chunki u da $H^{n-m+1}(\lambda) \geq 0$ va $(c^2)^{n-m+1} > 0$. Demak, v funksiya $D' = \Phi^{-1}(D)$ da $(A)m$-qavariqlik ta'rifidagi ikkala shartni ham qanoatlantiradi. Shuning uchun $v \in (A)m - cv(D')$. *Teorema isbotlandi.*

Xulosa. Maqolada olingan natijalar $(A)m$-qavariq funksiyalar sinfi klassik qavariq va subgarmonik funksiyalar sinflari kabi muhim geometrik hamda topologik invariantlik xossalariga ega ekanligini tasdiqlaydi. Xususan, almashtirishlarga nisbatan barqarorlik va $C^2_{\text{loc}}(D)$ topologiyasidagi yopiqlik xossalari ushbu sinf ustida matematik analiz operatorlarini qo'llash imkoniyatini kengaytiradi. Olingan natijalar kelgusida Hessian tipidagi nochiziqli differensial tenglamalar uchun hamda potensiallar nazariyasining turli masalalarida asosiy apparat sifatida xizmat qiladi.

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Razzokov Alijon Shonazarovich (Abu Rayhon Beruniy nomidagi Urganch davlat universiteti, H.Olimjon, 14, Urganch, 220100, O'zbekistan, f.-m.f.d. prof.; e-mail: a.razzokov777@gmail.com),

Koshchanova Durdona Ermatovna (Abu Rayhon Beruniy nomidagi Urganch davlat universiteti, H.Olimjon, 14, Urganch, 220100, O'zbekistan, o'qituvchi; e-mail: dona2525@mail.ru),

Abdullayeva Sevara Otaxon qizi (Abu Rayhon Beruniy nomidagi Urganch davlat universiteti, H.Olimjon, 14, Urganch, 220100, O'zbekistan)

$(GE2)_{1-X-Y}(GAAS)_X(ZNSE)_Y$ VA $SI_{1-X}GE_X$ QATTIQ QORISHMALARNING TERMODINAMIK PARAMETRLARINI ANIQLASH

Annotatsiya. *Mazkur ishda suyuq fazali epitaksiya usuli yordamida qalay (Sn) asosidagi eritmadan o'stiriladigan* $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ *ko'p komponentli va* $Si_{1-x}Ge_x$ *yarimo'tkazgich qattiq qorishmalarining termodinamik tahlili keltirilgan. Suyuq va qattiq fazalardagi komponentlarning aktivlik koeffitsiyentlarini tavsiflovchi umumlashtirilgan termodinamik model atomlararo o'zaro ta'sir parametrlariga hamda Gibbs erkin energiyasi formalizmiga asoslanib ishlab chiqilgan. Qattiq qorishmaning umumiy aralashish Gibbs erkin energiyasi, komponentlararo o'zaro ta'sir energiyasi aniqlangan* $(Ge_2)_{0.02}(GaAs)_{0.95}(ZnSe)_{0.03}$ *tarkibli va* $Si_{1-x}Ge_x$ $(0<x<1)$ *qattiq qorishmalar qalayli eritmadan, mos ravishda, 750C, 950C boshlang'ich haroratlarda o'stirilgan. Bunda* $(Ge_2)_{0.02}(GaAs)_{0.95}(ZnSe)_{0.03}$ *uchun Gibbs energiya qiymatlari* G^{mix}*=-2980 J/mol va* G^{ex}*= -1030 J/mol ga, kritik harorat esa 137 K ga teng bo'lgan.* $Si_{1-x}Ge_x$ *qattiq qorishma uchun* G^{mix}*=-6710 J/mol va kritik harorat 80 Kni tashkil qilgan.*

Kalit so'zlar: *epitaxy, Gibbs energy, activity koeffitsiyent, solid solution.*

Раззоков Алижон Шоназарович (Ургенчский государственный университет имени Абу Райхана Беруни, г. Ургенч, ул. Х.Алимджана, 14, Узбекистан; д.ф.-м.н. проф., предподаватель; e-mail: a.razzokov777@gmail.com),
Кошчанова Дурдона Эрматовна (Ургенчский государственный университет имени Абу Райхана Беруни, г.Ургенч, ул.Х.Алимджана, 14, Узбекистан; dona2525@mail.ru),
Абдуллаева Севара Отахон кизи (Ургенчский государственный университет имени Абу Райхана Беруни, г.Ургенч, ул.Х.Алимджана, 14, Узбекистан)

