Exotic nuclear shape due to cluster formation at high angular momentum†

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It is now well established that clustering plays a very important role in self-conjugate light nuclei and is also associated with strongly deformed shapes of nuclei.[1,2] One of the probes to study this deformation experimentally at high temperature (T) and angular momentum (J) is the γ-decay from the giant dipole resonance (GDR) built on excited states.[1,2] The GDR lineshape gets fragmented in deformed nucleus providing crucial information about the nuclear deformation. As a matter of fact, it has been successfully employed experimentally to study the Jacobi shape transition, an abrupt change of shape from non-collective oblate to collective triaxial or prolate shape above a critical spin, in several light nuclei such as ^{31}P, ^{45}Sc, ^{46}Ti and ^{47}V.[1,2] However, when this shape transition is examined in self-conjugate nuclei ^{32}S[1] and ^{28}Si[2] through the reactions ^{20}Ne + ^{12}C and ^{16}O + ^{12}C, respectively, the GDR lineshape fragments into two prominent peaks at high $J(\sim 20\hbar)$ providing a direct evidence of the large deformation but, intriguingly, the shapes found are completely different from those seen from Jacobi shape transition (signature of which is a sharp peak at 10 MeV arises due to the Coriolis splitting of the GDR frequencies). Therefore, these observations clearly highlight that the clustering is not only important in mass $A < 20$ region but could also play major role in $A \sim 30$, which has not been studied enough.

Microscopic effects such as shell structure, pairing and isospin effects play important role in deciding the nuclear structures at low excitation energy. However, even after incorporating these effects, the experimental GDR lineshapes ($T \sim 2.0$ MeV and $J \sim 20\hbar$) could not be explained for ^{28}Si and ^{32}S nuclei.[3] In the present work, an extended quantum molecular dynamics (EQMD) model[4] has been carried out to understand the GDR lineshapes of ^{28}Si and ^{32}S nuclei, and to investigate how the exotic shapes due to cluster formation at high T and J are manifested through GDR strength function.

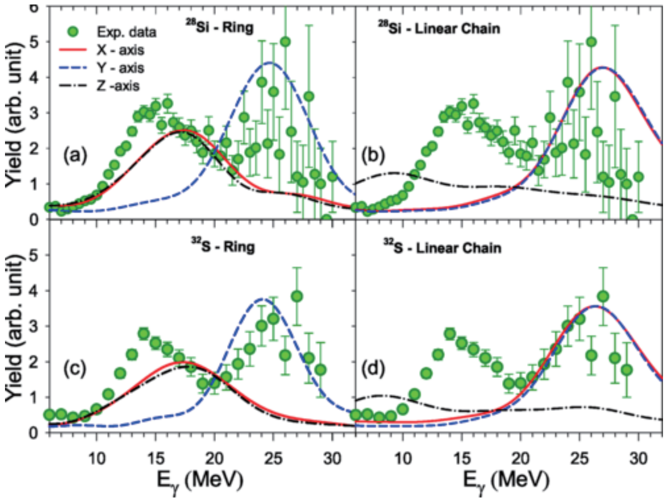

Fig. 1. EQMD calculations for both ^{32}S and ^{28}Si nuclei.

The results of EQMD calculation have been compared with the existing experimental data of ^{32}S and ^{28}Si as shown in Fig. 1. It should be mentioned that the alpha correlation is included in the EQMD model based on the fact that the many body nucleon-nucleon correlation is intrinsically embedded in all microscpic QMD type model and the details of EQMD results are discussed in Refs. 3, 4). It is found that the EQMD predicts the general trend of the experimental GDR strength functions for ^{32}S and ^{28}Si by considering the ring or toroidal configuration. Nevertheless, the peak around 25 MeV can only arrive due to cluster formation highlighting the existence of the α-clustering structure at such high T and J since this peak could not be predicted within the mean-field calculations. Interestingly, the rotation of these exotic shapes will not lead to the Coriolis splitting of the GDR strength function (due to larger moment of inertia leading to smaller angular frequency), which could be the reason for the absence of the Jacobi shape transition in ^{32}S and ^{28}Si. The present result highlights the role of α cluster states above the decay threshold, which is still an open field of investigation.

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