Electrical properties of optimized nBn structures based on HgCdTe grown by molecular beam epitaxy

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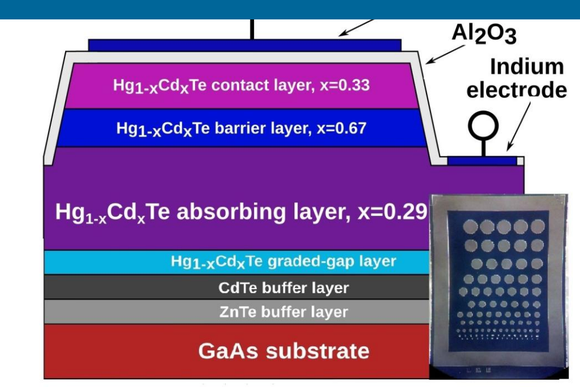
EXPERIMENTAL: SAMPLES AND TECHNIQUE

- $Hg_{1-x}Cd_xTe$ barrier structures were grown at Rzhanov Institute of Semiconductor Physics with molecular-beam epitaxy (MBE) on GaAs (013) substrates with CdTe/ZnTe buffer layers.
- The working region of the nBn structure consisted of an absorbing layer, a barrier layer, and a contact layer. The composition in the absorbing layer was 0.29, and in the barrier layer it was 0.67. The thicknesses of the barrier layer was 120 nm.
- In the fabrication of device nBn structures, the HgCdTe film was etched to form a mesa configuration. After that, about 90 nm thick PE ALD Al_2O_3 dielectric film was deposited.

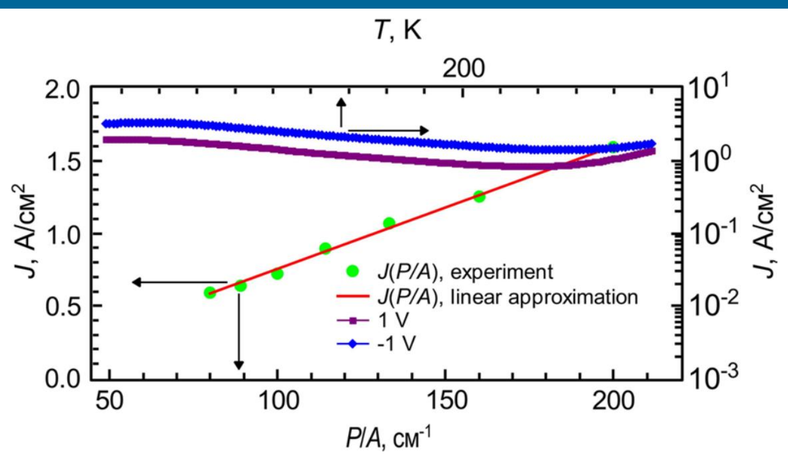
Device structures of two types were created: nBn structures and MIS devices based on nBn structures.



Schematic view of test MIS device based on nBn structure. The inset shows a photograph of the fabricated sample

RESULTS

DARK CURRENT STUDY



Dependence of the dark current density on temperature and on the ratio of the structure mesa perimeter to area (−2 V, 300 K)

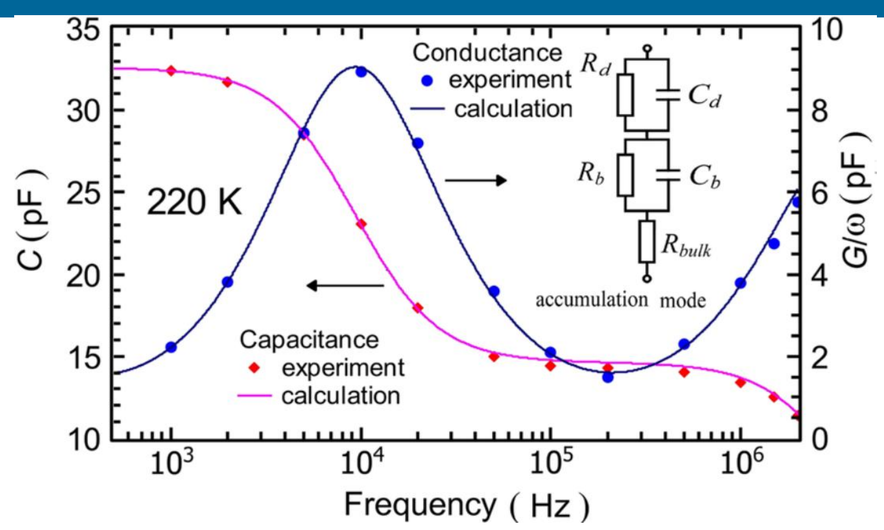
- The current-voltage characteristics are almost symmetrical at forward and reverse biases.
- The dark current density weakly depends on temperature. A surface-limited dark current at reverse bias is realized. The determined surface leakage current density (J_S) was 0.00848 A/cm.
- It is problematic to determine the bulk current density values from dark current measurements due to the dominance of the surface leakage component.