ОПРЕДЕЛЕНИЕ ТЕРМОДИНАМИЧЕСКИХ ПАРАМЕТРОВ ПОЛУПРОВОДНИКОВЫХ ТВЕРДЫХ РАСТВОРОВ $(GE_2)_{1-x-\gamma}(GAAS)_x(ZNSE)_\gamma$ И $SI_{1-x}GE_x$

Аннотация. *В данной работе представлен термодинамический анализ многокомпонентных* $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ *и* $Si_{1-x}Ge_x$ *полупроводниковых твердых растворов, выращиваемых из оловянного (Sn) раствора-расплава методом жидкофазной эпитаксии. На основе параметров межатомного взаимодействия и формализма свободной энергии Гиббса разработана обобщенная термодинамическая модель, описывающая коэффициенты активности компонентов в жидкой и твердой фазах. Определены общая свободная энергия Гиббса смешения твердого раствора и энергия межкомпонентного взаимодействия. Твердые растворы состава* $(Ge_2)_{0.02}\ (GaAs)\ _{0.95}(ZnSe)_{0.03}$ *и* $Si_{1-x}Ge_x$ $(0 < x < 1)$ *были выращены из оловянного раствора при начальных температурах* $750°C$ *и* $950°C$ *соответственно. При этом для* $(Ge_2)_{0.02}(GaAs)_{0.95}(ZnSe)_{0.03}$ *значения энергии Гиббса составили* -2980 *Дж/моль и* -1030 *Дж/моль, а критическая температура –* 137 *К. Для твердого раствора* $Si_{1-x}Ge_x$ *энергия взаимодействия составила* -6710 *Дж/моль при критической температуре* 80 *К.*

Ключевые слова: *жидкофазная эпитаксия, энергия Гиббса, коэффициент активности, твердый раствор.*

Razzokov Alijon Shonazarovich (Urganch State University named after Abu Raykhan Beruni, Kh.Alimdjan, 14, Urgench, 220100, Uzbekistan; f.-m.f.d. prof., teacher; e-mail: a.razzokov777@gmail.com),
Koshchanova Durdona Ermatovna (Urgench State University named after Abu Raykhan Beruni, Kh.Alimdjan, 14, Urgench, 220100, Uzbekistan; dona2525@mail.ru),
Abdullayeva Sevara Otaxon qizi (Urgench State University named after Abu Raykhan Beruni, Kh.Alimdjan, 14, Urgench, 220100, Uzbekistan)

DETERMINATION OF THE THERMODYNAMIC PARAMETERS OF $(GE_2)_{1-x-\gamma}(GAAS)_x(ZNSE)_\gamma$ AND $SI_{1-x}GE_x$ SEMICONDUCTOR SOLID SOLUTIONS

Annotation. *This work presents a thermodynamic analysis of multicrystalline* $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ *and* $Si_{1-x}Ge_x$ *semiconductor solid solutions grown from a tin (Sn)-based solution using the liquid-phase epitaxy (LPE) technique. A generalized thermodynamic model describing the activity coefficients of the components in both liquid and solid phases was developed based on interatomic interaction parameters and the Gibbs free energy formalism. The total Gibbs free energy of mixing for the solid solution and the intercomponent interaction energies were determined.* $(Ge_2)_{0.02}(GaAs)_{0.95}(ZnSe)_{0.03}$ *and* $Si_{1-x}Ge_x$ $(0 < x < 1)$ *solid solutions were grown from the tin solution at initial temperatures of* $750°C$ *and* $950°C$*, respectively. Under these conditions, the Gibbs free energy values for* $(Ge_2)_{0.02}(GaAs)_{0.95}(ZnSe)_{0.03}$ *were determined as* -2980 *J/mol and* -1030 *J/mol, with a critical temperature of* 137 *K. For the* $Si_{1-x}Ge_x$ *solid solution, the interaction energy was* -6710 *J/mol, and the critical temperature was found to be* 80 *K.*

