"Nanocomposites and nanomaterials"

Space-filling trees for microfluidic aplications

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Space-filling trees are branched tree-like structures without self cross sections, which compactly fill in some volume V so that in the ε vicinity of each point of V there is one of the smallest branches of the tree. Those objects were found useful for many transport, path-finding, logistics optimization problems [1]. The space-filling trees are widely used in nature for long-range transport of biological fluids. Those systems have optimal transport properties exhibiting minimal energy consumption $\dot{E}$ for both steady and periodical flows [2]. The principles of their construction can be used as nature inspired solutions for the fluid conveying systems at macro and micro scales [2]. Here their use at the nano scale is shown.

Novel advanced composites consisted of the anisotropic molecular matrix reinforced by the branching system of nanowires, ribbons or tubes are proposed. The tree-like structure having one or several inlets (roots) is located inside the volume. The fibers/tubes may conduct heat, flow or/and electric charge, while the matrix serves as the corresponding insulator. Due to high mechanical strength and unique conductivity of the nanostructures, one may expect obtaining the optimal devices (fuel cells, micro heaters/coolers, MEMS units) provided the conducting structure possesses the nature inspired optimal construction.

The equation governing the flux $\vec{q}_a$ maintained by the force ∇a

$$\tau\frac{d\vec{q}_a}{dt}+\vec{q}_a=-\lambda\nabla a+\kappa\nabla^2\vec{q}_a \tag{1}$$

where τ,λ,κ are material parameters is considered. When a is the temperature and $\vec{q}_a$ is the heat flux, (1) is the Guyer-Krumhansl equation. In other cases (1) generalizes mass and charge transfer for the nano scale structures.

Solution of the optimization problem $\{\dot{E}\to\min, V=\mathrm{const}\}$ basing on (1) is found and several classes of optimal structures are proposed for MEMS units.

1. *La Valle S.* Planning algorithms. Cambridge Univ. Press. – 2006.
2. *Kizilova N.* Computational approach to optimal transport network construction in biomechanics. // Lecture Notes in Computer Science. – 2004. – **3044**. – P.476-485.