Ultra-scaled Quantum Ballistic Ge Nanowire Photodetectors

Masiar Sistani, Philipp Staudinger, Emmerich Bertagnolli, Alois Lugstein

Institute of Solid State Electronics, Technische Universität Wien, Floragasse 7, 1040 Vienna, Austria

Email: masiar.sistani@tuwien.ac.at
Keywords: quantum ballistic transport, nanowire, germanium

The outstanding electrical and optical properties of Ge nanowires make them attractive for various optoelectronic applications favorable for monolithic integration with complementary metal oxide semiconductor technology.[1] Utilizing a thermally induced exchange reaction between single-crystalline Ge nanowires and Al contact pads, we fabricate monolithic Al-Ge-Al nanowire heterostructures with atomically sharp interfaces.[2] Integrating such nanowire heterostructures with ultra-scaled Ge segment lengths as active channels in electrostatically modulated back-gated field-effect transistor devices, we achieve unmatched internal gains exceeding 10^7 and responsivities as high as 10 A/µW at 532 nm wavelength. We discuss the photo-response in the framework of a charge trapping model under the consideration of the photo-gating effect in accordance with previous studies on low-dimensional photoconductors. Very recently, we have shown that for ultra-scaled Ge NWs integrated in back-gated FET devices, well-resolved conductance plateaus develop in the $G(V_g)$ trace, attributed to the electrostatically modulated population of single spin-degenerated 1D sub-bands.[3] Since the extraordinary high photosensitivity of our heterostructure devices allows reducing the detector area i.e. the Ge segment length and nanowire diameter down to sizes at which quantum ballistic transport occurs, we demonstrate that the charge carrier transport can be modulated directly by photons allowing the observation of quantized photocurrent even at room temperature (see figure 1).

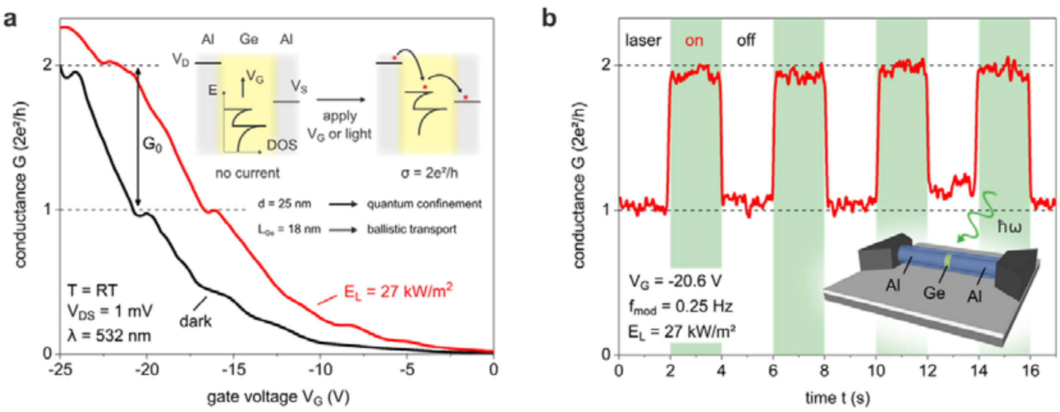

Figure 1. (a) *Conductance G as a function of gate voltage V_G for a device with L_{Ge} = 18 nm with (λ = 532 nm, E_L = 27 kW/m^2) and without laser illumination at room temperature. The conductance was directly obtained from the measured current according to $G = I_D/V_{DS}$. The inset shows schematically how conductance quantization originates in these structures by either applying a gate voltage or laser light. (b) Time resolved measurement at V_G = -20.6 V and pulsed laser light (f_{mod} = 0.25 Hz, λ = 532 nm, E_L = 27 kW/m^2).*

References

[1] Michel, J. et al., Nat. Photonics 4, 527–534 (2010).
[2] Kral, S. et al., Nano Lett. 15, 4783–4787 (2015).
[3] Sistani, M. et al., Nano Lett. 17, 4556–4561 (2017).