Keywords: *liquid-phase epitaxy, Gibbs free energy, activity coefficient, semiconductor solid solution, thermodynamic stability, spinodal decomposition.*

Kirish. Yarimoʻtkazgich materiallar texnologiyasida qattiq qorishmalarni suyuq faza (eritma)dan oʻstirish usuli eng samarali va keng qoʻllaniladigan usullardan biri hisoblanadi. Bunday jarayonlarda erituvchi sifatida odatda past erish haroratiga ega boʻlgan metall sistemalar, jumladan, qalayli (Sn asosidagi) eritmalar qoʻllaniladi. Ushbu eritmalar Ge, GaAs va ZnSe kabi murakkab yarimoʻtkazgich komponentlarini yetarlicha erita olishi bilan ajralib turadi va kristall oʻsish jarayonini pastroq haroratlarda amalga oshirish imkonini beradi [1,2].

Mazkur ishda $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ tarkibli qattiq qorishmani qalayli eritmadan kristallantirish jarayoni koʻrib chiqiladi. Dastlabki suyuq fazada Ge, GaAs va ZnSe komponentlari Sn asosidagi eritmada erib, gomogen eritma hosil qiladi. Oʻsish jarayoni boshlanishida tizimning harorati T=1023 K boʻlib, bu harorat komponentlarning suyuq fazada yetarlicha erishini va kristallanish uchun zarur termodinamik sharoitni ta'minlaydi.

Eksperimental kuzatuvlarga ko‘ra, hosil bo‘ladigan qattiq fazada tarkib doimiy bo‘lib qoladi va $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$qattiq qorishma uchun x=0.95 va y=0.03 qiymatlarda barqarorlashadi [3]. Bu holat qattiq qorishma tarkibining suyuq fazadagi boshlang‘ich konsentratsiyadan sezilarli darajada farq qilishini ko‘rsatadi va kristallanish jarayonida selektiv ajralish (segregatsiya) hodisasi mavjudligini bildiradi.

Suyuq faza va qattiq faza orasidagi taqsimlanish koeffitsiyentlari (segregatsiya koeffitsientlari) birlikdan sezilarli farq qiladi. Bu esa kristall o‘sishi davomida komponentlarning qattiq fazaga kirish ehtimolini cheklaydi va natijada qattiq qorishmada GaAs va ZnSe komponentlari faqat juda kichik ulushlarda saqlanadi [4].

Tadqiqot metodologiyasi. Suyuq fazali epitaksiya (SFE) usuli yordamida qalay (Sn) asosidagi cheklangan eritma–suyuqlanmadan GaAs(100) taglik yuzasida $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ tarkibli qattiq qorishmaning epitaksial qatlamlari sintez qilindi. Epitaksial qatlamlarni o‘stirish jarayoni kristallanish-ning boshlanish harorati T_oc = 750°Cda dasturiy boshqariladigan majburiy sovitish rejimida amalga oshiril-di.

Tajribalarda kristallografik yo‘nalishi (100) bo‘lgan, p-tip (p =5×10^{18} sm^{-3}) va n-tip (n=3×10^{17} sm^{-3}) elektr o‘tkazuvchanlikka ega, diametri 20 mm hamda qalinligi 380–400 mkm bo‘lgan galliy arsenid (GaAs) monokristall tagliklaridan foydalanildi.

Taqiqlangan energetik zona kengligi gradientiga ega$(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ qattiq qorishmasining epitaksial qatlamlarini o‘stirish uchun EPOS tipidagi epitaksial qurilmadan foydalanildi [5].

Eritma–suyuqlanma tarkibini optimallashtirish maqsadida Ge, GaAs va ZnSe komponentlarining qalaydagi (Sn) eruvchanligi 800–550°C harorat oralig‘ida eksperimental ravishda tadqiq qilindi. Bunda galliy arsenid va rux selenid namunalarining suyuq qalayda eritma to‘yingan holatga yetguniga qadar ushlab turilishi hamda ularning massa yo‘qotish qiymatlarini aniqlash usulidan foydalanildi. Shu bilan birga, GaAs komponentining ZnSening qalaydagi eruvchanligiga ko‘rsatadigan o‘zaro ta’siri ham hisobga olindi.

