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SIMULATION OF ISOTHERMAL CURRENT FILAMENT STATES IN GaAs STRUCTURES

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INTRODUCTION Formation of the current filaments in a semiconductor devises results in its local burnout and has been observed in various types of devices in condition of secondary breakdown and negative differential conductivity (NDC). For a number of devices (GaAs MESFET's, HEMT's, Si bipolar and MOSFET) physics of current filamentation may be converge to the 2-D spatial instability in n-i-n, reversed biased p-i-n or Shottky M-i-n [1-3] structures (where i-region may be presented as n^{-} or p^{-}-region). Understanding of the current filament states physics and its numerical simulation is important to proper application of various thermal models based on localised heat source assumption, reliability and CAD of semiconductor devices.

Another actual problem is formation spatial-temporal dissipate structures (DS) under breakdown in the distributed semiconductor structures. Physics of DS formation is the result of interaction between two spatial processes which result in cumulate current increase due to a current instability and damping of the current increase. Recently formation of DS like a periodic multifilament state was observed in GaAs FET in breakdown condition [1]. Formation of NDC in this structures is the result of avalanche-injection current instability in buffer semiinsulating layer, which formed accompany with source and drain n^{+}-region "built in" GaAs n-i-n structure [2]. Understanding DS formation is important not only for reliability of power transistors [1-3]. For future application of DS properties a GaAs microstructures have a number of advantages: 1-10 μm dimension DS may be realised in this structures under room temperatures, high speed, high efficiency of light emission and integration with GaAs IC's technology.

The purpose of this study is: (i) to demonstrate on the basis 2-D numerical simulation that spatial instability results in formation of a multifilament state in GaAs n-i-n and Shottky M-i-n structure; (ii) to investigate its evolution, kinetics and structure parameter influence. The quasi hydrodynamic model [2] was used for numerical simulation of the GaAs structures (Fig.1(a,b,c)).

RESULTS AND DISCUSSION Calculated I-V characteristics of the structures are presented in Fig.1(d). In n-i-n and n-p-n structures the NDC formation mechanism is the result of i-region conductivity modulation due to positive feedback between hole avalanche generation level in the anode avalanche high field region and electron injection from cathode n^{+}-contact [2]. In Shottky M-i-n structures NDC formation mechanism is i-region conductivity modulation due to double avalanche injection from the two multiplication areas: near the Shottky contact and near anode. In all structures with thing n-region only single filament was observed ([3] and Fig.2(a1,b1,c1)).

In the structures with a long contact n-region a new current distribution was realised. After step current increase in the n-i-n structure a new multifilament state was formed spontaneously during 100 ps. The field and carrier density distribution are presented in Fig.2(a2,b2,c2) and Fig.2(a3,b3,c3). With current increase the filament amplitude in DS is increased, DS spatial period decreased up to some minimum level. Kinetics of the spatial period decrease is the splitting of the new filaments from initial state. Kinetics of the spatial period increase is the damping of one of filament in the initial state and redistribution of filaments. For fixed current value the decrease of the n-region length results in spatial period and filament amplitude in DS increase up to formation of single filament state. For fixed current value the increase of the i-region length results in filament amplitude increase under unchanged spatial period of DS. Inserted local nonuniformity in the structure (as, for example, a gap in the contact) is not changed significantly parameters of DS, but determines DS localisation

CONCLUSION Using 2-D numerical simulation the spatial instability and formation of stable spatial DS are studied for breakdown of GaAs n-i-n (n-p-n) and Shottky M-i-n structures with long n-layer. It is revealed, that at some value of n-region length the DS is formed spontaneously like a multifilament periodic states. Spatial period of DS is of order of the n-region length and filament dimension of i-region length. Formation and evolution of the multifilament states in the n-i-n GaAs structure corresponds to the experimental data [1,2,4] for MESFET and HEMT breakdown in pulse regime.

References

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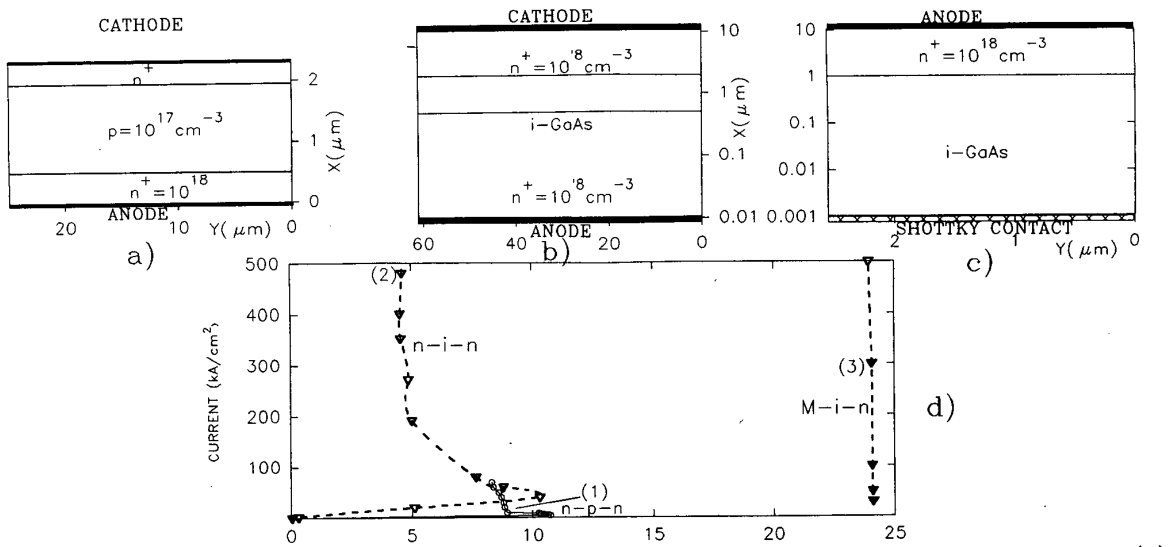

