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Mott insulating states and quantum phase transitions of correlated SU($2N$) Dirac fermions ZHICHAO ZHOU, School of Physics and Technology, Wuhan University, Wuhan 430072, China, DA WANG, National Laboratory of Solid State Microstructures and School of Physics, Nanjing University, Nanjing, 210093, China, ZIYANG MENG, Beijing National Laboratory for Condensed Matter Physics, and Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China, YU WANG, School of Physics and Technology, Wuhan University, Wuhan 430072, China, CONGJUN WU, Department of Physics, University of California, San Diego, California 92093, USA — We investigate the competing orders in the half-filled SU($2N$) Hubbard model on a honeycomb lattice, which can be accurately realized in optical lattices with ultracold large-spin alkaline-earth fermions. Employing large-scale projector determinant quantum Monte Carlo simulations, we have explored quantum phase transitions from the gapless Dirac semimetals to the gapped Mott insulating phases in the SU(4) and SU(6) cases. Both of these Mott insulating states are found to be columnar valence bond solid (cVBS) and to be absent of the antiferromagnetic Neel ordering and the loop current ordering. Inside the cVBS phases, the dimer ordering is enhanced by increasing fermion components and behaves nonmonotonically as the interaction strength increases. Although the transitions generally should be of first order due to a cubic invariance possessed by the cVBS order, the coupling to gapless Dirac fermions can soften the transitions to second order through a nonanalytic term in the free energy. Our simulations provide guidance for the experimental exploration of new states with alkaline-earth fermions.

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