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BOOK of ABSTRACTS

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Crystal growth and structural properties of nanostructures

Raman analysis of graphene on SiC
A. Babichev, K. Shubina, V. Sharov, I. Mukhin......**28**

Role of the wetting layer in the crystallization stage during droplet epitaxy of InAs/GaAs nanostructures
S. Balakirev, M. Eremenko, N. Chernenko, O. Ageev, M. Solodovnik......**30**

New polymorphic varieties of fluorographene forming during fluorine functionalization of 4-8 graphene layers
M. Belenkov, V. Chernov, E. Belenkov......**32**

The model for in-plane and out-of-plane growth regimes of III-V nanowires
Y. Berdnikov, N. Sibirev......**34**

Transmission electron microscopy of crystallization centers in antimony thin films with the use of the bend-contour atlas
A. Bokuniaeva, V. Kolosov, A. Yushkov......**36**

MISFIT STRESS RELAXATION BY DISLOCATION LOOPS IN CORE-SHELL NANOWIRES
A. Chernakov, M. Gutkin, A. Romanov, A. Kolesnikova......**38**

Effect of morphology features of a patterned surface on the nucleation processes of In/GaAs nanostructures during droplet epitaxy
N. Chernenko, S. Balakirev, M. Eremenko, M. Solodovnik, O. Ageev......**42**

In situ study of structural transformation of the (TeO)x(Mo,V,Nb)O14 nanocatalyst with a tunnel structure
E. Derevyannikova, T. Kardash, A. Marchuk, A. Simanenko, A. Ishchenko, D. Svintsitskiy, E. Lazareva......**44**

On the dendrite growth simulation during multitrack selective laser melting process
A. Dubrov, F. Mirzade, V. Dubrov......**46**

XPS analysis of metallic wetting layer in In/GaAs system obtained at different growth temperatures
M. Eremenko, S. Balakirev, N. Chernenko, O. Ageev, M. Solodovnik......**48**

Investigation of indium antimonide nanoparticles, obtained by the method of liquid chemical etching
M. Gavrikov, A. Mikhailov, V. Kabanov......**50**

CWDM demultiplexer using the anti-reflection, contra-directional couplers based on silicon nitride rib waveguide
E. Zubkova, A. Golikov, P. An, V. Kovalyuk, A. Korneev, G. Goltsman..**467**

Spintronics, Electro- and Magnetooptics

Advanced aperture cantilevers made by focused ion beam for both magnetic domain structure and morphology investigation in high resolution magneto optical microscopy
S. Krasnoborodko, Y. Vysokikh, D. Churikov, M. Bulatov, V. Shevyakov, A. Fedotov, A. Kolomiytsev, A. Shaposhnikov..**469**

Magneto-optical properties of terbium-doped metaphosphate and borate glasses
E. Kuljpina, A. Babkina, Y. Fedorov..**471**

Magneto-optical properties of easy-plane epitaxial films of ferrites-garnets for eddy current non-destructive testing
N. Lugovskoy, V. Berzhansky, E. Semuk, S. Lyashko, A. Shaposhnikov..**473**

Spin waves edge modes in chains of ferromagnetic pillars
S. Osokin, A. Sharaevskaya, A. Safin, D. Kalyabin, S. Nikitov..**475**

Electric, Magnetic and Microwave Devices

Effect of oxygen on the properties of Ga2O3:Si thin films
A. Almaev, E. Chernikov, B. Kushnarev, N. Yakovlev...**477**

Size effect in the electronic transport properties of Bi2Se3
V. Chistyakov, A. Domozhirova, J. Huang, V. Marchenkov...**479**

Formation of out-of-plane film micro arch by methods of technological control of internal stress
Y. Enns, E. Pyatishev, R. Kleimanov..**481**

Investigation of the piezoresistive properties and temperature coefficient of resistance of epitaxial GaN layers for sensor applications
Y. Enns, A. Kazakin..**483**

Investigation of the surface modification effect of aligned carbon nanotubes on their memristor properties
M. Ilina, A. Guryanov, O. Osotova, E. Solomin..**485**

Ti/4H-SiC Schottky diode with breakdown voltage up to 3 kV
D. Knyaginin, S. Rybalka, A. Drakin, A. Demidov..**487**

Quantum-mechanical models for calculating the electrical characteristics of semiconductor 2-d structures for technological optimization of nanoelectronics devices based on them
A. Koziy, N. Vetrova, K. Pchelintsev, V. Shashurin, S. Meshkov **489**

