On the origin of RTS noise in nanoFETs

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Abstract

Electronic nano-devices are giving rise to new phenomenological effects, since the high surface to volume ratio associated to their nano-scale volume makes superficial effects to predominate over bulk effects. With the reduction of the size of the devices to the nano-scale, the modeling of some phenomena traditionally treated as statistical effects should be carefully revised. A clear example of these phenomena is the noise in nano-devices whose dimensions have been reduced looking for “zero trap” (or “zero dopant”), and thus “zero noise” devices.

In this communication we analyze the Random Telegraph Signal (RTS) noise in a nano-scaled cylindrical transistor specifically designed to eliminate the presence of traps that commonly account for RTS noise in micro-sized devices [1], such as metal oxide semiconductor field effect transistors [2] or AsGa heterostructures [3]. We apply a new Admittance-based noise model [4], in which the electrical noise arises from Fluctuations of electrical energy in the susceptance of the device under test followed by their subsequent Dissipations by the accompanying conductance. This model, which complies with the thermodynamic laws and the principles of the quantum physics, has interesting repercussions in many systems, allowing to explain some of the effects [5,6] that are not well managed by the common theory in use today. In the field of electrical noise in field effect transistors, which is considered in this communication, it explains in a simple way the RTS instability observed in nano-scaled cylindrical transistors which are designed looking for a “zero-trap-device”. Contrary to common theory where the low–frequency noise in FETs has been attributed to modulation in mobility and/or carrier density owing to the trapping and de-trapping processes taking place at bulk and interface states, the Admittance-based model shows that any phenomenon that modulates the space charge region in the vicinity of the semiconductor surface causes a modulation of the channel trough the familiar Field-Effect used in transistors and not by an unlike (though possible) modulation of the channel conductivity. In particular, this explains why trapping effects appear in the “zero-trap” transistor presented in [1]. In this case, the ungated (thus uncontrolled) channel portion outside the controlling gate is the responsible of the excess of noise. Not only the Admittance-based model accounts for this excess of noise but also explains the tunability of this RTS noise with a surface voltage, which is disregarded in the traditional model.

In conclusion, the fluctuation-dissipation phenomena (noise) that take place by individual particles (electrons, phonons, polarons, etc) in nano-scaled electronic devices can be totally explained with the new Admittance-based model of noise. A correct evaluation of this noise based in thermodynamics and quantum mechanics principles is of major interest for designing new devices.

References

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