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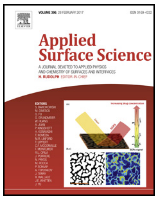

Full Length Article

Surface profile gradient in amorphous Ta_2O_5 semi conductive layers regulates nanoscale electric current stability

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ABSTRACT

A link between the morphological characteristics and the electric properties of amorphous layers is established by means of atomic, conductive, electrostatic force and thermal scanning microscopy. Using amorphous Ta_2O_5 (a-Ta_2O_5) semiconductive layer, it is found that surface profile gradients (morphological gradient), are highly correlated to both the electron energy gradient of trapped electrons in interactive Coulombic sites and the thermal gradient along conductive paths and thus thermal and electric properties are correlated with surface morphology at the nanoscale.

Furthermore, morphological and electron energy gradients along opposite conductive paths of electrons intrinsically impose a current stability anisotropy. For either long conductive paths ($L > 1\ \mu$m) or along symmetric nanodomains, current stability for both positive and negative currents i is demonstrated. On the contrary, for short conductive paths along non-symmetric nanodomains, the set of independent variables (L, i) is spanned by two current stability/intability loci. One locus specifies a stable state for negative currents, while the other locus also describes a stable state for positive currents.

1. Introduction

Amorphous semiconductors have attracted much attention recently, but because of a limited translational symmetry in a very short range order, their electric properties are still not well understood at a nanoscale level. In fact, even for amorphous structures of the same material, properties may vary greatly. Up to now, the electric current characteristics and instabilities in amorphous and crystalline semiconductors are attributed to mechanical fluctuations [1–3], interfacial inhomogeneities [4], internal feedback and charge trapping [5–7], electric field stressing [8,9], electron tunneling and confinement [10], atomic rearrangement in conductive junctions [11], local electron valence structures [12], different fabrication techniques [13,14], surface treatments [15], morphologies [16,17], sensitivities [18], contamination [19] and degradation [20]. Pioneering work that connects current instabilities and surface morphological features in crystalline solids was published earlier by Maroudas et al. [21,22].

Amorphous semiconductors, such as tantalum oxide (a-Ta_2O_5) or nitride, are usually grown at relatively lower temperatures, either by chemical vapor or pulsed laser deposition (CVD, PLD) [23]. Amorphous structures exhibit different electrical and kinetic characteristics than their crystalline counterparts, such as higher density of defective electronic states, lower leakage currents [24,25], lower strain and electric carrier diffusivity at interfaces [26,27], lack of pinning and surface polarization and bunching of electrons between the boundaries of nanodomains [4]. The electric current characteristics in crystalline semiconductors depend on the tunneling probability of electric carriers through the Coulombic potential barrier between the two contacts of the semiconductive material with the metallic electrodes and their energy in the barrier. The potential barriers are formed from the different position of the Fermi levels in the energy scale of the semiconductor and the metallic electrodes, [28–30]. Similarly, the logarithm of the electric current in amorphous dielectric materials is either proportional to the square root (Frenkel's effect), or to the first power of the electric field (Poole's law), according to the topological configuration

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