The effect of nano-inclusions on the magnetic properties of thin YBCO films
A. Kudriashov, L. Klyachkin, A. Malyarenko, V. Romanov, S. Rykov, N. Bagraev, A. Nashchekin **491**

Developing of normally-off p-GaN gate HEMT
O. Kukhtyaeva, V. Egorkin, V. Zemlyakov, A. Zaitsev, V. Kapaev, A. Tsatsulnikov, A. Nikolaev, A. Sakharov **494**

Aviation kerosene sensors based on nanocrystalline SnO2 thin films with various catalysts
B. Kushnarev, N. Maksimova, K. Ludmila, E. Chernikov, E. Sevastyanov, T. Davidova **496**

Wireless software-hardware complex for testing semiconductor structures
S. Loganchuk, T. Lotfi, S. Chebotarev, L. Goncharova, A. Varnavskaya, A. Mohamed, S. Lotfi **498**

Microwave low mass-dimensional frequency standard on Hg-199 ions
N. Lukashev, V. Davydov, V. Rud **500**

Control electrically conductive of thin films by using subminiature eddy current transducers
V. Malikov, A. Ishkov, A. Katasonov, A. Grigorev, A. Sagalakov **503**

Contact resistance and lifecycle of an ohmic MEMS switch with single and multiple contact bumps
N. Marukhin, I. Uvarov **505**

Features of transmission bearing and heterodyne receivers for signals in fiber-optic communication line in active phased array antenna
A. Moroz, V. Rud **507**

The effect of ion implantation and annealing on forming process in Al2O3/HfO2/Al2O3 memristor structure
O. Permyakova, A. Rogozhin, A. Miakonkikh, K. Rudenko **509**

Determation of dV/dt values for domestic SiC Schottky diodes
S. Sedykh, S. Rybalka, A. Drakin, A. Demidov, E. Kulchenkov **511**

Magnetic-field-driven electron transport in SOI back-gate device
L. Shanidze, A. Tarasov, A. Lukyanenko, M. Rautskii, I. Yakovlev, F. Baron, N. Volkov **513**

Modeling of transparent electromagnetic interference shielding materials based on a silver nanowires network
P. Shiriaev **515**

Ti/4H-SiC Schottky diode with breakdown voltage up to 3 kV

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Abstract. In this study the breakdown voltage for Ti/4H-SiC type Schottky diode with six guard rings and JTE layer has been calculated by mean of numerical simulations. It is established that increase of the *n*-type 4H-SiC epitaxial layer from 14 up to 20 μm and addition of JTE layer lead to increase of breakdown voltage value on ~900 V in contrast to the same diode without JTE. The above-mentioned diode's structure gives the possibility for designing and production of diode with higher breakdown voltage value up to 3 kV.

1. Introduction

It is known that the silicon carbide Schottky diodes on the base of semiconductor material such as the silicon carbide (SiC) is promising for the development of power electronics, microelectronics and optoelectronics devices [1]. For instance, SiC type Schottky diodes for power electronics now is produced by domestic company the ZAO «GRUPPA KREMNY EL» (Bryansk). It is clear that for development of component base on the base of SiC studying and optimization of such important device as Schottky diode it is necessary. The 4H-SiC type Schottky diodes without guard rings have been studied in our previous works [2–4]. In present work the main goal is studying of thickness of the epitaxial layer (4H-SiC) and addition of JTE (Junction Terminate Extension) on breakdown voltage 4H-SiC Schottky diode with Ti Schottky anode contact with guard rings for increasing of breakdown voltage value using physical simulation methods in the ATLAS program.

2. Materials and methods

In Fig. 1a shown the schematic silicone carbide Schottky diode structure for calculation. For numerical simulation were chosen the following the Schottky diode parameters: the concentration of donors (nitrogen) in the substrate equals $N^{+} = 10^{18}$ cm^{-3}, in the *n*-type epitaxial layer (nitrogen) equals $N^{-} = 4{,}75 \times 10^{15}$ cm^{-3}, in the guard rings (boron, depth of guard about 2 μm) regions $N_{p+} = 10^{18}$ cm^{-3}, in the JTE layer concentration $N_{JTE} = 10^{17}$ cm^{-3}, anode material is Ti (titanium), the thickness of the epitaxial layer (4H-SiC) was chosen equals 14 and 20 μm, the radius of the structure equals *r*=600 μm. The simulation of the reverse current-voltage (*I-V*) characteristics has been carried out in the ATLAS program, with taking into account close to reality situation the incomplete impact ionization and anisotropy in the direction (0001) by the Hummel-Newton method.

