\text{Sb}_{3-y}\text{M}_y)_3$ (bu yerda, T – In, Cd, Mg yoki Pb; M – Te, Sn yoki In guruh elementlari) [4] kimyoviy birikmalar hosil qilish uchun qo'shimcha kimyoviy jarayonlarni boshqarish talab etilishidir.

Shu sababli keltirib o'tilgan ma'lum ishlanmalarda har bir asosiy termoelektrik parametrlarning birini ikkinchisiga bog'liq bo'lmagan holda mustaqil o'zgarishini ta'minlab bo'lmastir termoelektrik sohada asos hisoblanmaydi.

Taklif etilayotgan yangi usulning vazifasi yuqorida keltirib o'tilgan kamchiliklardan holi bo'lgan ZnSb asosli termoelektrik materialni olish usulini arzonlashtirish, materialda har bir asosiy termoelektrik parametrlarning mustaqil o'zgarishini ta'minlashdan iboratdir.

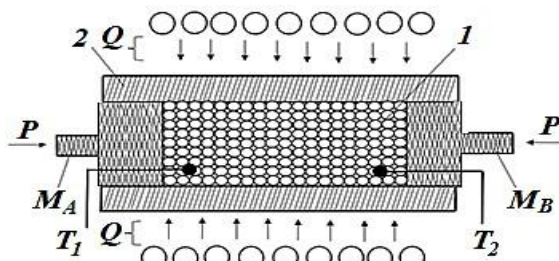
NATIJA VA MUHOKAMA

ZnSb asosli termoelektrik material tayyorlash uchun dastlabki xom ashyo sifatida istalgan, masalan, o'tkazuvchanligi p yoki n turga ega bo'lgan ZnSb yarimo'tkazgichli intermatel birikma qo'llanilishi mumkin. Dastlab, 2-3 millimetr o'lchamda ZnSb yarimo'tkazgichli intermatel birikma kristalchalari tayyorlanib, ular istalgan masalan, kislorodli muhitda kukunli texnologiya bilan kukunsimon holatga yetguncha tortiladi. Bunda o'lchami 1 mikrometrdan kichik bo'lgan ZnSb zarrachalari hosil qilinadi. So'ngra, 70 % etil spirti yordamida ZnSb zarrachalarining qorishmasi tayyorlanadi. Ta'kidlash joizki, etil spirt qo'shilganda ZnSb zarrachalari erimaydi yoki geli hosil bo'lmaydi, ular namlanadi. Namlanish zarrachalarning yopishqoqligini ya'ni, bir-biriga yopishish xususiyatini paydo qiladi. Tadqiqotlar shuni ko'rsatdiki, etil spirti bilan qorishma tayyorlash yoki namlash ZnSb zarrachalarini issiqqa bardosh masalan, trubka shaklidagi keramik taglikka kerakli miqdor va zichlashgan holda solish hamda ularni isrof bo'lishini oldini olish imkonini berdi. Bunda, zarrachalarni etil spirti bilan aralashmasi yoki namlanish nisbati hajmiy jihatdan 1:1 nisbatda bo'lishi maqsadga muvoffiq.

Tayyor bo'lgan ZnSb zarrachalari (1) qorishmasi issiqqa bardosh masalan, ichki diametri 1 millimetr bo'lgan trubka shaklidagi keramik (2) taglikka solinadi (1-rasm). Issiqqa bardosh keramik trubkaning ikki (A va B) tomonidan ZnSb zarrachalari metal (M_A va M_B) sterjenlar bilan R bosim kuchi ostida bosiladi. Natijadan trubka ichidagi ZnSb zarrachalari dimametri 1 millimetr bo'lgan sterjen shaklini oladi. Bu yerda M_A va M_B termoelektrik materialning Omik kontakti vazifasini

