Microscopic study of oblate to prolate shape transition at higher spins in neutron-rich $^{100\text{-}104}$Zr isotopes

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Neutron-rich Zr nuclei in the A~100 mass region have attracted both theoretical and experimental attentions because of some interesting phenomena observed in these nuclei. The ground states of Zr isotopes undergo a shape transition from spherical to well deformed prolate (or oblate) deformations at neutron number (N)~60 [1-4]. However, this transition becomes steadily weaker as proton number (Z) is increased. It has been shown by the theoretical relativistic [5,6] and non-relativistic [7,8] studies of the nuclear structural evolution in this mass region that there is a rapid change in the equilibrium shape of the nucleus as a function of number of nucleons, and shape coexistence is present with competing spherical, axially symmetric prolate and oblate shapes.

The ground-state bands in case of $^{100\text{-}104}$Zr isotopes have been extended up to high spins of 20^+, 20^+ and 14^+, respectively, by Hua et al.[9]. Besides yrast bands, the experimental data is available on electromagnetic quantities such as B(E2) transition probabilities and g-factors for neutron-rich $^{100\text{-}104}$Zr [10-13]. Smith et al. [11] have calculated B(E2; $2_1^+ \rightarrow 0_1^+$) values in ^{100,102}Zr from the lifetime measurement of 2_1^+ state. Hwang et al. [10] have also measured the lifetime and hence B(E2) value of 2_1^+ state in ^{104}Zr via γ-ray spectroscopy. The latest B(E2) values extracted from the lifetime of 2_1^+ state have been reported in ^{104}Zr by Browne et al. [13] by using *β-γ* spectroscopy. The experimental information on B(E2) values in neutron-rich $^{100\text{-}104}$Zr isotopes have been very rare until Smith et al. [12] presented new lifetime measurements for excited rotational states in these nuclei at spins I~10. These authors have measured the lifetimes for 8⟶6, 10⟶8, 12⟶10 transitions in the yrast bands of $^{100\text{-}104}$Zr isotopes. Moreover, transitional quadrupole moments at nuclear spins I~10 have been extracted and compared with various theoretical approaches [8,14]. It has been interpreted from the results that there is prolate oblate shape coexistence in Zr isotopes for spins less than 10^+, which in turn indicates that the shapes of Zr isotopes are unchanged up to 8^+. Another interpretation is that there is a gradual oblate to prolate shape transition at 10^+ in Zr isotopes. In the present work, the Projected Shell Model (PSM) [15] has been employed as a theoretical tool in order to examine the presence of prolate oblate shape coexistence in low-lying states of Zr isotopes as well as understand the mechanism underlying oblate to prolate shape transition at 10^+ as suggested by Smith et al. [12]. The PSM calculations have been performed for both prolate as well as oblate deformations for $^{100\text{-}104}$Zr isotopes. The valence space of the model consists of three harmonic oscillator shells N=2,3,4 for protons and 3,4,5 for neutrons.

In Fig.1(a,b,c) the theoretical yrast spectra obtained in PSM framework are compared with the experimental data for $^{100\text{-}104}$Zr isotopes, respectively. The results presented in Fig. 1(a) show that in case of ^{100}Zr, low-lying yrast states up to 6^+ are seen to be in agreement with the corresponding states arising from both prolate as well as oblate deformations with ε_2= 0.29 and -0.42, respectively. Thus, the PSM calculations predict coexistence of prolate and oblate shapes for low-lying states in ^{100}Zr. However, the yrast states from 8^+ to 14^+ show a better agreement with the corresponding states arising from the prolate deformation. Above spin 14^+, the prolate yrast spectrum is lower and the oblate yrast spectrum is higher than the observed yrast spectrum. In case of ^{102}Zr (Fig. 1(b)), the observed yrast spectrum up to 10^+ is reproduced by the corresponding states arising from both prolate as well as oblate deformations with ε_2= 0.33 and -0.47, respectively, thereby suggesting shape coexistence in this nucleus up to 10^+.

However, for the yrast states above 10^+, the energy states arising from prolate deformation are in better agreement than those arising from oblate deformation. In case of ^{104}Zr (Fig. 1(c)), the observed yrast spectrum up to 10^+ is in agreement with the corresponding states arising from both prolate as well as oblate deformations with ε_2=0.32 and -0.40, respectively, thereby suggesting shape coexistence in this nucleus up to spin 10^+. However, the observed yrast spectrum at spin 12^+ is well reproduced by the yrast spectrum arising from prolate deformation.

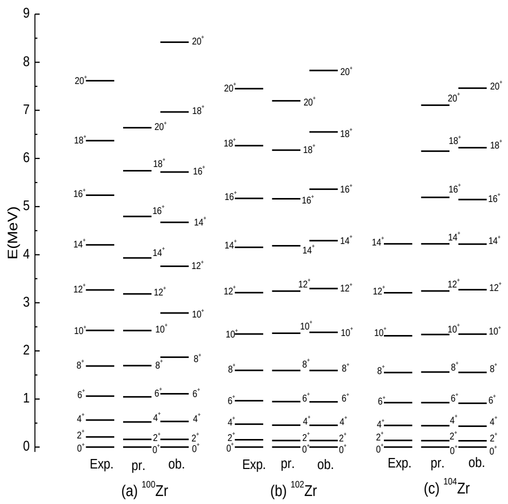

Fig. 1 Comparison of calculated yrast sepctra with the experimental data for (a)^{100}Zr (b)^{102}Zr (c)^{104}Zr, respectively

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