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The role of GNDs in Bauschinger effect of thin films

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It is familiar that geometrically necessary dislocations (GNDs) play an important role in microscale plasticity, such as size effect and Bauschinger effect. There are several ways to take GNDs into account. Starting with the seminal paper by Ashby (1970), which established the connection between strain gradients and GNDs, it has been widely assumed that the GND density gives rise to the slip resistance via a generalized Taylor equation. In more recently proposed models, on the other hand, GNDs are assumed to contribute to a back stress proportional to gradients of the GND density fields, or to contribute to both the slip resistance and the back stress. It remains unclear whether GNDs influence both the slip resistance and the back stress or only one of them. In our work, we compared different dislocation-based strength model in a loading-unloading process of thin films, where the back stress will cause Bauschinger effect. A higher-order crystal plasticity model based on the continuum description of dislocation dynamics is developed to investigate the role of GNDs. In this model the back stress and the slip resistance for each slip system are incorporated into a standard diffusion for crystal slip. Based on the second law of thermaldynamics, we establish a formula for the unloading process. We compared the results with experiments and find that if both the slip resistance and the back stress include the effect of GNDs , the strength will be overestimated and the Bauschinger effect is not as obvious as in experiments. It is more reasonable to think that GNDs influence the plasticity via the back stress than via a generalized Taylor equation.

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