Fig.1. The n-p-n (a), n-i-n (b), Shottky M-i-n (c) GaAs structures and its I-V characteristics (d).

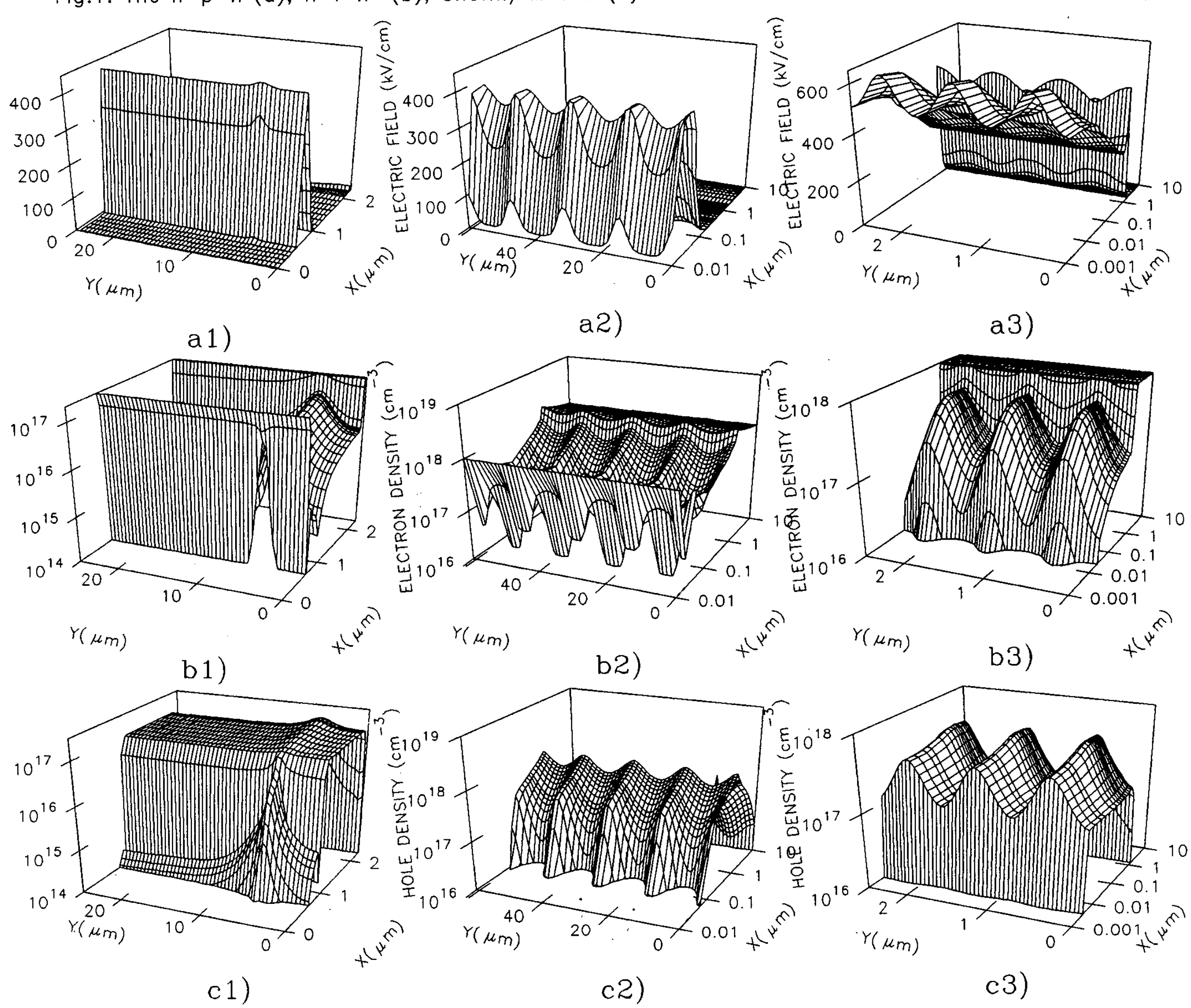

Fig.2. Examples of current filamentation and periodic multifilament structure formation in the structures (Fig.1a,b,c). Electric field (a1,a2,d), electron (b1,b2,e) and hole (c1,c2,f) density distributions in the calculated structures for the states marked by (1), (2), (3) on the consequent IV characteristics (fig.1(d)).