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## **(G\*) Dynamic behaviour of microtubules around the critical temperature and effect of the electric field produced by these vibrations on its environment**

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In this paper, we study the microtubule as a ferroelectric system. The behaviour of microtubules around the critical temperature was evaluated, and the effect of the electric field produced by the microtubules on its environment was determined. Also, the mean-field theory approximation (MFTA) was used to evaluate the total polarization and free energy around the critical temperature. These parameters are evaluated according to the physiological and critical temperatures in the absence and the presence of the electric field produced by the vibrations of the microtubule network. Results show that the microtubule (MT) has a spontaneous polarization in the absence of an electric field which collapses above the critical temperature. Moreover, the transition from ferroelectric to paraelectric state occurs with increasing physiological temperature. The microtubule stability is observed at the minimal free energy. The free energy is higher in the paraelectric state than in the ferroelectric state and changes its behaviour at high temperatures. The electric field stabilizes and orients the microtubule in the direction of the field. The microtubule produces electric fields that strongly interact with its biological environment at a short distance while long-distance interactions are weak.

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