# Dependence of heavy-ion fusion reaction on nuclear deformation

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We have studied the dependence of heavy-ion fusion reaction on nuclear deformation in order to investigate experimentally the gentle fusion [1] or the hugging fusion [2], which have been theoretically propose as a new approach to the superheavy element production. In this type of fusion reaction between well-deformed nuclei, the relative orientation of the symmetry axes of the deformed nuclei significantly changes the Coulomb barrier height and the compactness of the touching configuration. It is predicted that the most compact configuration at the touching point would lead to high formation probability in the entrance channel. To check this speculation experimentally, we have measured the excitation functions near the Coulomb barrier, firstly in the reactions of $^{60,64}$Ni+$^{154}$Sm, $^{32}$S+$^{182}$W, $^{76}$Ge+$^{150}$Nd and $^{28}$Si+$^{198}$Pt for the production of Th-U regions [3,4,5,6], and next in $^{82}$Se+$^{176}$Yb and $^{64}$Ni+$^{198}$Pt to produce $^{258}$Rf (Z=104) and $^{262}$Sg (Z=106), respectively, which had been synthesized in the cold fusion of $^{50}$Ti+$^{208}$Pb and $^{54}$Cr+$^{208}$Pb.

In order to obtain direct evidence that the heavy projectile really fuses with the deformed target, the fusion evaporation residues emitted along the beam direction were separated in-flight by the JAERI recoil mass separator (RMS) and identified on the basis of time- and position-correlated alpha-decays. The angular distributions of fission fragments were also measured around the target to obtain the total fusion cross sections.
The measured cross sections were compared with the coupled channel calculation CCDEF for the fusion process (entrance channel) and the statistical model calculation HIVAP for the evaporation process (exit channel). In the small charge product system of $^{32}$S+$^{182}$W ($Z_1Z_2$=1184), a good agreement between the data and the calculated results was obtained both for the fission and evaporation residue cross sections. On the contrary, in the case of the large $Z_1Z_2$ system of $^{60}$Ni+$^{154}$Sm, the measured evaporation residue cross sections for all evaporation channels of *x*n, p*x*n and alpha-*x*n were much less than the calculated results, even though the deexcitation process from the compound nucleus $^{214}$Th is completely same with in $^{32}$S+$^{182}$W. The similar result was obtained in $^{76}$Ge+$^{150}$Nd and $^{28}$Si+$^{198}$Pt where the same compound nucleus $^{226}$U was formed.

It was finally found that the fusion probability in the low energy region, where only collision at the tip of the deformed targets is possible, was significantly hindered, while the fusion hindrance was negligible in the high energy region where side collisions become possible. This supports the original idea of the hugging fusion that the compact touching configuration in the side collision is more favorable for complete fusion than the elongated configuration in the tip collision. In order to convince the present conclusion, further experimental studies in heavier systems are in progress and more realistic calculations of the fusion dynamics between deformed nuclei should be carried out. Together with our recent experimental data, we will discuss the effect of nuclear deformation on heavy-ion fusion reaction.

References

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