Phase transition mechanism of the pressure-induced $\beta \leftrightarrow \gamma$ transformations in tin

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Abstract

Solid-solid phase transformation mechanisms need to be understood to establish suitable kinetic laws. Two classes of solid-solid phase transformations are described in the literature. Martensitic transformations have a 'military' displacive atomic mechanism that produces a new phase seed with a time scale that can be as low as sub-ns; however, they induce elastic stresses that need to be relaxed, which is a phenomenon at the microstructure scale. Reconstructive transformations, with nucleation and diffusional growth steps, sometimes massive, are thermally activated and slower but produce a microstructure at mechanical equilibrium. The understanding of the transformation mechanism is necessary to establish suitable kinetic laws for each transformation.

Sn (tin) exhibits a rich polymorphism under high pressure and varying temperatures that has been studied with different techniques and platforms. This makes it an archetypal system to study phase transformations in metals and their mechanisms. Here, we investigate the β-Sn $\leftrightarrow$ γ-Sn phase transformations occurring at ~10 GPa at room temperature.

Single crystals have been statically compressed and characterized using in situ x-ray diffraction. Multiple transformation cycles were performed in diamond anvil cells to measure their conditions and the associated microstructures. The crystal orientation of the child phase can be deduced from the orientation of its parent, which characterizes a martensitic mechanism: $(101)_\beta$ || $(110)_\gamma$ and $[10\bar{1}]_\beta$ || $[1\bar{1}1]_\gamma$ orientation relationships (OR) between β-Sn and γ-Sn, never reported before, are repeatedly observed. An atomic pathway to account for these observations will be discussed.

New insight into the transformation mechanism can now be obtained with a micrometer resolution 2D XRD method, which reveals the full microstructure of the compressed sample.