Sn–Ge–GaAs–ZnSe tizimiga mansub eritma–suyuqlanmaning boshlang‘ich tarkibi adabiyotlarda keltirilgan ma’lumotlar hamda dastlabki eksperimental tadqiqotlar natijalari asosida, tizimni tashkil etuvchi ikkilik komponentlarning fazaviy muvozanati va eruvchanlik xususiyatlari inobatga olingan holda hisoblab chiqildi [6].

Nazariy va eksperimental qism. Yarimo‘tkazgich materiallar va ular asosida strukturalar olish, ularning priborsozlikda barqaror va uzoq muddatli ishlashida muhim omil hisoblanadi. Shuning uchun ushbu bo`limda $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$, $Si_{1-x}Ge_x$ qattiq qorishmalarini suyuq fazadagi, qattiq va suyuq fazalardagi muvozanatli holatdagi, qattiq fazadagi termodinamik parametrlarini aniqlash ma`lumotlarini keltiramiz.

Agar 5 (A,B,C,D,E) komponentali $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$qattiq qorishma uchun suyuq fazadagi komponentlarning faollik koeffitsiyentlari tenglamasini yozsak, quyidagi ko‘rinishda bo‘ladi [7]:

$$RTln\gamma_A^l = \alpha_A^l(x_A^l)^2 + \alpha_{AB}^l(x_B^l)^2 + \alpha_{AC}^l(x_C^l)^2 + \alpha_{AD}^l(x_D^l)^2 + \alpha_{AE}^l(x_E^l)^2 + (\alpha_A^l + \alpha_{AB}^l - \alpha_B^l)x_A^l x_B^l + (\alpha_A^l + \alpha_{AC}^l - \alpha_C^l)x_A^l x_C^l + (\alpha_A^l + \alpha_{AD}^l - \alpha_D^l)x_A^l x_D^l + (\alpha_A^l + \alpha_{AE}^l - \alpha_E^l)x_A^l x_E^l;$$

$$RTln\gamma_B^l = \alpha_B^l(x_B^l)^2 + \alpha_{AB}^l(x_A^l)^2 + \alpha_{BC}^l(x_C^l)^2 + \alpha_{BD}^l(x_D^l)^2 + \alpha_{BE}^l(x_E^l)^2 + (\alpha_B^l + \alpha_{AB}^l - \alpha_A^l)x_A^l x_B^l + (\alpha_B^l + \alpha_{BC}^l - \alpha_C^l)x_B^l x_C^l + (\alpha_B^l + \alpha_{BD}^l - \alpha_D^l)x_B^l x_D^l + (\alpha_B^l + \alpha_{BE}^l - \alpha_E^l)x_B^l x_E^l;$$

$$RTln\gamma_C^l = \alpha_C^l(x_C^l)^2 + \alpha_{AC}^l(x_A^l)^2 + \alpha_{BC}^l(x_B^l)^2 + \alpha_{CD}^l(x_D^l)^2 + \alpha_{CE}^l(x_E^l)^2 + (\alpha_C^l + \alpha_{AC}^l - \alpha_A^l)x_A^l x_C^l + (\alpha_C^l + \alpha_{BC}^l - \alpha_B^l)x_B^l x_C^l + (\alpha_C^l + \alpha_{CD}^l - \alpha_D^l)x_C^l x_D^l + (\alpha_C^l + \alpha_{CE}^l - \alpha_E^l)x_C^l x_E^l;$$

$$RTln\gamma_D^l = \alpha_D^l(x_D^l)^2 + \alpha_{AD}^l(x_A^l)^2 + \alpha_{BD}^l(x_B^l)^2 + \alpha_{CD}^l(x_C^l)^2 + \alpha_{DE}^l(x_E^l)^2 + (\alpha_D^l + \alpha_{AD}^l - \alpha_A^l)x_A^l x_D^l + (\alpha_D^l + \alpha_{BD}^l - \alpha_B^l)x_B^l x_D^l + (\alpha_D^l + \alpha_{CD}^l - \alpha_C^l)x_C^l x_D^l + (\alpha_D^l + \alpha_{DE}^l - \alpha_E^l)x_D^l x_E^l;$$

