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Structural evolution of the intruder band in ^{118}Sn*

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Abstract Excited states of the positive-parity intruder band in ^{118}Sn have been studied via the ^{116}Cd(^{7}Li, 1p4n) reaction at ^{7}Li energy of 48 MeV using techniques of in-beam γ-ray spectroscopy. This intruder band has been observed up to 7187 keV with spin (16^{+}). The structural evolution of this intruder band with increasing angular momentum has been discussed in terms of the aligned angular momentum and the ratio of the E-Gamma Over Spin (E-GOS) curve.

Key words intruder band, quasiparticle alignment, structural evolution

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1 Introduction

Sn isotopes, with the magic proton number $Z = 50$, have recently been shown to possess a wealth of interesting nuclear structure phenomena, and have been of enduring experimental and theoretical interest[1—4]. The coexistence of both spherical and deformed structures has been systematically observed in the even-A Sn isotopes. Spherical states are to be expected considering the influence of the shell gap. Despite the strong influence of the shell gap, low-lying deformed states are known to exist in Z=50 Sn nuclei. Proton particle-hole excitations across the Z=50 gap are responsible for these deformed states, which result in collective rotational bands[5, 6]. In even-Sn nuclei, rotational bands based on a two-particle two-hole configuration $(\pi g_{7/2})^2 \otimes (\pi g_{9/2})^{-2}$, called the "intruder band", have been observed from ^{110}Sn to ^{118}Sn[5—10].

^{118}Sn is a semi-magic nucleus with $Z = 50$ and $N = 68$. Excited states have already been studied using radioactive decay[11] and the α-induced reaction[5, 6]. Although some experimental studies have been done on ^{118}Sn, data on high spin states in ^{118}Sn are still scarce. This is mainly due to the lack of heavy-ion reactions in the previous measurements. In the present work, we report our investigation of the higher spin states in ^{118}Sn using the ^{116}Cd(^{7}Li, 4n1p) reaction.

2 Experiment

The high-spin states of ^{118}Sn were populated through the ^{116}Cd(^{7}Li, 4n1p)^{118}Sn fusion-evaporation reaction at a bombarding energy of 48 MeV. The ^{7}Li beam was provided by the HI-13 tandem accelerator at the China Institute of Atomic Energy (CIAE) in Beijing. The ^{116}Cd target was a self-supporting foil of 2.5 mg/cm^2 in thickness. Two-fold γ-γ coincident events were collected using an array of twelve Compton-suppressed HPGe detectors and two LEPS (low-energy photon spectrometer) detectors. All detectors were calibrated using the standard ^{152}Eu and

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^{133}Ba γ-ray sources. A total of 2×10^8 γ-γ coincidence events were accumulated in event-by-event mode. In the off-line analysis, the coincidence data were recalibrated to 0.5 keV/channel and sorted into a 4096 by 4096 channel symmetrized E_γ-E_γ matrix. Multipolarity information of the γ-ray was extracted from the data using the method of directional correlation of the oriented state (DCO ratios).

3 Results and discussions

The partial level scheme of ^{118}Sn established from the present work is displayed in Fig. 1. The present work confirms the placement of γ-rays in the level scheme previously reported by Bron et al[5]. In addition, three new transitions have been placed. Band 1, previously reported up to the 12^+ state at 5378 keV[5], has been extended with the addition of the new 897.1 and 912.3 keV transitions, leading to the 6275 keV and the 7187 keV levels, respectively. Another new transition added in the level scheme is the 812.5 keV γ-ray, which is proposed to connect the 8^+ and 6^+ states. A sample γ-ray spectrum is shown in Fig. 2.

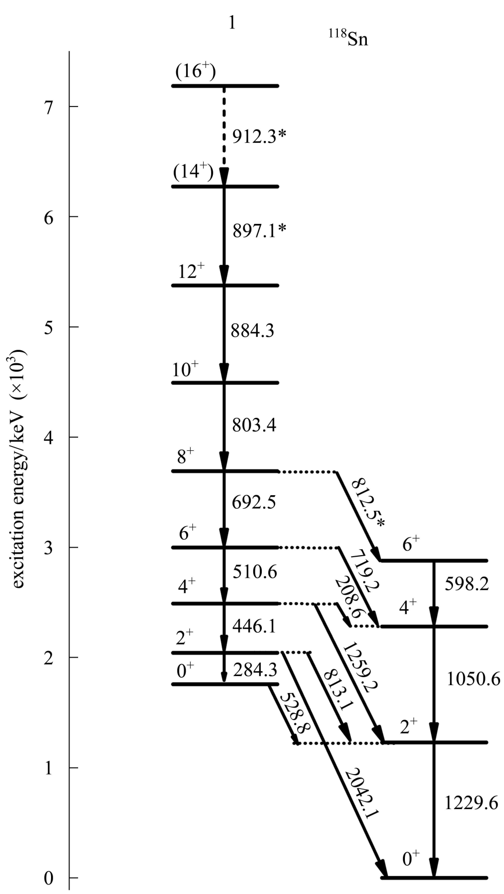

Fig. 1. Partial level scheme of ^{118}Sn. New transitions observed in the present work are indicated with a star.

