Subtle project: Noise enhanced sensing and switching with nanoelectronic devices

L. Worschech, A. Forchel, Technische Physik, Universität Würzburg, Germany
J. Ahopelto, Technical Research Centre of Finland, Finland
H. Xu, Lund University, Sweden
M. Büttiker, University of Geneva, Switzerland
L. Gammaitoni, Dipartimento di Fisica Universita degli Studi Perugia, Italy
S. Strähle, XENOS Semiconductors Technologies GmbH, Germany

lukas.worschech@physik.uni-wuerzburg.de

SUBTLE

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With increasing miniaturization of semiconductor electronics an increasing fraction of the power to the circuit is converted into nondeterministic signals that add to the ambient noise. In commonly used device concepts noise degrades the performance. Interestingly, there are cases where noise, instead of degrading the device performances, can lead to enhanced signal to noise ratios, if principles of Stochastic Resonance (SR) are used. The partners of the SUBTLE project (http://subtle.fisica.unipg.it/SUBTLE) undertake a coordinated effort including groups working on device theory, nanofabrication and device characterization to investigate the feasibility and potential of SR–nanoelectronic semiconductor devices. Using e.g. special FET like devices with tailored internal feedback the nonlinear dynamic transport properties in this regime will be explored for sensing and switching of sub thermal signals with the help of stochastic resonance-like dynamics. Within the project several key devices like “residence time detectors” and “electrochemical capacitance feedback transistors” will be realized and investigated for the first time. Concepts of integrated nanoscale circuits with efficient readout schemes, enhanced signal resolution in a noisy environment and stochastic resonance enhanced detection will be tested. By utilizing nonlinear transport in nanosystems the proposal has the potential to open a new window for electronic applications covering stochastic resonance phenomena, sub thermal switching and on chip noise control applications.

It is the main objective of the SUBTLE project to evaluate the potential of nanoelectronic SR devices by physics and device modeling, nanodevice fabrication techniques as well as static and dynamic device characterization. The scientific approach of SUBTLE is based on the application of two effects in miniaturized electronics, which one usually tries to avoid in device design: back-action of the channel on the gate and noise induced switching. In order to make use of them and even to obtain signal gain, we will realize new types of transistors and circuits, which should allow exploiting noise enhanced switching by means of stochastic resonance phenomena (SR) and device intrinsic capacitance couplings associated with the electrochemical capacitance (EC) of low dimensional systems[i]. Recently proposed detection schemes will be applied in nanoelectronic semiconductor devices[ii]. In particular, three key properties will be addressed within the frame of the project:

- Subthermal signal resolution
- Noise activated switching
- Noise enhanced signal processing

The goal of the project includes the realization of three nanoelectronic key devices, which are based on SR and EC for enhanced switching in order to resolve sub thermal signals hidden by thermal noise if classical amplification schemes are applied:

- Electrochemical capacitance induced feedback transistors
- Noise activated nonlinear devices
- Noise enhanced signal processing nodes

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[i] D. Sanchez, M. Büttiker, "Magnetic-field asymmetry of nonlinear mesoscopic transport", Phys. Rev. Lett. 93, 106802 (2004)

[ii] L. Gammaitoni, A. R. Bulsara, "Noise Activated Nonlinear Dynamic Sensors", Phys. Rev. Lett. 88, 230601 (2002)