MICROTUBULE BEHAVIOR UNDER STRONG ELECTRIC FIELDS: AN ATOMIC FORCE MICROSCOPY STUDY.

R.R. Ramalho[a,b], H. Soares[b,c], L.V. Melo[a,]*
[a] *Physics Department and IN, Instituto Superior Técnico,Lisboa, Portugal*
[b] *Instituto Gulbenkian de Ciência, Oeiras, Portugal*
[a] *Escola Superior de Tecnologia da Saúde de Lisboa, Lisboa, Portugal*
[*] *lhvm@fisica.ist.utl.pt*

Microtubules (MTs) are tubular polymers of the heterodimeric protein α/β-tubulin. As part of the cytoskeleton, they cooperate with its other components to define, maintain, and remodel the overall structure and compartmentalization of the cell. They are involved in intracellular transport (through motor proteins), chromosome seggregation during mitosis and meiosis and signal transduction. They are also major building blocks of several specialized cell structures, like cilia and axons.

The versatility of MTs' functions has to do with both their structural properties and their dynamics. They are strong and rigid enough to function like struts, while still flexible enough to provide suport for motile structures like cilia. Their outer surface has several binding sites for motor proteins like kinesins and dyneins, and the surface area is big enough to support large protein complexes, like the ones that drive the movement of cilia. The fact that their structure is also polar (with only β subunits at the plus end and α subunits at the minus end) is used by the motor proteins to define their motion's direction.

On the other hand, microtubules are far from inert: they can quickly alternate between stages of polymerization and depolymerization (due to dynamic instability), and can be stabilized or destabilized by various factors in the cell. Different isotypes (genetically encoded) and isoforms (resulting from post-translational modifications) of tubulin exist, and the specific constitution of a microtubule is known to regulate its structural and dynamic properties.

Theoretical studies [1] have concluded that tubulin heterodimers have a permanent electric dipole. MTs should, then, have a significant axial dipole moment, and an electrical field of sufficient magnitude should be capable of aligning MTs parallel to its direction. In our work this was verified experimentally by AFM measurements.

Taxol-stabilized MTs obtained by polymerization of mouse brain tubulin were adsorbed to poly-L-lysine-coated glass slides and imaged by AFM. Samples of MTs adsorbed under electric fields of different magnitudes. Alignment was not apparent for a 6 kV/m field, but clearly observable for a 400 kV/m field, supporting the existence of a dipolar moment (results in print [2]).

Our work is currently focused on designing and testing substrates to use as physical supports for the deposition of microtubule patterns.

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References:

[1] Tuszynski J., Luchko, Carpenter E., Crawford E., J. Comp. Theor. Nanosci. 4 (1) (2004) 392.

[2] Ramalho R.R., Soares H., Melo L.V., "Microtubule behavior under strong electromagnetic fields", Materials Science and Engineering C (2006), doi:10.1016/j.msec.2006.09.045