ADMITTANCE STUDY

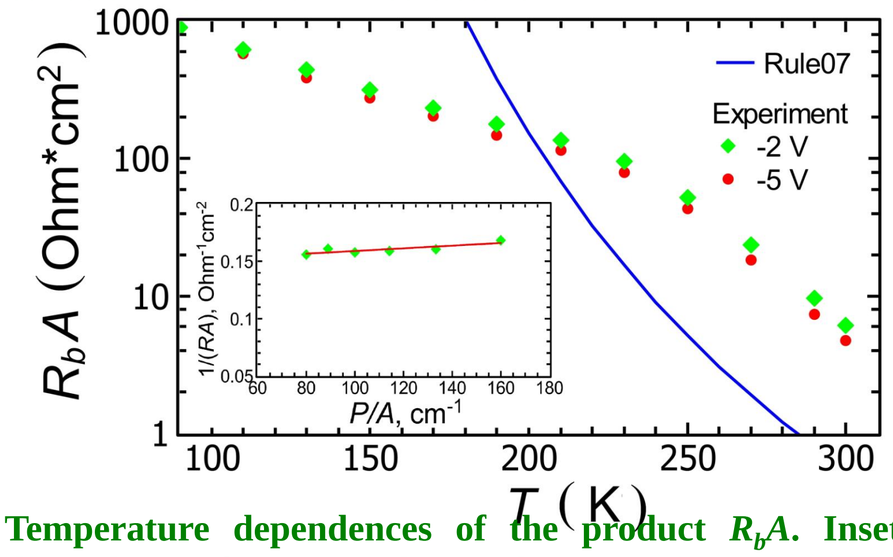
The admittance dependences of barrier structures (nBn and MIS devices) were investigated in a wide range of frequencies and temperatures.

nBn structures. It is shown that measurements of the C–V characteristics of nBn structures based on MBE HgCdTe can be used to determine the dopant concentration in the absorbing layer in a wide range of frequencies and temperatures. At temperatures close to room temperature, an adequate description requires a more complex equivalent circuit due to the effect of defect level recharge at the heterointerface and large current values at forward voltage bias. The activation energy of surface states at the boundary between the barrier and absorbing layers was determined, which turned out to be equal to about 331-334 meV.

MIS devices based on nBn structures. The frequency dependences of the capacitance and conductance of the MIS device can be explained using the equivalent circuit, in which the elements R_b and C_b characterize the barrier layer, and R_{bulk} – the resistance of the absorbing layer bulk. All elements of an equivalent circuit are easily found from admittance measurements. An interesting feature of the admittance measurements is the ability to determine the dynamic resistance of the barrier layer. In this case, information on the bulk component of the current can be obtained, even if the dark current is limited by surface leakage. It can be seen that with the exception of surface leakage for this sample with a composition close to the optimal in the barrier layer (x = 0.67), diffusion-limited characteristics can be obtained.



Frequency dependences of the capacitance and normalized conductance of the nBn structure



Temperature dependences of the product R_bA. Inset - dependence of $1/(R_bA)$ value on the P/A ratio (2 V, 300 K)

CONCLUSIONS

The electrical properties of mid-wave infrared nBn structures based on HgCdTe MBE with - Al_2O_3 passivation were studied, with the composition in the absorbing layer being 0.29 and the composition in the 120 nm thick barrier layer being 0.67. The dark current of nBn structures in a wide temperature range is limited by surface leakage. Admittance measurements of barrier structures (nBn structures and MIS devices) make it possible to determine the main parameters of the absorbing, barrier, and contact layers. Equivalent circuits of barrier structures are proposed, which can be used to describe the experimental dependences of admittance. It has been established that measurements of the admittance of test MIS devices from nBn structures based on MBE HgCdTe make it possible to determine the dynamic resistance of the barrier layer with the exclusion of surface leakage current.