$$RTln\gamma_E^l = \alpha_E^l(x_E^l)^2 + \alpha_{AE}^l(x_A^l)^2 + \alpha_{BE}^l(x_B^l)^2 + \alpha_{CE}^l(x_C^l)^2 + \alpha_{DE}^l(x_D^l)^2 + (\alpha_E^l + \alpha_{AE}^l - \alpha_A^l)x_A^l x_E^l + (\alpha_E^l + \alpha_{BE}^l - \alpha_B^l)x_B^l x_E^l + (\alpha_E^l + \alpha_{CE}^l - \alpha_C^l)x_C^l x_E^l + (\alpha_E^l + \alpha_{DE}^l - \alpha_D^l)x_D^l x_E^l;$$

bu yerda: T-harorat, α_E^l- atomlarning o‘zaro ta’sir parametrlari, x-konsentratsiya, γ_E^l- aktivlik koeffitsiyenti, R- universial gaz doiymiysi.

Mazkur umumiy tenglamani yoyilmasini qattiq faza uchun yozsak, psevdokomponentlarning aktivlikni aniqlovchi tenglama quyidagi ko‘rinishga keladi:

$$RTlna_{13}^S = RTln\,xy + \alpha_{12}(1-x)^2 + \alpha_{34}z(1-y) + \alpha_{35}(1-y)(1-y-z) - \alpha_{45}z(1-y-z) + \{[-\alpha_{c1} - \alpha_{31}x - \alpha_{76}y - \alpha_{98}z](1-y-z) + [-\alpha_{c3} - \alpha_{21}x - \alpha_{54}y]z\}(1-x);$$

$$RTlna_{14}^S = RTln\,xz + \alpha_{12}(1-x)^2 + \alpha_{34}y(1-z) - \alpha_{35}y(1-y-z) + \alpha_{45}(1-z)(1-y-z) + \{[-\alpha_{c2} - \alpha_{32}x - \alpha_{76}y - \alpha_{98}z](1-y-z) + [\alpha_{c3} + \alpha_{21}x - \alpha_{54}z]y\}(1-x);$$

$$RTlna_{15}^{S} = RTln\,x(1-y-z) + \alpha_{12}(1-x)^2 - \alpha_{34}yz + \alpha_{35}y(y+z) + \alpha_{45}z(y+z) + \{[\alpha_{c2} + \alpha_{32}x - \alpha_{54}y - \alpha_{98}(1-y-z)]z + [\alpha_{c1} + \alpha_{31}x - \alpha_{76}(1-y-z)]y\}(1-x);$$

$$RTlna_{23}^{S} = RTln\,(1-x)y + \alpha_{12}x^2 + \alpha_{34}z(1-y) + \alpha_{35}(1-y)(1-y-z) - \alpha_{45}z(1-y-z) + \{[\alpha_{c1} - \alpha_{31}(1-x) + \alpha_{76}y - \alpha_{98}z](1-y-z) + [\alpha_{c3} - \alpha_{21}(1-x) + \alpha_{54}y]z\}x;$$

$$RTlna_{24}^{S} = RTln\,(1-x)z + \alpha_{12}x^2 + \alpha_{34}y(1-z) - \alpha_{35}y(1-y-z) + \alpha_{45}(1-z)(1-y-z) + \{[\alpha_{c2} - \alpha_{32}(1-x) + \alpha_{76}y + \alpha_{98}z](1-y-z) + [-\alpha_{c3} + \alpha_{21}(1-x) + \alpha_{54}z]y\}x;$$

$$Tln\,a_{25}^{S} = RTln\,(1-x)(1-y-z) + \alpha_{12}x^2 - \alpha_{34}yz + \alpha_{35}y(y+z) + \alpha_{45}z(y+z) + \{[-\alpha_{c2} + \alpha_{32}(1-x) + \alpha_{54}y + \alpha_{98}(1-y-z)]z + [-\alpha_{c1} + \alpha_{31}(1-x) + \alpha_{76}(1-y-z)]y\}x.$$

