NN.9P THERMOELECTRIC POWER FACTOR OF DOUBLE QUANTUM WELL STRUCTURE

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Experimental and theoretical investigations [1-4] of coupled double quantum well structures GaAs/GaAlAs had shown that due to effect of wave function modulation the carrier mobility may exceed the corresponding in single quantum well (SQW). In that paper we have studied theoretically the thermoelectric opportunities of similar structures. Well and inner barrier thickness dependencies of mobility, Seebeck coefficient and power factor in symmetrical and asymmetrical (100) oriented PbTe/$Pb_{1-x}Eu_xTe$ double QW structures had been investigated.

The model with rectangular confinement potential U=173 meV for both quantum wells had considered. The energies E_α of levels of dimensional quantization, dispersion law, Fermy energy E_F ware calculated as a function of wells widths. Qualitatively all these dependencies are the same as in single QW. Here we note only some peculiarities. i) The doubling of levels in couple QWs gives relatively small effect on value of Fermy energy. However the difference E_1 - E_F that define carriers statistic on most populated first level is reduced. ii) Small violation of the symmetry between wells results in small changing of all parameters excluding the wave functions. At great distance between the wells the later are subjected to essential reconstruction in comparison with strictly symmetrical system. The electrons on first level now localized mainly in wider QW, on second level with very close energy in thinner well and so on.

Kinetic coefficients were calculated on the base of Boltzmann equations which were solved by iterations. Used formalism [5] is general enough to take into account the intrasubband and intersubband transitions of electrons scattering on acoustic and optical phonons, the nonparabolicity of dispersion law, the dependence of effective masses on QWs height and width of wells and inner barrier, the presence or lifting of valley degeneracy, and the effect of wave function penetration into the barriers.

The dependencies of mobility μ on inner barrier thickness b have been investigated. With increasing b mobility increases - effect of wave function modulation [2]. This increasing right up to some b^*, when new level of dimensional quantization appear in wells and new channel of energy relaxation with carrier intersubband transition becomes open. With further increasing of b the levels of dimensional quantizations approach to each other, the scattering strength increase and mobility decrease. The value of mobility at great b depends on symmetry. In strictly symmetrical structure μ approach from above to the value that is lower than in SQW. In asymmetrical system the redistribution of carriers wave functions between the wells suppress the intersubband scattering with carrier transfer between the wells and the mobility again become increase, reaching the values in SQW at very great b. The minimum on the dependence $\mu(b)$ appears.

The investigation of Seebeck coefficient S had shown its unusual behavior in the range $0<b<b^*$. With increasing b Seebeck coefficient slowly increases simultaneously with mobility, reaching poorly expressed maximum at $b=b^*$. Maximum value of S is lower than in SQW. In the range $b>b^*$ Seebeck coefficient increases with increasing b, as it was possible to expect. In strictly symmetrical structure S approach to the value that is higher than in single well with same width. In asymmetrical structure the dependence $S(b)$ has the maximum corresponding to the minimum of the mobility. For $b>>b^*$ the values of Seebeck coefficient are higher than in SQW. Note also that in strongly asymmetrical systems the minimum of μ and maximum of S almost disappear. Investigated dependencies of power factor as a function of b have the maximum at $b=b^*$. It was found that at wells widths $d_1=d_2$=20 Å, b^*=20 Å, temperature T=300 K and carrier concentration $n=2\times10^{19}$ cm^{-3} the power factor P = 170 $\mu W cm^{-1} K^{-2}$. This value exceed the corresponding P = 155 $\mu W\ cm^{-1} K^{-2}$ in single QW calculated in the same approximations at the same parameters and well width d=20Å and considerably higher than P= 75$\mu W\ cm^{-1} K^{-2}$ at d=40 Å.

Reference

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