Nuclear structure investigation of odd-odd $^{92-98}$Y nuclei

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The structure of the energy states and its decay properties in odd-odd $^{92-98}$Y isotopes have been investigated via the framework of the interacting boson fermion-fermion model (IBFFM-1). To complete the system of the model, the nuclear structure of the even-even $^{90-96}$Sr isotopes has been described from the IBM-1 as a core part. The nuclear structure of odd-Z $^{91-97}$Y and odd-N $^{91-97}$Sr isotopes is studied in the IBFM-1. The single-, quasi-particle energies and the occupation of valence protons (neutrons) $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$ and $1g_{9/2}$ ($2d_{5/2}$, $2d_{3/2}$, $1g_{7/2}$, $3s_{1/2}$ and $1h_{11/2}$) single-particle orbitals have been calculated. Angular momentum assignments for some uncertain experimental levels made based on the model calculations. The model calculations gave consistent and detailed description of the nuclear structure of even-even, odd-A, and odd-odd Sr and Y of this mass region nuclei.

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I. INTRODUCTION

Shape coexistence and intruder orbitals are quite common phenomena in the $Z \approx 40$ nuclei [1–3]. The neutron-rich $^{90-98}$Sr and $^{91-98}$Y nuclei, for example, show a sudden beginning of deformations between neutron numbers $N = 52$, with spherical shapes, $N = 58$, with nearly spherical shapes, and $N = 59$, where the ground states are deformed [4,5]. In $A \approx 100$ region, the neutron-rich yttrium isotopes are of particular interest because they are located between to some extent spherical and a well-deformed region [6–12]. This is noticeable for the isotopic chains near $Z \approx 40$, namely Nb, Zr, Sr, and Y nuclei [13–15]. The nuclear structure with $N \leqslant 58$ can be understood in terms of the shell model for spherical nuclei (the lighter isotopes up to $N = 58$ hold a stable spherical shape), whereas the $N \approx 60$ isotones are deformed in their ground states [16]. Thus, an important question arises about the behavioral nature of the last $N = 59$ isotones for ^{97}Sr and ^{98}Y isotopes, which are the link between the spherical and deformed regions and for which shape coexistence is expected. In this mass region, the $\pi g_{9/2}$ and $\upsilon h_{7/2}$ orbitals are located near the Fermi surface and play a major role in the bands structure of this region [17].

Several theoretical and experimental works were carried out investigate the nuclear structure for Sr and Y isotopes. Tel *et al.* [18] have theoretically calculated the nuclear neutron and proton densities and binding energies of the Sr isotopes ($A = 84$–96). They used the Skyrme-Hartree-Fock (SHF) parameters to investigate the ground-state properties and the nuclear shape. Clément and Zielińska [19] discussed the shape coexistence in the nuclear structure of ^{96,98}Sr isotopes. The results showed that the shape shift at $N = 60$ leads to the coexistence of a highly deformed prolate, and a spherical configuration in $N = 98$ with low configuration mixing.

Nomura *et al.* [20] studied the shape coexistence in the $^{92-108}$Sr isotopes within the IBM model with microscopic

Gogny-D1M energy density functional. They have mapped the deformation PES in the quadrupole deformation parameters (β, γ). A clear coexistence is found between very weakly oblate (up to $N = 58$) and strongly prolate-deformed shapes (starting at $N = 59$). Régis *et al.* [21] showed that the results of the sudden change of shape for Sr isotopes near $N = 60$ resulted from the excitation of many protons in the $g_{9/2}$ orbit. The Monte Carlo shell-model results have been done without truncation on the occupation numbers of the orbits with eight protons and eight neutron orbits. Wimmer *et al.* [22] investigated the presence of spherical-deformed shape transition for neutron-rich Sr isotopes. Monte Carlo shell model calculation for ^{95}Sr nucleus predicted the coexistence shape of the ground band, prolate excited intruder states, and a triaxial deformed band built on the low-lying $7/2^+$ state.

Esmaylzadeh *et al.* [5] used the Lohengrin spectrometer to measure delayed γ rays from neutron-rich ^{97}Sr fission fragments and measured several lifetimes of excited states using fast-timing technique. The experimental results are compared with a boson-fermion model based on the microscopic energy density functional. They concluded that the ^{97}Sr nucleus is exactly at the spherical-deformed limit. Cruz *et al.* [23] based on the idea of a dramatic ground-state transition from spherical (near) below $N = 60$ in Sr and Zr nuclei to deformed shapes in heavy isotopes. The single-particle structure of $^{95-97}$Sr, that approximates the ground-state transition at ^{98}Sr, was investigated using (d, p) interaction in inverse kinetics. The experimental results were compared with shell model calculations and they showed that the ground state is weakly deformed in the ^{96}Sr nucleus and that the first two excited levels overlap significantly, while we find that the ground state of ^{97}Sr nucleus has a different structure. The single-particle and collective structure in Sr ($N = 50$–58) isotopes have been investigated using shell model [24]. The energy spectra and transitions rates of these isotopes were well described in this