3. Results and discussion

Fig. 1b shows the reverse *I-V* characteristics of Schottky diode with thickness of the epitaxial layer (*h*) and distance between rings (*l*) calculated in ATLAS for diode with JTE (*h*=20 μm, *l*=2,5 μm). As follows from Fig. 1b the diode breakdown starts at 2,87 kV i.e. breakdown voltage value equals ~3

kV. For comparison in Fig. 1b also presented *I-V* characteristics of Ti/4H-SiC Schottky diodes with reduced thickness of the epitaxial layer (h=14 μm) and increased distance between guard rings (l=5 μm) and without JTE layer. In this case the value of breakdown voltage value equals 1,94 kV.

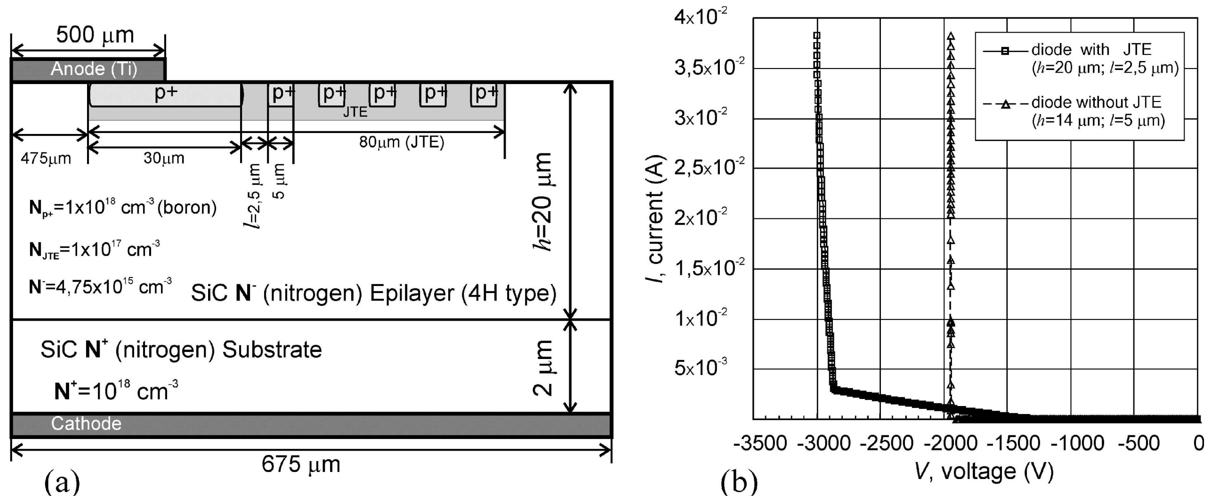

Figure 1. (a) Ti/4H-SiC silicone carbide Schottky diode schematic structure in cylindrical coordinates for calculation; (b) reverse *I-V* characteristics of Ti/4H-SiC Schottky diodes with different of thickness of the epitaxial layer (h) and distance between rings (l) calculated in ATLAS for diode with JTE (h=20 μm, l=2,5 μm) and without JTE (h=14 μm, l=5 μm).

Thus, the increase of the 4H-SiC epitaxial layer thickness from 14 up to 20 μm and a decrease of the distance between the guard rings from 5 to 2.5 μm and also the addition of the JTE layer leads to a significant increase of the breakdown voltage of the diode on ~ 900 V. In addition, on the basis of analysis of the distribution of the impact ionization rate it is established that the maximum values of the velocity of impact ionization rate (23÷25 $cm^{-3}\cdot s^{-1}$) are reached in the area between first and second guard rings. Therefore, with aim to reduce the probability of breakdown in this place the depth of the JTE layer must be increase.

4. Conclusions.

The perspective Ti/4H-SiC Schottky diode with six guard rings and JTE layer was projected on the basis of numerical simulation on physical analytical model in ATLAS program. It is shown that breakdown voltage up to ~3 kV corresponds to Schottky diode structure with the 4H-SiC epitaxial layer thickness of 20 μm, distance between p+ guard rings of 2.5 μm and JTE layer with a width of 80 μm.