The relatively poor statistics of the 897.1 and 912.3 keV transitions prevent us from obtaining reliable DCO ratios. These assignments for two transitions shown in Fig. 1 are proposed tentatively based on systematic comparisons with neighboring nuclei, as indicated by parentheses.

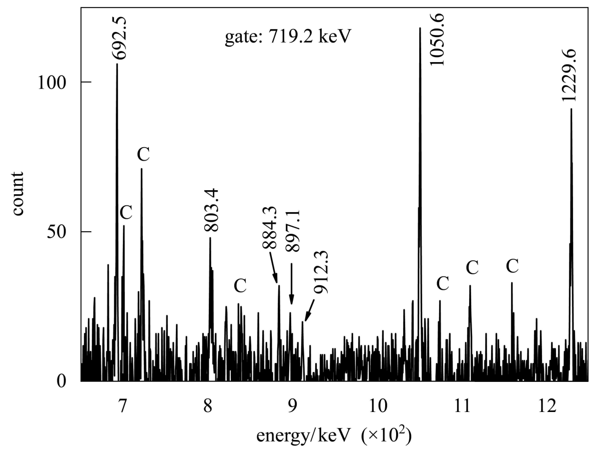

Fig. 2. The γ-ray spectrum gated on the 719.2 keV transition. The peaks labelled C indicate contaminations.

As shown in Fig. 1, two 0^+ states were known in ^{118}Sn. The ground state was characterised by a spherical shape, and the 2_1^+ and 4_1^+ states arose from the vibrational pattern. The excited 0_2^+ state was interpreted as proton-pair excitations across the Z=55 shell gap leading to a deformed state, coexisting with the spherical ground state[5]. To examine this pattern, the configuration-fixed constrained triaxial RMF approach[12] is applied to determine the quadrupole deformations β_2 and γ for the ground state and the excited 0_2^+ state in ^{118}Sn. Self-consistent deformation parameters $\beta_2=0$ and $\beta_2=0.31$, $\gamma=0°$ are obtained from the present RMF approach corresponding to the ground state and the second 0^+ state. The RMF calculations indicate the coexistence of for spherical and prolate shapes in ^{118}Sn, the latter corresponding to the $(\pi g_{7/2})^2\otimes(\pi g_{9/2})^{-2}$ configuration.

Like in several neighbouring tin isotopes, a ΔI=2 rotational band built on this excited 0^+ state was also observed in ^{118}Sn. In Ref. [5], this ΔI=2 rotational band was observed up to spin $I=12^+$, and assigned to be built on the configuration $(\pi g_{7/2})^2\otimes(\pi g_{9/2})^{-2}$. In the present work, this intruder band labelled 1 has been extended up to spins where the rotational alignment of a pair of quasiparticles occurs. In Fig. 3, the experimental alignment for the positive-parity intruder band in ^{118}Sn is plotted as a function of rotational frequency. Obviously, the intruder band shows a sharp upbending at $\hbar\omega=0.45$ MeV, dividing the band into the intruder-g band and the intruder-aligned band for the parts below and above the back-bending, respectively. The first alignment in this mass region is expected to be due to the alignment of two quasineutrons $(\nu h_{11/2})^2$[13]. In ^{116}Sn, ^{114}Sn, and ^{112}Sn the corresponding alignment is observed at the frequency of 0.46 MeV[10], 0.41 MeV[9] and 0.37 MeV[14], respectively. The largest alignment frequency was observed in ^{116}Sn with N=66. It formed a parabola-shaped pattern centered at N=66 (neutron midshell). This parabola-shaped pattern centered at N=66 can be associated with the shell effects and increased collectivity at the neutron midshell.

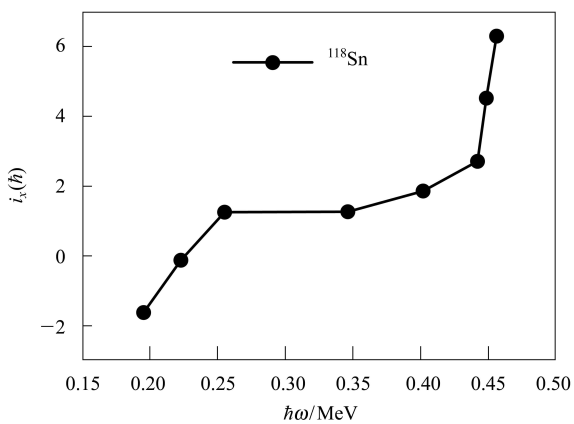

Fig. 3. Experimental alignment plot for the intruder band in ^{118}Sn. A reference configuration with Harris parameters of $J_0 = 15\ \hbar^2\text{MeV}^{-1}$ and $J_1 = 25\ \hbar^4\text{MeV}^{-3}$ has been subtracted.

