New '1/f noise' discovery promises to improve semiconductor-based sensors

May 9 2007

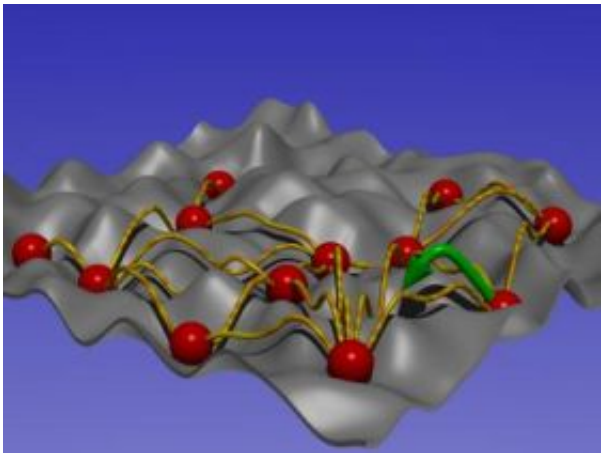

Illustration of a Coulomb glass system: Electrons (red) in a random landscape, interacting with each other (yellow-orange lines). Noise of the resistance of the system is created by collective "hopping" of the electrons (green arrow). Credit: Argonne National Laboratory

More sensitive sensors and detectors based on semiconductor electronics could result from new findings by researchers from the United States, Norway and Russia.

Their research has yielded a decisive step in identifying the origin of the universal "one-over-f" (1/f) noise phenomenon; “f” stands for "frequency."

"One-over-f noise appears almost everywhere, from electronic devices

and fatigue in materials to traffic on roads, the distribution of stars in galaxies, and DNA sequences," said Valerii Vinokour or Argonne's Materials Science Division. "Finding the common origin of one-over-f noise in its many forms is one of the grand challenges of materials physics. Our theory establishes the origin and lower limit to one-over-f noise in semiconductor electronics, helping to optimize detectors for commercial application."

Noise is a fluctuation in time, a deviation from the average. Humans and other animals carry a common example in their heartbeats, where 1/f noise can be detected as a deviation from normal pulse. In nanomaterials, such as the tiny circuits in semiconductor electronics, the noise generated by the random motion of a single electron can be devastating, since there are so few electrons in the system.

Vinokur and his team showed that the 1/f noise in doped semiconductors, the platform for all modern electronics, originates in the random distribution of impurities and the mutual interaction of the many electrons surrounding them. These two ingredients — randomness and interaction — trap electrons in the Coulomb glass, a state like window glass where electrons move by hopping from one random location to another. 1/f noise arises from the electrons; hopping motion. After discovering the theoretical connection between 1/f noise and formation of the Coulomb glass, Vinokur and his collaborators confirmed it with large-scale computer simulations: suppression of the interactions was found to remove the Coulomb glass behavior and 1/f noise.

“Our results," Vinokour said, "establish that one-over-f noise is a generic property of Coulomb glasses and, moreover, of a wide class of random interacting systems and phenomena ranging from mechanical properties of real materials and electric properties of electronic devices to fluctuations in the traffic of computer networks and the Internet.”

These research findings were published in the May 11 issue of *Physical Review Letters*.

Source: Argonne National Laboratory