Conventional crystal plasticity models cannot predict the deformation of BCC polycrystals or single crystals. These models often use a hardening rule that was originally developed for FCC materials. Thus, this hardening rule cannot accurately predict the deformation of a single crystal BCC. Moreover, the yield criterion of conventional crystal plasticity models assumes dislocation slip initiates when the resolved shear stresses on the slip plane and parallel to slip direction reaches a threshold. BCC materials have a non-planar screw dislocation core that spreads on three planes. Therefore, stresses on planes other than the slip plane can affect the initiation of dislocation slip.

In this study, a non-Schmid crystal plasticity model was developed and verified for single crystal ferrite. The conventional crystal plasticity could not predict the deformation behavior of this material.

To address the shortcomings of the conventional Hill type hardening rule, two novel hardening models were derived and developed. These models are named, the Differential-Exponential and the Dynamic hardening rules.

The Differential-Exponential hardening model was implemented in the non-Schmid crystal plasticity model. This model was then verified for the single crystal ferrite micropillars that show stage I and stage II hardening.

The Dynamic hardening rule was implemented in the Schmid type crystal plasticity model. With this hardening rule, the crystal plasticity model can adequately predict the deformation behavior of Nb single crystals.

Next, hydroforming of a large grain Nb tube was modeled with the above model. The predictions of this model match with the experiment semi-quantitatively.