It is worth noticing that an irregularity alignment plot at low rotational frequencies is displayed in Fig. 3. This has been interpreted as due to mixing the intruder structures at low spin region with spherical vibrational structures[10]. Thus, a spherical vibration-like mode may be expected to take place at low spins in Band 1. To clarify this hypothesis, the ratio of the E-Gamma Over Spin (E-GOS) curve[15] is applied to the analysis of the intruder band in ^{118}Sn. This ratio may provide an effective way to distinguish axially symmetric rotational and harmonic vibrational modes, and can often be used to analyze the ground band in even-even nuclei[15, 16]. In the present work, this method is first applied to analyze the intruder band. Fig. 4(a) shows the theoretical limits plotted for two schematic nuclei. For a vibrator, the value of this ratio gradually diminishes to zero as the spin increases, while for an axially symmetric rotor it approaches a constant, $4(\hbar^2/2J)$. The yrast band in ^{102}Ru is usually considered as a good example of the evolution from vibrational to rotational structure, as shown in Fig. 4(b). The E-GOS value for the intruder band in ^{118}Sn is plotted in Fig. 4(c). The E-GOS curves indicate that in the low spin region (0—6 $\hbar$), the intruder band of ^{118}Sn indeed shows an approximate hyperbolic locus expected for vibrational mode. After these spin intervals, the E-GOS curves are similar to the rotational mode. This means that the intruder band in ^{118}Sn undergoes an evolution from quasivibrational to quasirotational structure with increasing angular momentum. We note, however, that the E-GOS curves of the intruder band in ^{118}Sn are

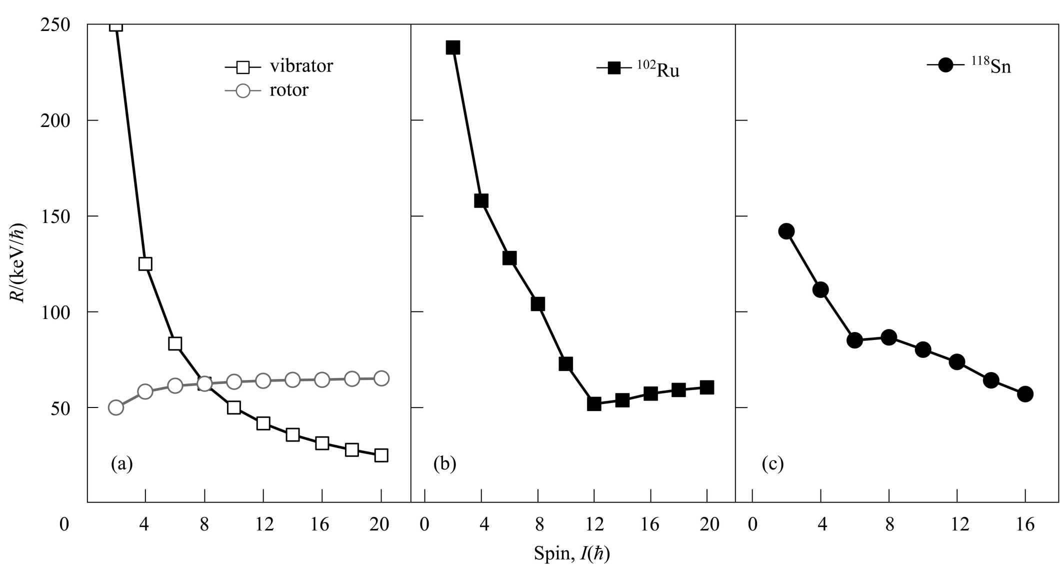

Fig. 4. (a) E-GOS curves for a perfect harmonic vibrator and axially symmetric rotor with the first 2^+ excitations of 500 and 100 keV, respectively. (b) E-GOS plot for the yrast band in ^{102}Ru. (c) E-GOS plot for the intruder band in ^{118}Sn.

different from the yrast band in ^{102}Ru at high spins. As shown in Fig. 4, ^{118}Sn decreases gradually, whereas ^{102}Ru slightly increases as a function of spin at high spins. This gradually decreasing curve may account for a gamma-soft mode corresponding to the $O(6)$ limit[15]. As introduced in Ref. [15], for a gamma-soft nucleus (the $O(6)$ limit), $E_\gamma/I=[E(2^+)/4](1+2/I)$, which decreases with spin, but at a slower rate than for a vibrator. Taking the above information into account, we propose that the intruder band in ^{118}Sn undergoes an evolution from quasivibrational to quasirotational structure with increasing angular momentum and possibly involves a gamma-soft $O(6)$ mode at high spins. Another possible explanation is that vibration-like excitations for the level above $I\approx 14$ in the intruder band are caused by band crossing, which strongly disturbs the regularity of the rotational band at these spin intervals.

4 Conclusions

In summary, excited states of the positive-parity intruder band in ^{118}Sn, populated in the ^{116}Cd(^{7}Li, 1p4n)^{118}Sn reaction at a beam energy of 48 MeV, have been studied. The band has been observed up to 7187 keV with spin (16^+). The characteristics of alignment plot and E-GOS curve for the intruder band in ^{118}Sn suggest that the intruder band undergoes an evolution from quasivibrational to quasirotational structure with increasing angular momentum and possibly involves a gamma-soft $O(6)$ mode at high spins. There is, however, a need to extend the experimental study to higher spins in order to make a more conclusive inference.

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