$(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ qattiq qorishma uchun suyuq fazadagi komponentlarning aktivlik koeffitsiyentlarini topishni soddalashtiramiz va uchta komponenta masalasiga olib kelamiz ($Si_{1-x-y}Ge_x(GaAs)_y$, $Si_{1-x-y}Ge_xSn_y$ va boshqalar). Tenglamalar quyidagi shaklga ega bo‘ladi:

$$RTln\gamma_{Ge_2} = \alpha_{12}x_2^2 + \alpha_{13}x_3^2 + (\alpha_{12} + \alpha_{13} - \alpha_{23})x_2x_3$$

$$RTln\gamma_{GaAs} = \alpha_{12}x_1^2 + \alpha_{23}x_3^2 + (\alpha_{12} + \alpha_{23} - \alpha_{13})x_1x_3$$

$$RTln\gamma_{ZnSe} = \alpha_{13}x_1^2 + \alpha_{23}x_2^2 + (\alpha_{13} + \alpha_{23} - \alpha_{12})x_1x_2$$

$(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ qattiq qorishma uchun qattiq fazada aralashish Gibbs energiyasi ushbu tenglama bilan topiladi [8]:

$$G^{mix} = RT\sum x_i lnx_i + \sum \alpha_{ij}x_ix_j$$

Hisob-kitoblarga muvofiq, G^{mix}=-2980 J/mol. va G^{ex}= -1030 J/mol. Manfiylik qiymati barqaror qattiq qotishma ekanligini bildiradi. Kritik harorat esa 137 K ga teng bo‘ldi. Xuddi shunday, 950°C haroratda o‘stirilgan $Si_{1-x}Ge_x$ qattiq qorishmani 2 komponentali bo‘lgani uchun soddalashtirib mazkur parametrlari hisoblandi. Bunda G^{mix}=-6710 J/mol va kritik harorat esa 80 Kni tashkil qildi.

Ko‘p komponentli sistemalarda esa Gesse matritsasining nol xususiy qiymatiga mos yo‘nalish bo‘yicha uchinchi tartibli hosila ham nol bo‘lishi talab qilinadi. Shuning uchun

$$\det(H) = 0\ va\ \frac{\partial^3 G}{\partial x_i^3} = 0$$

Hisob-kitoblarga muvofiq,$(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$qattiq qorishma uchun det(H)=$1.57\cdot10^{11}$>0. Determinantning echimiga bog‘liq ravishda qattiq qorishmaning degradatsiyga chidamliligini xarakterlash mumkin. Agar $\det(H) > 0$ musbat qiymatga ega bo‘lsa, qattiq qorishma barqaror, manfiy qiymatga ega bo‘lsa, $\det(H) < 0$ beqaror yoki o‘z-o‘zidan tarkib komponentalari ajraladigan (parchalanib boruvchi) kristall strukturaga ega bo‘ladi. Chegaraviy holatni esa (spindodal chegara) kritik chegara deb, $\det(H) = 0$ qiymatidagi echimdan topiladi.

Xulosa. Mazkur ishda qalayli eritmadan suyuq fazali epitaksiya usuli yordamida o‘stiriladigan $(Ge_2)_{1-x-y}(GaAs)_x(ZnSe)_y$ ko‘p komponentli va $Si_{1-x}Ge_x$ qattiq qorishmalarning termodinamik modeli ishlab chiqildi. Suyuq va qattiq fazalardagi komponentlarning aktivlik koeffitsiyentlarini tavsiflovchi umumiy analitik tenglamalar atomlararo o‘zaro ta’sir parametrlarini hisobga olgan holda hosil qilindi. Ko‘p komponentli model amaliy hisoblashlarni soddalashtirish maqsadida Ge_2–GaAs–ZnSe kvazibinar uch komponentli tizimga keltirildi va ushbu tizim uchun aktivlik koeffitsiyentlari hamda aralashish Gibbs erkin energasi ifodalari olindi.

Qattiq qorishmaning termodinamik barqarorligini baholash uchun Gibbs energiyasining ikkinchi tartibli hosilalaridan tashkil topgan Gesse matritsasi qo‘llanildi. Gesse matritsasi determinantining ishorasi asosida fazaning barqarorligi, beqarorligi hamda spinodal chegarasi aniqlandi.

