Nuclear structure studies of very neutron-rich nuclei at RIKEN RIBF

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RIKEN RI Beam Factory (RIBF) started its operation in the end of 2006. RIBF is an accelerator complex designed to provide wide rage of light- and heavy-ion beams. Especially its capability of creating nuclei very far from the stability by projectile fragmentation or in-flight uranium fission exceeds the one in other facilities currently in operation. With the increase of the beam intensity, various new results have been obtained demonstrating its high potential.

One of the major subjects is nuclear structure study in the region very far from the stability valley. Large imbalance of numbers of neutron and proton may cause, for example, disappearance of magic numbers established by studies of nuclei in and around the stable region. Disappearance of the N=20 closed shell is already known as "island of inversion" where the order of shell filling is inverted in the neutron rich nuclei around ^{32}Mg. A question is if such changes of shell structure occur for other magic numbers. Appearance of new magic numbers might also be expected as already known for N=16.

Even if weakening of shell closure does not reach its disappearance, influence is expected to the r-process nucleosynthesis, which takes place in very high-temperature and high-density conditions and hence involves very neutron-rich nuclei. RIKEN RIBF started to approach some of the nuclei expected in the r-process path.

Another interesting nuclear structure is extended neutron spatial distribution called neutron hallo. It is observed in a few neutron-rich nuclei in light nuclei at the drip line such as ^{11}Li and ^{11}Be. The neutron responsible for the halo structure is in the s-orbital in which the centrifugal barrier is missing. RIBF can reach the drip line for heavier nuclei. A question there is if similar halo structure is found in sd-shell nuclei where s-wave neutron cannot be always play such role.

Nuclear structure studies at RIBF has so far three major focus: search for possible shell structure changes in the neutron-rich regions around N= 20-50, nuclear properties related to the r-process in a wide range including the N=82 region, and neutron halo in isotopes around Ne.

Recent highlights are finding of well developed deformation in the "doubly magic" nucleus ^{42}Si and the high lying 2^+ state observed in ^{54}Ca indicating the new magic number N=34. The experiments were performed by measuring γ rays associated with direct reactions like inelastic scattering and nucleon removal reactions with fast RI beams. These results support shell model theories taking into account new non-central effective forces and/or the ones involving three nucleons, necessity of which is not visible in less neutron-rich nuclei.

Properties of heavier nuclei are studied by β−γ and isomer spectroscopy of stopped RIs. Collaboration program called EURICA (EUro ball RIken Cluster Array) uses Clover detectors used in the Euroball. It is powerful in the studies of this kind, and lifetimes of nuclei in the r-process path have already been determined. Another approach with the in-beam γ measurement mentioned was also applied to, for example, neutron-rich Pd isotopes to study the extent of shell quenching at N=82.

Neutron halo was looked for first by interaction cross-section measurement. The halo candidate ^{31}Ne was examined independently by a completely different method, Coulomb dissociation. The results of the two experiments both point to the halo nature, confirming that p-wave neutron can be responsible for halo. The newly constructed spectrometer SAMURAI enables particle correlation experiments, which are expected to provide more detailed information on the halo structure.