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Akulov Vasily, 172
Almaev Aleksei, 477
Andra NareshKumarReddy, 306
Arkhipov Rostislav, 226
Artemyev Alexander, 308
Ashurov Matin, 310
Assim Ara, 175
Babichev Andrey, 28
Baimagambetova Roza, 312
Baksheeva Kseniya, 177
Balakirev Sergey, 30
Balmaev Ivan, 314
Baranov Artem, 228
Bastrakova Marina, 316
Basyrova Liza, 318
Begletsova Nadejda, 532
Belenkov Maxim, 32
Belonovskii Aleksei, 320
Berdnikov Yury, 34
Bezverkhnii Nikolay, 180
Bikberdina Narkiza, 182
Bobrova Daria, 184
Bogdanov Oleg, 321
Boikov Ivan, 230
Bokuniaeva Aleksandra, 36
Borodin Bogdan, 534
Borodkin Alexey, 232
Budkin Ivan, 323
Butt Ali, 325
Cheblokov Aleksandr, 186
Chekhonin Igor, 327
Chernakov Anton, 38
Chernenko Natalia, 42
Chernov Maksim, 329
Chistyakov Vasiliy, 479
Choban Tatyana, 234
Dashkov Alexander, 236
Davydchenko Michael, 536
Davydov Roman, 189
Degterev Alexander, 238
Denisova Galya, 331
Derevyannikova Elizaveta, 44
Diginasheva Olesia, 538
Dragunova Anna, 333
Dubrov Alexander, 46
Dvoretckaia Lily, 335
Dyagileva Darya, 337
Egorov Ivan, 540
Enns Yakov, 483
Enns Yakov, 481
Eremenko Mikhail, 48
Ermakov Alexander, 240
Ezhova Olga, 542
Fadeenko Varvara, 544
Fetisova Marina, 339
Fimin Andrey, 546
Fomchenkov Sergey, 341
Fomin Aleksandr, 548
Frolov Ilya, 242
Galiakhmetova Diana, 244
Gavrikov Maksim, 50
Gavrish Vladimir, 52
Geldash Andrei, 55
Gerasimenko Vladislav, 343
Gorbunova Joanna, 345
Grashchenko Alexander, 550
Grebenikova Nadezhda, 348
Grebenyuk Georgy, 553
Greshyakov Vladimir, 57
Gridchin Vladislav, 59
Gubaydullin Azat, 350
Gudkina Zhanna, 191
Gurin Sergey, 61
Gushchin Sergey, 351
Hashemi Mahdieh, 353
Iachuk Vladimir, 355
Ignateva Lada, 357
Ignateva Lada, 246
Ilin Oleg, 555
Ilina Marina, 485
Ilkiv Igor, 359
Ivanov Andrey, 361
Kalyuzhnyy Nikolay, 248
Kaydashev Vladimir, 363
Khabarov Kirill, 557
Khalaf Hyam, 193
Kharchenko Anton, 250
Khavlyuk Pavel, 63
Khorin Pavel, 365
Klimov Aleksandr, 65
Knyaginin Dmitry, 487
Kokshina Anna, 559
Kolodny Stanislav, 367
Kolokolnikov Ilya, 369
Komarov Ivan, 195
Komrakova Sophia, 371
Korenev , 256
Korenev Vladimir, 252
Korepanov Oleg, 67
Kormilina Tatiana, 69
Korolev Dmitry, 374
Koryakin Aleksandr, 73
Koshelev Oleg, 75
Koshuro Vladimir, 561
Kotlyar Konstantin, 77
Kots Ivan, 79
Kovalchuk Anna, 563
Koziy Andrey, 489
Krasnoborodko Sergey, 469
Kudriashov Andrei, 491
Kudriashov Dmitrii, 256
Kuimov Evgeny, 81
Kukhtyaeva Olga, 494
Kulagina Anastasia, 83
Kuljpina Ekaterina, 471
Kushnarev Bogdan, 496
Kuzikova Anna, 198
Kuzin Alexey, 376
Kuzmenko Vitaly, 85
Kvitsinskiy Anatoly, 378
Lazarenko Aleksandra, 258
Lazarenko Petr, 87
Lednev Maxim, 380
Leonidov Andrey, 89
Leshchenko Egor, 91
Levina Svetlana, 260
Liashenko Tatiana, 93
Lisovskii Stepan, 262
Liu Xinrui, 382
Loganchuk Sergey, 498
Logunov Semen, 264
Lugovskoy Nazar, 473
Lukashev Nikita, 500
Lukyanenko Anna, 95
Makhov Nikolay, 267