Taklif etilgan termodinamik model ko‘p komponentli yarimo‘tkazgich qattiq qorishmalarining aktivligini, fazalar barqarorligini, degradatsiya chegaralarini va epitaksial geterostrukturalarning uzoq muddatli ishlash ishonchliligini oldindan baholash imkonini beradi. Mazkur yondashuv ko‘p komponentli yarimo‘tkazgich tizimlarining termodinamik tahlili uchun ham qo‘llanishi mumkin.

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Ismoilov Elbek Abdirashitovich (Samarqand davlat universiteti, fizika-matematika fanlari bo‘yicha falsafa doktori; eismoilov.samsu@gmail.com)

ICHKI QOVUSHOQ SUYUQLIK TA’SIRIDAGI SILINDRIK QOBIQNING KUCHLANGANLIK HOLATI VA MUSTAHKAMLIGINI TAHLIL QILISH

Annotatsiya. *Mazkur maqolada ichki qovushoq suyuklik bilan o‘zaro ta’sirlashuvchi transversal-izotrop silindrik qobiqning kuchlanganlik-deformatsiyalanganlik holati va mustahkamligi tadqiq etilgan. Qobiq va suyuqlikning o‘zaro ta’sirini tavsiflovchi matematik model asosida kuchlanish tenzori komponentalari analitik ifodalanib, ularni sonli usullar yordamida hisoblash algoritmi ishlab chiqilgan. Olingan natijalar asosida Von Mises sharti bo‘yicha ekvivalent kuchlanish aniqlanib, qobiqning mustahkamligi baholangan. Hisoblash natijalari ichki qovushoq suyuqlikning kuchlanishlarning taqsimlanishiga sezilarli ta’sir ko‘rsatishini hamda qaralayotgan konstruksiya berilgan yuklanish ostida mustahkamlik talablarini qanoatlantirishini ko‘rsatadi.*

Kalit so‘zlar: *silindrik qobiq, qovushoq suyuqlik, transversal-izotrop material, kuchlanganlik holati, mustahkamlik, Von Mises sharti, kuchlanish tenzori.*

Исмоилов Элбек Абдирашитович (Самаркандский государственный университет, доктор философии по физико-математическим наукам; eismoilov.samsu@gmail.com)

АНАЛИЗ НАПРЯЖЕННОГО СОСТОЯНИЯ И ПРОЧНОСТИ ЦИЛИНДРИЧЕСКОЙ ОБОЛОЧКИ ПОД ДЕЙСТВИЕМ ВНУТРЕННЕЙ ВЯЗКОЙ ЖИДКОСТИ

Аннотация. *В данной работе исследуются напряженно-деформированное состояние и прочность трансверсально-изотропной цилиндрической оболочки, взаимодействующей с внутренней вязкой жидкостью. На основе математической модели, описывающей взаимодействие оболочки и жидкости, компоненты тензора напряжений были выражены аналитически, а также разработан алгоритм для их численного расчета. На основе полученных результатов определено эквивалентное напряжение по критерию Фон Мизеса и оценена прочность оболочки. Результаты расчетов показывают, что вязкая жидкость внутри оболочки оказывает существенное влияние на распределение напряжений и что рассматриваемая конструкция удовлетворяет требованиям прочности при заданных условиях нагружения.*

Ключевые слова*: цилиндрическая оболочка, вязкая жидкость, поперечно-изотропный материал, состояние напряжений, прочность, критерий фон Мизеса, тензор напряжений.*

Ismoilov Elbek Abdirashitovich (Samarkand State University, Doctor of Philosophy in Physics and Mathematics; eismoilov.samsu@gmail.com)

ANALYSIS OF THE STRESS STATE AND STRENGTH OF A CYLINDRICAL SHELL UNDER THE INFLUENCE OF AN INTERNAL VISCOSOUS FLUID

Annotation. *This article investigates the stress-strain state and strength of a transversely isotropic cylindrical shell interacting with a viscous fluid inside it. Based on a mathematical model describing the interaction between the shell and the fluid, the components of the stress tensor were expressed analytically, and an algorithm was developed for their numerical calculation. Based on the results obtained, the equivalent stress was determined using the von Mises criterion and the strength of the shell was assessed.*