NANO HIGHLIGHT
Self-organization of microtubule-based nanosystems via reaction-diffusion processes

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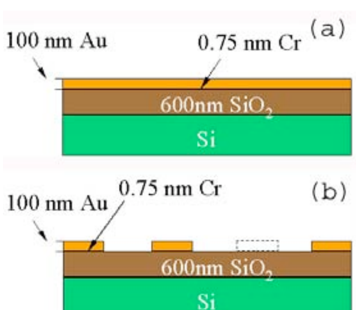
Reaction-diffusion processes that are involved in the self-assembly of microtubules (MT) are shown to lead to the self-organization of complex MT structures and offer a path toward the development of novel approaches to construct large scale nanosystems. MTs are subcellular proteinaceous filaments with nanometer scale diameters and micrometer scale lengths. MTs self-assemble reversibly from two protein monomers, _- and _-tubulin. The self-organization of MT systems is enabled by our recent progress in controlling the nucleation and growth of MTs from surfaces on microchips functionalized with γ-tubulin, a tubulin isoform known to serve as a MT nucleating agent. The morphology of the system of MTs grown from patterned substrates is shown to depend on the geometry of the pattern. We consider two functionalized patterns: (a) a square lattice of small gold pads on a hydrophilic oxidized silicon wafer and (b) a large flat surface (Fig. 1). The large gold electrode shows a low surface density (~0.92MTs per 100_m^2) of long MTs (average length ~ 22±17_m). MTs grown from the small gold pads are no more than ~ 10 _m with a surface density of MTs in excess of 60 MTs per 100_m^2. Comparison between experiments and computer simulations of MT growth from substrates functionalized with nucleation centers that accounts for the reaction dynamics of MT assembly and the diffusion of tubulin monomers shows that the morphologies observed experimentally result from competition between reaction and diffusion processes (Fig. 3).



(a) **(b)**

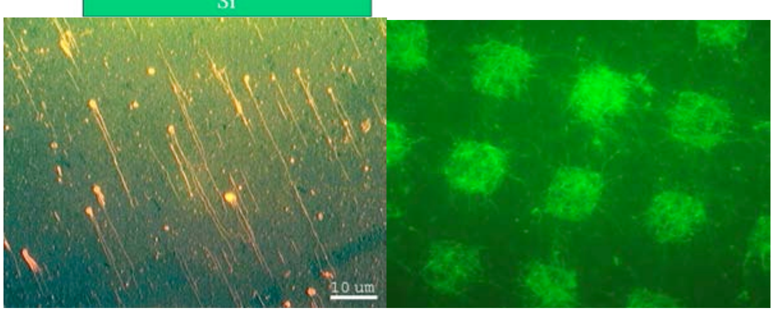


Fig. 1: The cross sections of the oxidized silicon substrate patterned with (a) a large gold electrode (1.9x3.8mm^2) and (b) an array of small gold pads (10x10 _m^2).

Fig. 2: Fluorescent microscope images of MTs grown from (a) large functionalized gold substrate and (b) square array of functionalized gold pads after 30-minute polymerization at 37C

Fig. 3: Color contour maps of the steady-state length (in _m) of simulated MT nucleated on (a) a solid surface with a uniform distribution of nucleation centers (35x35 _m^2); (b) a solid surface (20x20 _m^2) with a non-uniform distribution of nucleation centers (central 10x10 _m^2). Periodic boundary conditions are applied.