Discovery of 18 new isomers using in-flight fission of 345 MeV/u ^{238}U: Evolution of the shell structure and shape coexistence

D. Kameda[1*], T. Kubo[1], T. Ohnishi[1], K. Kusaka[1], A. Yoshida[1], K. Yoshida[1], M. Ohtake[1], N. Fukuda[1], H. Takeda[1], K. Tanaka[1], N. Inabe[1], Y. Yanagisawa[1], Y. Gono[1], H. Watanabe[1], H. Otsu[1], H. Baba[1], T. Ichihara[1], Y. Yamaguchi[1], M. Takechi[1], S. Nishimura[1], H. Ueno[1], A. Yoshimi[1], H. Sakurai[1], T. Motobayashi[1], T. Nakao[2], Y. Mizoi[3], M. Matsushita[4], K. Ieki[4], N. Kobayashi[5], K. Tanaka[5], Y. Kawada[5], N. Tanaka[5], S. Deguchi[5], Y. Satou[5], Y. Kondo[5], T. Nakamura[5], K. Yoshinaga[6], C. Ishii[6], H. Yoshii[6], Y. Miyashita[6], N. Uematsu[6], Y. Shiraki[6], T. Sumikama[6], J. Chiba[6], E. Ideguchi[7], A. Saito[7], T. Yamaguchi[8], I. Hachiuma[8], T. Suzuki[8], T. Moriguchi[9], A. Ozawa[9], T. Ohtsubo[10], M. A. Famiano[11], H. Geissel[12], A. S. Nettleton[13], O. B. Tarasov[13], D. Bazin[13], B. M. Sherrill[13], S. L. Manikonda[14], J. A. Nolen[14]

[1] RIKEN Nishina Center, [2] University of Tokyo, [3] Osaka Electro-Communication University, [4] Rikkyo University, [5] Tokyo Institute of Technology, [6] Tokyo University of Science, [7] CNS, University of Tokyo, [8] Saitama University, [9] University of Tsukuba, [10] Niigata University, [11] Western Michigan University, [12] Gesellschaft fuer Schwerionenforshung mbH, [13] National Superconducting Cyclotron Laboratory, Michigan State University, [14] Argonne National Laboratory

A comprehensive search for isomers among fission fragments of 345 MeV/u ^{238}U has been performed at RIKEN RI Beam Factory (RIBF) to investigate evolution of shell structure and nuclear shape in the very neutron-rich nuclei with Z ~ 20 to 50. Fission fragments were analyzed and identified using the BigRIPS in-flight separator [1, 2], and delayed γ-rays were measured at the focal plane using three clover-type germanium detectors. In total we identified 54 microsecond isomers over a wide range of neutron-rich exotic nuclei, including observation of 18 new isomers: ^{59m}Ti, ^{90m}As, ^{92m}Se, ^{93m}Se, ^{94m}Br, ^{95m}Br, ^{96m}Br, ^{97m}Rb, ^{108m}Nb, ^{109m}Mo, ^{117m}Ru, ^{119m}Ru, ^{120m}Rh, ^{122m}Rh, ^{121m}Pd, ^{124m}Pd, ^{124m}Ag and ^{126m}Ag. The fruitful spectroscopic information allows us to propose (or extend) level schemes of the observed isomers: ^{59m}Ti, ^{82m}Ga, ^{92m}Br, ^{94m}Br, ^{95m}Br, ^{97m}Rb, ^{98m}Rb, ^{108m}Nb, ^{108m}Zr, ^{109m}Mo, ^{117m}Ru, ^{119m}Ru, ^{120m}Rh, ^{122m}Rh, ^{121m}Pd, ^{124m}Ag and ^{125m}Ag. We also investigate the nature of nuclear isomerism for these isomers that is sensitive to evolution of the shell structure and shape coexistence. For instance, the existence of ^{59m}Ti suggests that the N=34 sub-shell gap between $\nu p_{1/2}$ and $\nu f_{5/2}$ gets smaller as the neutron number increases due to the attractive monopole interaction [3]. Shape isomerism is discussed for ^{97m,98m}Rb and ^{95m}Br based on the well-known shape coexistence in the region with N~60 and Z=38-42 [4]. We speculate shape isomerism of ^{117m,119m}Ru, ^{120m,122m}Rh, ^{121m}Pd and ^{124m}Ag, in analogy to the N~60 shape coexistence. The region at N~75 and Z~39-45 is predicted to be a new deformation region by a nuclear mass model [5].

In this paper, we present our experimental results and the proposed nuclear isomerism. The relevant nuclear structure and its evolution are also discussed.

[1] T. Kubo, Nucl. Instr. and Meth. **B 204**, 97, (2003). [2] T. Ohnishi, *et al.*, J. Phys. Soc. Japan, **79**, 073201, (2010). [3] T. Otsuka, *et al*., Phys. Rev. Lett. **104**, 012501, (2010). [4] K. Heyde and J. Wood, Rev. Mod. Phys. **83**, 1467, (2011). [5] J. M. Pearson, *et al*., Phys. Lett. B **387**, 455, (1996).

* Corresponding author: RIKEN Nishina Center, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan, kameda@ribf.riken.jp