Solving nearly century-old problem: Using graphene, professor finds out what causes low-frequency electronic 1/f noise

March 7 2013, by Sean Nealon

Alexander Balandin, a professor electrical engineering at UC Riverside

(Phys.org) —A University of California, Riverside Bourns College of Engineering professor and a team of researchers published a paper today that show how they solved an almost century-old problem that could further help downscale the size of electronic devices.

The work, led by Alexander A. Balandin, a professor of electrical engineering at UC Riverside, focused on the low-frequency electronic 1/f noise, also known as pink noise and flicker noise. It is a signal or process with a power spectral density inversely proportional to the frequency. It was first discovered in vacuum tubes in 1925 and since then it has been found everywhere from fluctuations of the intensity in music recordings to human heart rates and electrical currents in materials and devices.

The importance of this noise for electronics motivated numerous studies of its physical origin and methods for its control. For example, the signal's phase noise in a radar or communication gadget such as smart phone is determined, to a large degree, by the 1/f noise level in the transistors used inside the radar or smart phone.

However, after almost a century of investigations, the origin of 1/f noise in most of material systems remained a mystery. A question of particular importance for electronics was whether 1/f noise was generated on the surface of electrical conductors or inside their volumes.

A team of researchers from the UC Riverside, Rensselaer Polytechnic Institute (RPI) and Ioffe Physical-Technical Institute of The Russian Academy of Sciences were able to shed light on 1/f noise origin using a set of multi-layered graphene samples with the thickness continuously varied from around 15 atomic planes to a single layer of graphene. Graphene is a single-atom thick carbon crystal with unique properties, including superior electrical and heat conductivity, mechanical strength and unique optical absorption.

In addition to Balandin, who is also the founding chair of the materials science and engineering program at UC Riverside, the team of researchers included: The team included: Guanxiong Liu, a research associate in Balandin's Nano-Device Laboratory (NDL); Michael S.

Shur, Patricia W. and C. Sheldon Roberts Professor of Solid State Electronics at RPI; and Sergey Rumyantsev, research professor at RPI and Ioffe Institute.

"The key to this interesting result was that unlike in metal or semiconductor films, the thickness of graphene multilayers can be continuously and uniformly varied all the way down to a single atomic layer of graphene – the ultimate "surface" of the film," Balandin said. "Thus, we were able to accomplish with multilayer graphene films something that researchers could not do with metal films in the last century. We probed the origin of 1/f noise directly."

He added that previous studies could not test metal films to the thicknesses below about eight nanometers. The thickness of graphene is 0.35 nanometers and can be increased gradually, one atomic plane at a time.

"Apart from the fundamental science, the reported results are important for continuing the downscaling of conventional electronic devices," Balandin said. "Current technology is already at the level when many devices become essentially the surfaces. In this sense, the finding goes beyond graphene field."

He also noted that the study was essential for the proposed applications of graphene in analog circuits, communications and sensors. This is because all these applications require acceptably low levels of 1/f noise, which contributes to the phase noise of communication systems and limits sensor sensitivity and selectivity.

The results of the research have been published in the journal *Applied Physics Letters*.

More information: The paper, "Origin of 1/f Noise in Graphene

Multilayers: Surface vs. Volume" is available at:
apl.aip.org/resource/1/applab/v102/i9/p093111_s1

Provided by University of California - Riverside