Tensor force and shape evolution of Si isotopes in Skyrme-Hartree-Fock model†

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In the present study, we focus on the tensor effect on the shape evolution of Si isotopes. We determined whether the tensor-force-driven deformation is present in neutron-rich Si isotopes, especially ^{30}Si with a possible $N = 16$ subshell, because some models (e.g., the FRDM) predicted a spherical shape for these nuclei[1)] while their large $B(E2)$ values suggested a deformed nature[2)]. For this purpose, we use the deformed Skyrme-Hartree-Fock model (DSHF)[3)] with BCS approximation for the nucleon pairing. We show in Fig. 1 the energy curves of ^{30}Si (left panel) and ^{32}Si (right panel) as a function of the quadruple deformation parameter β_2 using the Skyrme interactions with tensor terms T22, T24, T44, T64, and T66[4)]. The energy minima are indicated with triangles. ^{30}Si is suggested to be deformed, but T22 and T44 with relatively large pairing strengths ($\sim$ 1000 MeV) fail to give deformed energy minima. In contrary, a deformed ground state can be achieved using the T24, T64 and T66 parametrization with a small pairing strength ($\sim$ 800 MeV). Moreover, the predicted oblate shape of these nuclei is consistent with the recent RMF result[5)]. A possibility of achieving a deformed ground state using weak nucleon pairing may stem from a well-known fact that the pairing interaction forms the $J = 0^+$ pairs of identical particles that have spherically symmetric wave functions. As a result, nuclei tend to be more spherical when a strong pairing coupling exists between neutrons and protons as in the cases of T22 and T44; otherwise nuclei are more likely to be deformed, as in the cases of T24, T64, and T66. This suggests that the resulting shape of a nucleus is sensitive to the nucleon pairing in this nucleus, and the experimentally determined deformed shape of ^{30}Si suggests that a relatively weak paring correlation is present in the Skyrme effective forces T24, T64 and T66. We also notice that a large tensor force present in T64 and T66 tends to produce a deep energy surface; i.e., the tensor force exerts a dramatic effect that maintains a deformed ground state in ^{30}Si. The effect of the tensor force is also observed in ^{32}Si as shown in the right panel of Fig. 1. Its shape is predicted to be spherical using T22, T24, and T44 but oblate using T64 and T66 with large tensor forces. The spherical result in the first three cases is obviously not consistent with experiments, and the shape change from spherical to oblate when introducing a large tensor force is intriguing.

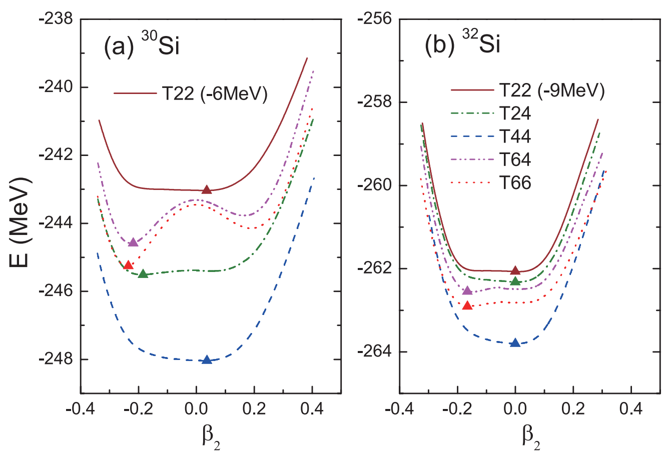

Fig. 1. (Color online) Energy curves of ^{30}Si (left panel) and ^{32}Si (right panel) as a function of the quadruple deformation parameter β_2 using the Skyrme interactions T22, T24, T44, T64, and T66. The energy minima are indicated with triangles.

In summary, we used the DSHF model to investigate the shape evolution of the quadruple deformation of Si isotopic nuclei. We found interesting manifestations of the tensor force and pairing effect in several isotopic nuclei, such as ^{30}Si and ^{32}Si. The effect of tensor force is observed when we compare the predicted shape of ^{32}Si using increasing tensor forces in the HF energy density. The tensor-force-driven deformation in these nuclei should be investigated in more details because it may result in a further improvement of many theoretical models or parameterizations toward a better description of theories on the shell structures of nuclei in general, such as the shell model and SHF model.

References
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