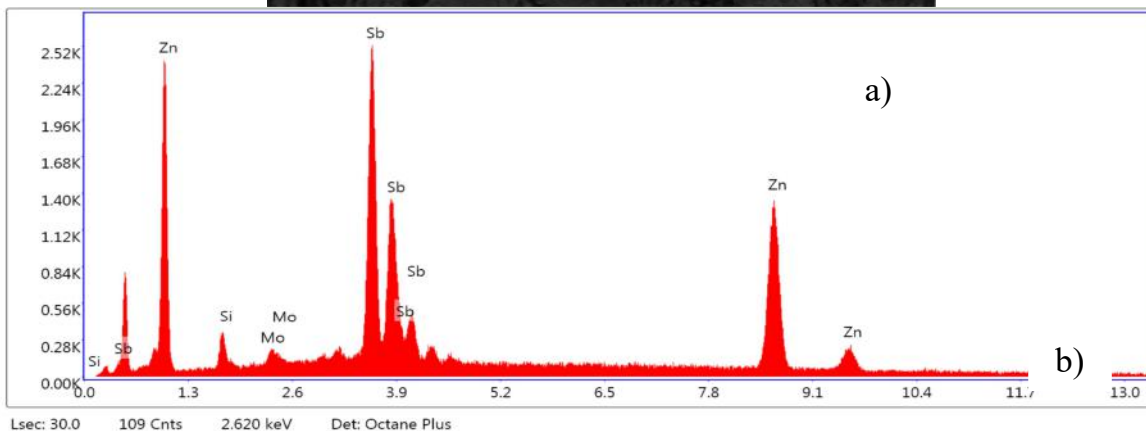
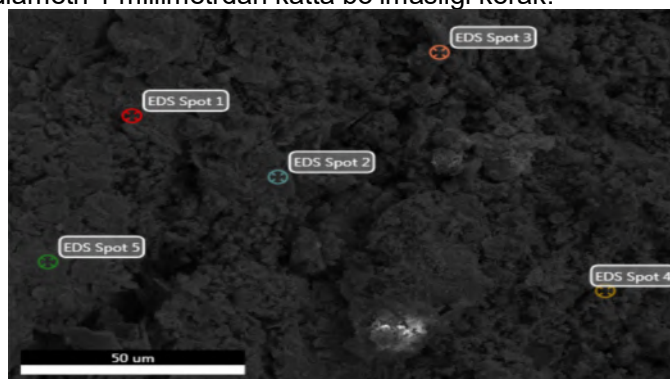
FIZIKA-TEXNIKA

bajaradi hamda zarrachalarning sochilishini oldini oladi. M_A va M_B Omik kontaktlar orqali ZnSb zarrachalari qarshiligi (R)ni nazorat qilish orqali P bosim kuchi boshqariladi. Bunda $R=1$ kOmdan ortmasligi kerak.



1-rasm. ZnSb zarrachalarini qizdirib biriktirish sxemasi

Keyingi bosqichda, ZnSb birikmaning erish temperaturasiqa yaqin $T=400-600$ °C temperaturalarda zarrachalar Q issiqlik energiyasi bilan qizdirib biriktiriladi (1-rasm). Tadqiqotlar shuni ko'rsatadiki, ushbu temperatura diametri 1 millimetr bo'lgan sterjen shaklidagi ZnSb zarrachalarini qizdirib biriktirish imkonini beradi. 2-rasmda ZnSb polikristal tuzilmasining mikrofotografiyasi va kimyoviy tarkibi (EDAX TEAM) tasvirlangan. Tadqiqot natijalari ko'rsatadiki, ushbu usul yordamida olingan ZnSb asosli termoelektrik material polikristal tuzilishga ega. Agar issiqqa bardosh keramik trubka ichki diametri 1 millimetrdan katta bo'lsa, trubka markazidagi ZnSb zarrachalarini biriktirish uchun kerakli miqdordagi issiqlik energiyasi yetib bormaydi. Natijadan ZnSb zarrachalarining birikishi yoki kristallanishi yuz bermaydi. Shuning uchun issiqqa bardosh keramik trubka ichki diametri 1 millimetrdan katta bo'lmasligi kerak.



2-rasm. ZnSb polikristal tuzilmasining mikrofotografiyasi va kimyoviy tarkibi (EDAX TEAM).

Qizdirish 0 °C dan $T=400-600$ °C gacha bir me'yorda ortib borish jarayonida bajariladi. Temperatura ko'tarilish vaqti 30 minut bo'lib, maksimal temperaturada 20 minut ushlab turiladi. So'ngra, huddi shu tezlikda sovutiladi. Qizdirib biriktirish bosqichi 6 yoki 7 marta bajarilish

maqsadga muvofiq. Termik ishlov berishning har bir bosqichida M_A va M_B Omik kontaktlar orqali ZnSb zarrachalarini R bosim kuchi bilan bosish talab etiladi. Yuqorida aytilgandek, R bosim kuchi ZnSb zarrachalari qarshiligi (R)ni nazorat qilish orqali boshqariladi va u $R=1$ kOmdan ortmasligi kerak. Bunda $R=1$ kOmdan ortmasligi kerak.

XULOSA

Yakuniy mahsulot sterjen shaklidagi ZnSb polikristal tuzilma bo'lib, uning hajmidagi donadorliklararo chegara sohalari lokal energetik sathli tunnelli kontaktlar hosil qiladi. Bunda energetik sathlar elektronlarning rezonansli tunnellashtirilishini ta'minlaydi.

Taklif etilgan termoelektrik materiallar tayyorlash usuli ZnSb asosli termoelektrik materiallar xom ashyo bazasini kengaytirish, materiallar tayyorlash tannarhini arzonlashtirish, materialning termoelektrik parametrlarini mustaqil o'zgarishini ta'minlash imkonini beradi. Xom ashyo va asosiy xarakteristikalari mavjud analoglardan tubdan farq qilishi bilan talablarga javob beradi.

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