Symmetry energy at subnuclear densities and macroscopic properties of neutron-rich nuclei

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We systematically examine how macroscopic properties of neutron-rich nuclei in laboratories and neutron-star crusts are sensitive to symmetry energy at subnuclear densities. The key parameters describing the energy are the symmetry energy S_0 and its derivative coefficient L at nuclear density.

For this purpose, we systematically generate about 200 macroscopic nuclear models which fit both masses and radii of stable nuclei almost equally. The rms deviations of the calculated masses from the measured values [1] are about 3 MeV, which is roughly as large as the deviations obtained from Weizsäcker-Bethe type mass formula. From these fittings, we find that the symmetry energy S_0 and its derivative coefficient L are strongly correlated ($S_0 = 28 + 0.075L$ MeV), and that values of only L and the incompressibility K_0 are significantly uncertain [2].

We calculate the macroscopic properties of neutron-rich unstable nuclei and find that their masses and radii have appreciable L dependence almost independently of K_0. Furthermore, we also find by comparison with empirical two-proton separation energies that a smaller symmetry energy at subnuclear densities, corresponding to a larger density symmetry coefficient L, is favored. This tendency, which is clearly seen for nuclei that are neutron-rich, nondeformed, and light, can be understood from the property of the surface symmetry energy in a compressible liquid-drop picture [3].

We also perform calculations of the equilibrium properties of nuclei in neutron-star crusts and find that the proton number of the nuclei and the core-crust boundary density are decreasing functions of L almost independently of K_0. It is also found that pasta nuclei in neutron-star crusts can not exists for large L values ($L > 100$ MeV) [4].

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