P79

Significant influence of metal surface morphology on photon emission from a local tunnel junction at ambient conditions

I.S. Mukhin[1,2], V.A. Shkoldin[1,2], D.V. Permyakov[1], K.S. Ladutenko[1], A.A. Vasiliev[2], A.V. Uskov[4], A.A. Bogdanov[1], A.O. Golubok[1,3], A.K. Samusev[1]

[1]*ITMO University, 197101, St. Petersburg, Russia*
imukhin@yandex.ru

[2]*St.Petersburg Academic University, 194021, St. Petersburg, Russia*

[3]*Institute for Analytical Instrumentation RAS, 198095, St. Petersburg, Russia*

[4]*P.N. Lebedev Physical Institute Russian Academy of Sciences, 119991, Moscow, Russia*

Modern computational devices are based on conventional integrated circuits, where data transfer is organized via electronic signals. Nowadays performance of these devices is close to their theoretical limit. One of the promising ways to overcome the current limitations is based on a transition to optical platform with photonic integrated circuits, which may provide increase of operating frequencies along with the reduced Joule heating.

For real implementation of the integrated optoelectronic circuits, development of electrically driven localized photonic and plasmonic emitters is required. Tunnel electrical contact is one of the promising ways to develop sub-micron optical emitters. According to Lamb and McCarthy the light emission is governed by inelastic electron tunneling in a planar metal-insulator-metal structure with a thin potential barrier. According to the results of several theoretical and experimental works [5], light emission in this system is related to quantum oscillations of the tunnel current. An enhanced photon emission in a tunnel contact between a metal tip of scanning tunneling microscope (STM) and a metal layer was demonstrated by Gimzewski et al. [6]. This effect occurs due to the increase of the local density of optical states (LDOS) in the tunnel gap under the STM probe. In this system, the tunnel gap has a few nanometer size and can be considered as electrically driven subwavelength optical source.

We study light emission from a tunnel contact between thin Au film on a cover glass and STM W probe covered with Au layer. At ambient conditions we investigate the dependence of the photon emission intensity on Au film surface morphology, namely on geometrical parameters of constituent nanometer-scale Au grains. AIST-NT CombiScope – STM with integrated inverted optical microscope was used to study the light emission in tunnel junction. The emission was collected under the substrate covered with Au. The photon emission was observed when STM operated in “threshold” mode with excited feedback [3]. In this mode the system promotes fast approach of the probe to the sample and when the current flow occurs the feedback system immediately brakes the contact moving the probe from the sample. As a result, oscillations of the gap occur leading to the tunnel current fluctuations while the total integral current value remains. It was demonstrated experimentally that this regime provides maximum photon emission efficiency. Analysis of the experimental data reveals that photon emission is more efficient with decrease of grain height and increase of grain width. The atomically flat monocrystalline Au sample allows to achieve maximum efficiency of photon emission. In the same STM regime, one could tailor the emission efficiency in four orders of magnitude range by changing the surface morphology. The observed phenomena are explained by the fact that the effective area of tunnel contact is inverse proportional to the square of the grain aspect ratio.

The obtained results demonstrate the critical influence of nanometer surface roughness of the sample on the efficiency of photon emission from tunnel junction. Due to low quantum yield of the emission in the tunneling process our results would have important value for development of effective single photon emitters which could be the basic of optoelectronic components.

1. F. Bigourdan, J.-P. Hugonin, F. Marquier, C. Sauvan, J.-J. Greffet. *Phys.Rev. Lett.* **116**, 106803 (2016).
2. J. Kern, R. Kullock, J. Prangsma, M. Emmerling, M. Kamp et al. *Nature Photonics* **9**, 582 (2015).
3. B. Rogez, S. Cao, G. Dujardin, G. Comtet, E. Le Moal et al. *Nanotechnology* **27**, 465201 (2016).