Alpha inelastic scattering and cluster structures in light nuclei

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Alpha particle clustering is an important concept in nuclear physics for light nuclei. On the basis of the Ikeda diagram, the alpha cluster structure is expected to emerge near the $\alpha$-decay threshold energy. It has been suggested that the 7.65-MeV $0^+_2$ state in \textsuperscript{12}C, which locates at the excitation energy higher than the $3\alpha$-decay threshold by 0.39 MeV, has a $3\alpha$-cluster configuration.

This $0^+_2$ state is theoretically described by introducing a quite novel concept of the nuclear structure, i.e., this state has a dilute-gas-like structure where three $\alpha$ particles are weakly interacting and are condensed into the lowest $s$-orbit. The existence of the cluster-gas-like phase of the atomic nucleus increasingly attracts much attention to the alpha cluster structures in light nuclei, and similar dilute-gas states of $\alpha$ clusters have been theoretically predicted in the other self-conjugate $N=4n$ nuclei.

The alpha clustering phenomena in $N \neq 4n$ nuclei are also of interest. Excess nucleons or holes on a $n\alpha$ core are considered to behave as covalent particles between alpha clusters and modify the cluster structures in such nuclei. It is, therefore, desired to perform a comprehensive study on the alpha cluster structures in light $N = 4n$ and $N \neq 4n$ nuclei.

Recently, we proposed large isoscalar monopole strengths at relatively low excitation energies are regarded as a signature of spatially well-developed alpha-cluster states, and this idea was theoretically supported by T. Yamada et al. Since the alpha inelastic scattering is widely known as a very useful probe to determine the isoscalar monopole strengths, we intended to measure the $^{11}$B, $^{12}$C, $^{13}$C, and $^{24}$Mg($\alpha, \alpha'$) reactions at $E_\alpha = 400$ MeV to study the cluster structures in those nuclei.

The several low-lying states in $^{11}$B, $^{13}$C, and $^{24}$Mg as well as the $0^+_2$ states in $^{12}$C were found to be strongly excited by the isoscalar monopole transitions. Since the isoscalar monopole strengths for those states are not described by the shell-model (SM) calculations at all, those states are regarded to have non-SM-like structures.

The non-SM-like structures are considered to be due to the alpha clustering. Since the theoretical description of the clustering phenomena under the SM framework requires a huge number of single-particle bases, it is generally difficult to treat the clustering phenomena in the truncated SM space. Actually, the cluster-model calculations reasonably well describe the large isoscalar monopole strengths for those states.

In the present talk, we will present the experimental details and results, and will discuss the alpha cluster structures in light nuclei with focus on $^{11}$B, $^{13}$C, and $^{24}$Mg.