High-Spin States in $^{136}$La
Studied by Using $^{17}$N RI Beam Induced Fusion Reaction

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Mid-shell nuclei in transitional mass region show shape coexistence, shape evolution from spherical to prolate deformation as change of neutron number, and so on. Especially, in transitional odd-odd nuclei with $A \sim 130$, signature splitting, signature inversion, chiral band, and so on have been observed. These phenomena are interpreted to be caused by $\gamma$ softness and triaxial deformation due to the effect of a proton $h_{11/2}$ particle and a neutron $h_{11/2}$ hole. To reveal these exotic nuclear structure, we have investigated isomers which are very sensitive to variation of nuclear shape and nuclear motion.

As the first step, the high-spin states in the odd-odd nucleus $^{136}$La have been populated in a fusion reaction of $^{124}$Sn($^{17}$N,5n), induced by a low-energy radioactive nuclear beam. The use of the RI beam based on $\gamma$-ray spectroscopy with a large efficiency Ge-detector array enables significantly high-S/N measurements of the isomers so far unobserved. Because of rather low intensity ($2 \times 10^5$ pps) of the $^{17}$N beam, the beam particle could be detected by the PPAC detector one-by-one. This information helps us to reduce the background, and at the same time, serves as the time reference for the $\gamma$-rays emitted from the isomers. Detailed experimental procedures were reported in ref. [1].

Gamma-rays in $^{136}$La were categorized into two groups by gating on the time difference between the PPAC and the Ge detectors: “prompt” and “delayed” associated with the gates on ±50 nsec and 100-800 nsec, respectively. Then, a “prompt”-$\gamma$ and “delayed”-$\gamma$ coincidence matrix was obtained. Figures 1(a) and (b) show the total projection $\gamma$-ray spectra of the matrix to the “delayed” axis and that to the “prompt” axis, respectively. The fact that $\gamma$ rays of 156, 281, 407, 425 and 585 keV can be seen in the “delayed”-$\gamma$ spectrum, as shown in Fig. 1(a), indicates that we found a new isomer in $^{136}$La. Gamma rays above the isomer can be obtained, comparing the “delayed”-$\gamma$ and “prompt”-$\gamma$ spectra in Fig. 1(a) and (b), respectively. This new isomer was assigned to the state with spin of (14) at 2.3 MeV higher excitation energy above the known isomer with $T_{1/2} = 114$ nsec [2]. Constructed level scheme with new 9 transitions and 6 levels is shown in Fig. 2. By the analysis of time difference between $\gamma$ rays above and below new isomer, half life was determined to be $T_{1/2} = 187(27)$ nsec. Low-spin states can be well explained by the weak coupling between valence and core with small $\gamma$ collectivity. Detailed nuclear structure of $^{136}$La will be discussed in ref. [3].

References
[3] H. Nishibata et al., to be submitted.