# TERAHERTZ RESONANT TUNNELING DIODES BASED ON GaN/AlGaN STRUCTURES

## DIODE REZONANTE DE TUNEL TERAHERTZ BAZATE PE STRUCTURI GaN/AlGaN

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The terahertz (THz) region, typically defined as 0.1-10 THz was often referred as "terahertz gap" due to the difficulties in efficiently generating, manipulating and detecting THz radiation. This spectral region covers intermolecular vibrations of biological molecules and low frequency crystalline lattice vibrations (phonon modes) of chemical materials, including drugs, viruses and explosives [1-6]. Moreover, THz waves have a low photon energies (~ 4.1 meV for 1 THz), which is about 1 million times weaken than energy of X-ray photon, and it will not cause harmful ionization in biological tissues [7, 8]. Thus, the THz waves considered as a safe method for investigation of biological materials and can be used in medicine for THz imaging and for other applications. The conventional THz sources usually are based on GaAs heterostructures [9]. However, they can only provide incomplete spectral coverage and remain limited to cryogenic temperatures due to an intrinsic property of GaAs, namely the presence of LO-phonons with THz-range frequencies. Among II-VI and III-V semiconductor compounds, GaN/AlGaN seems to be a promising candidate for room temperature THz sources thanks to its much larger LO phonon energy (92 meV) [10-12]. GaN offers prospects for THz quantum cascade devices, which can operate in a much broader spectral range from 1 to 15 THz and in particular in the 5-11 THz, which cannot be covered by other III-V semiconductors [13].

Terahertz resonant tunneling diodes (RTDs) based on $Al_xGa_{1-x}N$/GaN quantum structures with one quantum well and double quantum barriers (Al, x=0.30), and with two quantum wells and triple quantum barriers (Al, x=0.25) have been investigated numerically using non-equilibrium Green's function formalism. The schematic structure of GaN-based RTD device with one quantum well and two quantum barriers is presented in Fig. 1.

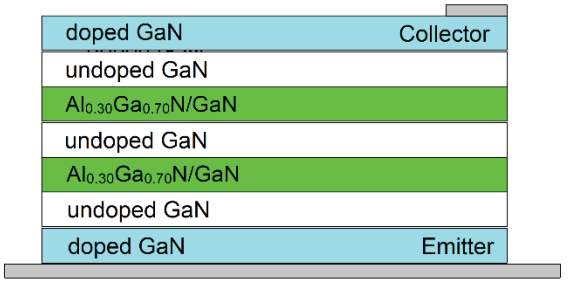



Fig.1 Schematic structure terahertz resonant tunneling diode based on $Al_{0.30}Ga_{0.70}N$/GaN structure with one quantum well and double quantum barriers. The layer stack of such RTD device from the emitter is following: 100 nm GaN (emitter)/10 nm UID GaN (spacer) /2nm $Al_{0.30}Ga_{0.70}N$ (QB)/3nm GaN (QW)/ 2nm $Al_{0.30}Ga_{0.70}N$ (QB)/ 10 nm UID GaN (spacer)/ 100 nm GaN (collector)

The effect of collector n-type doping on conduction band diagram and energetic spectra of electrons for $Al_{0.30}Ga_{0.70}N$/GaN quantum structures with one quantum well (QW) and double quantum barriers (QBs) have been investigated numerically (Fig. 2). For this RTD device it was found that the increasing of doping level of collector contact from $1\times10^{18}$ $cm^{-3}$ to $8\times10^{19}$ $cm^{-3}$ leads to narrowing polarization-induced collector barrier width from ~ 50 nm to 10 nm and enhances resonant tunneling transmission.

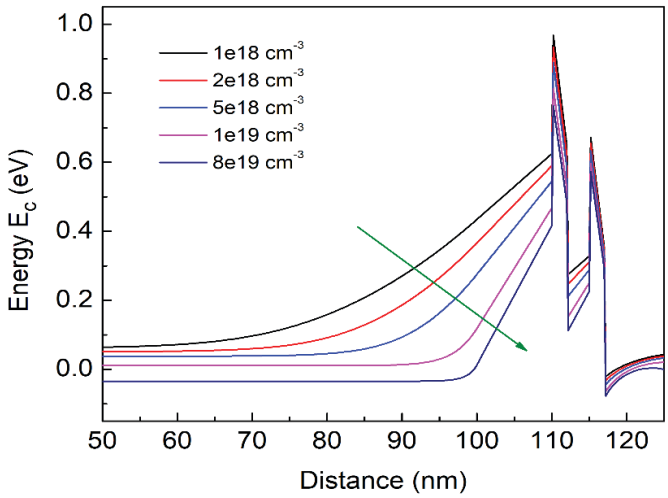



Fig. 2. Conduction band energy versus depth for various doping levels. The thickness of the collector spacer is equal to be 10 nm

Also, the effect of collector n-type doping on conduction band diagram and transmission coefficient of electrons for polar c-plane $Al_{0.25}Ga_{0.75}N$/GaN quantum structures with two quantum wells (QWs) and triple quantum barriers (QBs) have been investigated and the results are presented in Fig. 3. It was established that the transmission coefficient

is increasing with increasing of n-type doping level of collector. From Fig. 3 it was found that at n-type doping of collector with a concentration of $1\times10^{19}$ $cm^{-3}$ the first resonance energy is estimated to be ~ 0.24 eV.

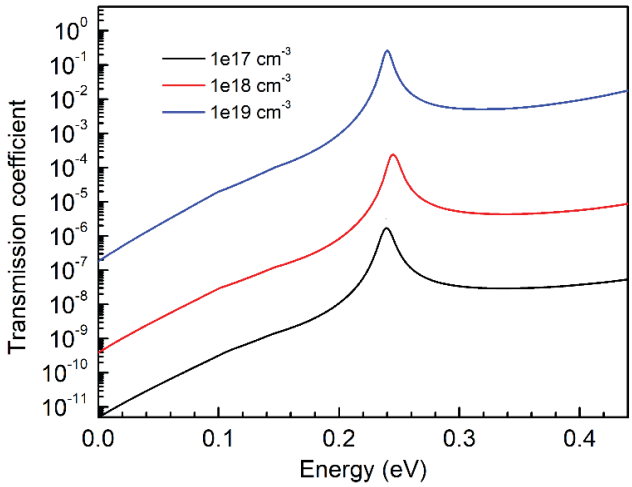



Fig. 3. Transmission coefficients vs voltage bias for GaN-based RTD with two QWs and triple QBs

**Conclusions.** Terahertz resonant tunneling diodeы based on GaN/AlGaN qunatum structures with double and tripple quantum barries have been investigated numerically. It is found that the increasing of collector n-type doping leads to the narrowing polarization-induced collector barrier width and thus creates favorable condition for resonant tunneling transmission for electrons.

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