Gallium crystallization: implication for the inner core elastic anisotropy.

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Seismic studies have demonstrated that the inner core is generally anisotropic, and that the amount of anisotropy varies from one hemisphere to the other. Compressional wave speeds are about 3% faster along polar paths compared to equatorial paths, and the symmetry axis of the fast direction is tilted with respect to the mantle spin axis by about 10^o. A variety of different mechanisms have been proposed to explain the elastic anisotropy of the inner core, including (1) the inner core may consist of a few large crystals; (2) lattice preferred orientation resulting from solid state convection; (3) lattice preferred orientation by the geomagnetic field during or after solidification; and (4) lattice preferred orientation due to inhomogeneous growth along the inner core boundary. All these models rely on special assumptions and none provide a simple explanation for the 10^o tilt of the axis of anisotropy. We have made a series of experiments to identify physical factors that influence the elastic anisotropy of a crystallizing liquid metal. Our experiments are made with nearly pure gallium. Gallium crystallizes at 29.8^oC and is highly anisotropic in the solid state, both in elasticity and in transport properties such as thermal conductivity, electrical conductivity. Different conditions of solidification were investigated, including directional crystallization with only thermal conduction, directional crystallization with thermal convection, crystallization in the presence of a uniform magnetic field, and in the presence of turbulence in the liquid. Ultrasonic and temperature measurements enable us to follow the solidification front during the experiments. We measured the anisotropy and the heterogeneity in anisotropy using the ultrasonic *pulse-echo* technique. The experiments always resulted in polycrystalline solids with grains elongated in the growth direction. Spatially coherent anisotropy ranging from 20% to 80% of single crystal-anisotropy were measured. We find that the anisotropy is not sensitive to the external controls listed above. On the contrary, our results indicate that the initial nucleation is the critical ingredient controlling the preferred lattice orientation in the polycrystal. Application to the inner core suggests that the pattern of anisotropy may not reflect the present conditions but instead may be a relic of conditions early in the process of inner core formation.