Malikov Vladimir, 503
Malinkina Olga, 97
Manova Nadegda, 384
Markin Alexey, 565
Marukhin Nikita, 505
Masharin Mikhail, 269
Mashinsky Konstantin, 386
Masyukov Maxim, 388
Maximova Alina, 271
Medvedeva Ekatrina, 390
Merkulova Irina, 99
Mikhailova Tatyana, 392
Mikhailova Tatiana, 101
Mikhailovskii Mikhail, 394
Mikhaylin Ilya, 103
Mikheev Konstantin, 105
Minnullin Ramil, 396
Mintairov Mikhail, 273
Mironov Sergey, 398
Miropoltsev Maksim, 400
Moiseev Eduard, 275
Mokhov Alexey, 402
Moroz Angelina, 507
Morozov Ivan, 277
Morozov Konstantin, 410
Morozova Kate, 567
Morozova Julia, 107
Moshkova Maria, 411
Muretova Maria, 279
Myazin Nikita, 413
Nevenchannyy Yury, 281
Nezhentsev Aleksei, 569
Nikolaev Kirill, 283
Nikolskaya Alena, 109
Nizameev Irek, 111
Osokin Sergey, 475
Osychenko Alina, 200
Panchenko Ivan, 571
Pavlov Nikolay, 285
Permyakova Olga, 509
Petriev Iliya, 113
Petrova Olga, 415
Polikarpov Yury, 202
Polupanov Nikita, 573
Polyakova Margarita, 417
Polykova Victoria, 115
Prasolov Nikita, 575
Proskuryakov Vitaly, 287
Rakhmanova Gulnaz, 419
Raudik Sergei, 289
Redkov Alexey, 117
Reshetov Ilya, 421
Reznik Rodion, 119
Reznik Vladislav, 204
Rezvan Alexey, 120
Rezvan Alexey, 424
Rochas Stanislav, 291
Rogozny Mikhail, 426
Romanov Nikolay, 206
Rozhkov Mikhail, 122
Rudyk Nikolay, 124
Ruzankina Julia, 428
Ryashentsev Dmitry, 126
Salii Roman, 293
Salimgareev Dmitrii, 431
Saushin Aleksandr, 295
Savchuk Aleksandr, 128
Savelyev Dmitry, 433
Scherbak Sergey, 435
Sedykh Sergey, 511
Sergushichev Kirill, 577
Serin Artem, 297
Shanidze Lev, 513
Shariaty Faridoddin, 208
Sharov Vladislav, 131
Shiriaev Pavel, 515
Shishkin Ivan, 299
Shishov Konstantin, 579
Shkoldin Vitaliy, 437
Shlepakov Pavel, 517
Shostka Natalia, 439
Shubina Kseniia, 133
Shugurov Konstantin, 135
Shumilin Aleksandr, 137
Sidorov Fedor, 585
Sigaev Alexander, 139
Sinicyna Ekaterina, 441
Sivkov Danil, 141
Smirnov Maksim, 443
Smolyarova Tatyana, 143
Snigirev Leonid, 146
Sobolev Maxim, 148
Soboleva Victoria, 150
Sokolenko Bogdan, 445
Sokolovskii Andrei, 152
Sokura Liliia, 447
Son Aleksandra, 154
Starnikova Alexandra, 158
Stepanova Oxana, 210
Stolpner Anna, 212
Stupin Daniil, 214
Tapinova Olga, 216
Taranets Konstantin, 587
Tikhomirov Vladimir, 519
Timkaeva Diana, 589
Titova Nadezhda, 521
Tomilin Sergey, 449
Tomilina Olga, 160
Toropova Alexandra, 218
Trofimov Pavel, 451
Tupik Aleksandra, 220
Uvarov Alexander, 523
Vakulov Zakhar, 162
Vasiliev Oleg, 453
Vasilyeva Olga, 591
Ved Mikhail, 164
Vershinin Andrew, 166
Volcheck Vladislav, 525
Volkova Natalya, 455
Volokitina Anna, 457
Voronenkov Vladislav, 168
Votyakov Sergei, 593
Voyko Aleksey, 527
Vysokikh Yury, 595
Yanibekov Iskander, 459
Yarunova Elizaveta, 301
Zelentsov Kirill, 303
Zharikov Igor, 304
Zhukov Mikhail, 529
Zhukova Maria, 461
Zhuravlev Andrey, 463
Zhuravlev Anton, 465
Zinphyo Kyaw, 170
Zograf George, 222
Zorin Vitaly, 224
Zubkova Evgenia, 467