Biological connections in microelectronics

February 12 2013

Miniaturization of electronic components is reaching a physical limit. While the solution of three dimensional assembly has the advantage of reducing bulk, the manufacture of electrical connections in these new products remains a technological challenge. Biologists and physicists from the CEA, CNRS, Université Joseph Fourier and Inra in Grenoble have developed a system of self-assembled connections using actin filaments for 3D microelectronic structures. Once the actin filaments become conductors, they join the various components of a system together. The results are published in the February 10, 2013 issue of *Nature Materials*.

Computers and smartphone performance improves each year due to the increased density of the microelectronic components they contain. This densification is the result of increasingly advanced miniaturization. It is in the process of reaching a technical limit due to the size of certain components that is close to that of some atoms. The microelectronics industry is thus confronting a physical barrier for increasing the integration density of components that only a technological breakthrough can overcome.

One solution may be the integration of microelectronics in three dimensions. Current microelectronic circuits are flat. Stacking components on top of one another is a solution for further densification, improving performance and reducing electric consumption. This poses a new challenge: how to connect the components together once they are stacked. Although manufacture and stacking are based on mature technologies, creating vertical connections to link them together and running a current remains complex. While current 3D microelectronic technologies for these high density connections are effective, alternative methods are worth evaluating.

Biologists and physicists from the CEA, CNRS, UJF and Inra in Grenoble had the idea of using the extraordinary self-assembly properties of certain biological components so these connections can construct themselves. In human cells, many regular, complex structures are continually assembling and disassembling. This is the case of the filament networks that constitute the cell skeleton (cytoskeleton). Such filaments are primarily composed of actin. They interact to form braids, bundles, layers and columns whose architecture and mechanical properties regulate and control cell shape. The formation of these superstructures follows mechanical and geometrical laws that are studied and understood by a team from the Laboratory of Vegetable Cellular Physiology[1] (CEA/CNRS/UJF/INRA). These researchers have developed a technique for controlling self-assembly of actin filaments in 3D between two glass plates. Using technologies of the Microelectronics Technologies Laboratory (CNRS/UJF/LTM) and CEA-Leti, the plates were placed 30 microns apart and microstructured with a laser beam. The researchers then injected between the two surfaces a solution containing actin monomers that polymerized due to the microstructure geometry. Actin columns in controlled shapes and sizes thus self-assembled from the two surfaces and joined to establish connections. In the same fashion, the researchers succeeded in making columns grow from a surface and entering in deep cylinders based on the shape of the other, like a male/female connection. Using the expertise of CEA-Leti researchers, these connections were made metallic with gold nanoparticles to run an electric current between the two surfaces.

These results demonstrate that the self-assembly process of actin filaments may have unanticipated industrial applications. They illustrate how fundamental research into basic cell processes may be an extremely rich source of inspiration for engineering processes, even in very far removed fields.

Provided by French Alternative Energies and Atomic Energy Commission

Citation: Biological connections in microelectronics (2013, February 12) retrieved 11 May 2024 from https://phys.org/news/2013-02-biological-microelectronics.html

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