

Supplementary Materials

S1. Verification of the scaling parameter *via* stacking fault energy

The plausibility of the scaling stress, S , determined by the approach in Fig. 3 can be checked by comparing to other FCC metals with different stacking fault energy (SFE), γ_{SF} [23]. According to Kocks and Mecking, saturation stress, σ_v , under given temperature, T , and strain rate, $\dot{\epsilon}$, is described as follows based on the thermal activation theory of mobility and annihilation probability (*i.e.*, dynamic recovery) of dislocations [23].

$$\frac{\sigma_v}{G} = \frac{\sigma_{v0}}{G_0} \left\{ 1 - \left(\frac{1}{g_0} \frac{kT}{Gb^3} \ln \frac{\dot{\epsilon}_0}{\dot{\epsilon}} \right)^{1/2} \right\}^2 \quad (\text{S1})$$

Here, g_0 is material constant, b is the magnitude of Burgers vector, k is Boltzmann's constant, $\dot{\epsilon}_0$ is $10^7/\text{s}$, and σ_{v0} and G_0 are saturation stress and shear modulus at zero temperature. Plotting $(\sigma_v/G)^{1/2}$, *i.e.*, $S^{1/2}$, versus the second term in the bracket of the right-hand side yields a straight line, the slope and intercept of which depend on σ_{v0} , a parameter specific to materials through their SFE. Fig. S1 showcases such a plot constructed from the saturation stress in Fig. 3 (a). Other data included together are the properties of pure metals, wherein straight lines are arranged in the order corresponding to their normalized SFE, γ_{SF}/Gb [23]. The γ_{SF}/Gb in Ag and Cu were measured to be 0.0018 and 0.0047, respectively [23]. Meanwhile, the γ_{SF} in Type310S steel is around 40 mJ/m^2 [13], giving rise to the value of γ_{SF}/Gb as ≈ 0.0022 . Indeed, the plot of Type310S steel in Fig. S1 lies in between those of Ag and Cu. This consistency with other materials in terms of SFE justifies the development of the master curve in Fig. 3 (c) and (d).

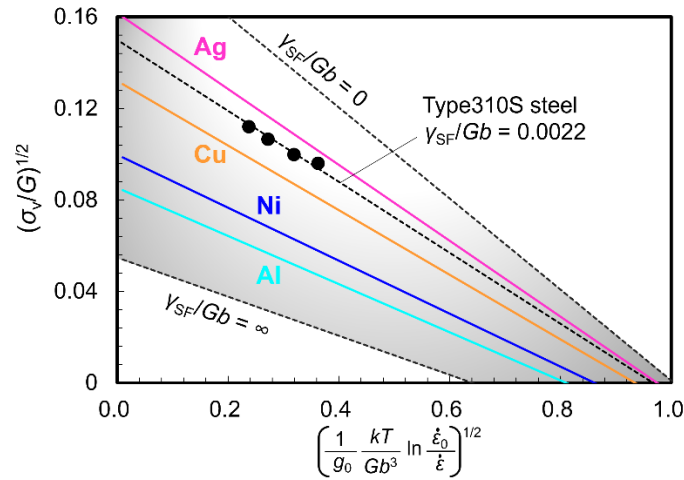


Fig. S1 Plot of scaling stress determined in Fig. 3 (a) with data of pure FCC metals [23].

S2. Possibility for dynamic H-dislocation interaction at low temperatures

The previous studies on H-assisted deformation twinning in austenite pointed out the importance of dynamic interactions between diffusible H and mobile dislocations for its manifestation [1,5,15,17]. More specifically, the atmosphere of H atoms migrating with dislocations changes the dislocation mobility and its interaction strength with other dislocations, impacting the nucleation process [26-28] of deformation twins. Nevertheless, such a complete equilibration of the H atmosphere around moving dislocations is definitely infeasible during the deformation at low temperatures such as 173 K, as demonstrated in our simple calculation [19]. In order to get to the bottom of H-TWIP at low temperatures, it is mandatory to quantify whether the segregation of H into dislocations occurs even partially or not.

The kinetics of solute atmosphere formation around dislocations has been mathematized in an old treatment by Harper [29].

$$q = 1 - \exp\left\{-2\rho\left(\frac{\pi}{2}\right)^{1/3}(E_B Dt/RT)^{2/3}\right\} \quad (\text{S2})$$

where q is the fraction of atmosphere condensation with respect to the equilibrium state, ρ is dislocation density, E_B is the binding energy between dislocation and solute atom (≈ 10 kJ/mol for H in austenite [31]), D is solute diffusivity, t is the time duration, and R is the universal gas constant. Adopting an estimated H diffusivity at 173 K ($\approx 7 \times 10^{-23}$ m²/s [30]) and approximating $\rho = 10^{14}$ m/m², only a few seconds is required for the atmosphere to reach its equilibrium. Thus, even if the interaction of H with continuously moving dislocations is implausible, it is likely that the segregation of H still occurs when dislocations temporarily slow down or rest at obstacles. A diminishment of the H-effect on WHR at a strain rate of 5×10^{-5} /s (Fig. 1 (d)) implies that such quasi-dynamic interaction is a sufficient but necessary condition for the appearance of H-TWIP since the interaction frequency should be lowered at a faster deformation. The postulated mechanisms [1,5,15,17] might be revisited by taking this new insight into account, which is a critical task in our ongoing studies.