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Quantum phase diagram, ferroelectricity and fractional charge excitations in the ionic Hubbard model

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Recent research confirmed that the half-filled ionic Hubbard chain (the Hubbard chain with alternating on-site energy) has three insulating phases: a band insulator (BI) , a Mott insulator (MI) and a spontaneously dimerized insulator (SDI) that appears between the other two. We show the quantum phase diagram obtained by the method of topological transitions (or jumps in Berry phases). The ferroelectric nature of the SDI phase and its low-energy excitations is clarified mapping a slightly modified effective Hamiltonian for small hopping into an exactly solvable isotropic SU(3) Heisenberg model [C.B. Batista and A.A. Aligia, Phys. Rev. Lett. 92, 246405 (2004) ; Phys. Rev. B 71, 125110 (2005)]. In spite of the presence of a charge gap, the charge-charge correlations in the MI phase display a power-law decay [A.A. Aligia, Phys. Rev. B 69, 041101(R) (2004)]. This is shown using bosonization and is in excellent agreement with DMRG results [S.R. Manmana *et al.*, Phys. Rev. B 70, 155115 (2004)]. The topological charge transition can be detected in transport through nanoscopic rings or molecules [A.A. Aligia *et al.*, Phys. Rev. Lett. 93, 076801 (2004)]. Generalization of the results for chains with larger unit cells (compounds AB_n with filling $1/(n+1)$) is briefly discussed.

Keywords : ionic Hubbard model, ferroelectricity, fractional charge excitations, Berry phases, correlation functions