Shape Coexistence in N = 40 Isotones

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The phenomenon of shape coexistence in N = 40 isotones pulled in various efforts from theoretical and experimental fronts in recent years. Using Hartree-Fock-Bogoliubov approach with Gogny D1S effective interaction N = 40 isotones are investigated by their quadrupole modes of excitation [1]. On the other hand, spherical-oblate-prolate shape transition is reported along the isotonic chain of N = 40 by analyzing the potential energy surfaces from the relativistic mean-field plus BCS method with the PC-PK1 force [2] and shape coexistence in $^{76-80}$Sr, $^{80-84}$Zr and ^{82,84}Mo is described by calculation of Total-Routhian-Surface(TRS) [3]. Moreover, Ge and Se nuclei have been found to exhibit a pronounced competition between different configurations associated with a variety of intrinsic shapes [4]. Recently, shape coexistence in ^{72}Ge is investigated using projectile multistep Coulomb excitation with GRETINA and CHICO-2 [5] and shape coexistence in the Ge and Se isotopes are studied within the interacting boson model (IBM) with the microscopic input from the self-consistent mean-field calculation based on the Gogny-D1M energy density functional [6]. In view of above studies, we investigate the phenomenon of shape coexistence in N = 40 isotones using Relativistic Mean-Field (RMF) plus BCS approach with TMA parameter [7–9] and Nilson Strutinsky (NS) method [10, 11] that includes triaxial shapes also.

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Here we look for shape coexistence and shape transitions for N=40 isotones and plot binding energy surface as a function of quadrupole deformation in FIG. 1 and trace energy minima. Our calculations predict ^{68}Ni to be spherical with zero deformation (β_2 = 0.0) in accord with recent communication [12]. Moving towards higher Z, this minima becomes little flatter as can be seen for ^{70}Zn from FIG. 1(b) whereas from FIG. 1(c) two small minima can be found around $\beta_2 = \pm 0.2$ giving rise to oblate-prolate shape coexistence in nucleus ^{72}Ge which is of recent experimental interest to visualize shape-coexistence [5]. For ^{74}Se, in FIG. 1(d) oblate minima is found more dominant with β_2 = -0.25 whereas again shape coexistence is observed in ^{76}Kr with two minima with β_2 = -0.30 and 0.45 at an excitation energy (energy difference between two minima) of 0.305 MeV which is mentioned in Table I for other nuclei also. For ^{78}Sr and ^{80}Zr the prolate shape is more dominant (seen in FIG. 1(f) and (g) respectively) although another shallow minima of oblate shape is also visible. Another shape coexistence with oblate and prolate shapes is reported in ^{82}Mo, with excitation energy 0.484 MeV with shape transition to oblate minima in ^{84}Ru.

In nutshell, one can see rapid shape coexistence and transitions in N = 40 isotones from spherical in ^{68}Ni to oblate in ^{74}Se to prolate in ^{78}Sr and ^{80}Zr to oblate in ^{82}Mo and ^{84}Ru which is in accord with our calculations using NS Method using triaxially deformed Nilson potential [10, 11] except that the triaxial shape compete closely with prolate shape for a minima (to be presented in subsequent work). Two energy minima of

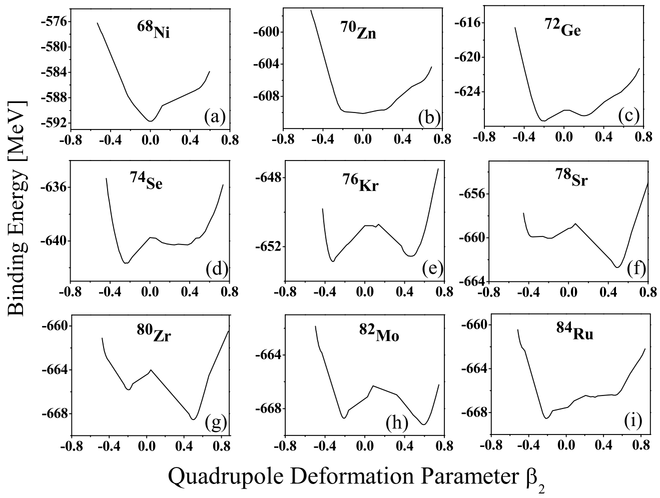

FIG. 1: Binding energy versus Quadrupole Deformation Parameter β_2 for N = 40 Isotones using RMF(TMA).

TABLE I: Results of excitation energy (energy difference between two minima) as obtained in the deformed RMF calculations using TMA force parameters for N = 40 Isotones.

Nucleus	Excitation Energy (MeV)
^{72}Ge	0.543
^{74}Se	1.388
^{76}Kr	0.305
^{78}Sr	2.672
^{80}Zr	2.714
^{82}Mo	0.484

oblate and triaxial shape are seen in ^{84}Ru, ^{74}Se with deeper oblate (in accord with RMF). Shape co-existence between prolate and oblate in ^{72}Ge, ^{76}Kr and ^{82}Mo are predicted by RMF as evidenced by Table I.

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