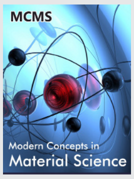

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Mini Review

Interaction of Mobile Dislocation with Additives in Ionic Crystals

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Abstract

The mechanical properties of materials are affected by the interaction of mobile dislocation with additive ions. Although this has been widely investigated by various methods (yield and proof stress measurements, microscopy observations of dislocation, internal friction measurements, stress relaxation tests and so on), it is difficult to obtain the information on mobile dislocation-additives interaction during plastic deformation of bulk. While, the strain-rate cycling tests between two strain-rates of 1.1×10^{-5} s^{-1} and 5.5×10^{-5} s^{-1} with ultrasonic oscillations (original method) would overcome the weak points of them. The original method is considered to give the information of dislocation mobility on the slip plane contained mainly with two kinds of obstacles: forest dislocations and additive ions. Some results will be presented here.

Keywords: Dislocation; Point defects; Plastic deformation; Ultrasonic oscillation; Strain rates

Strain-Rate Cycling Tests Combined with Ultrasonic Oscillations

Study on the strength of materials has been often conducted with simple ionic crystals so far [1-3]. The reason is that the crystals are readily available and have a slight number of glide systems, comparing with metals. On account of it, the crystals contained additives are excellent, when the mechanical properties of materials are investigated. It is well known that the solution hardening due to the additives are caused by the result that mobile dislocations are obstructed by the point defects around them in the crystal at low temperature. The plasticity of crystal varies with dislocation motions in a microscopic observation and the dislocation-additive ions interaction affects the hardening. Dislocation motion on a slip plane has been extensively studied by many different methods: measurements of yield and proof stress (e.g., [4-8]), micro-hardness tests (e.g., [9,10]), microscopy observations (e.g., [11,12]), measurements of internal friction (e.g., [13,14]), or stress relaxation (e.g., [15,16]), but it is difficult to obtain the results on the movement of the dislocation which glides forward breaking-away from the forest dislocations and the point defects such as additives on the slip plane in bulk. On the other hand, the original strain-rate cycling test combined with ultrasonic oscillations is different from the well-known methods. The original tests would be possible to clear up it. Figure 1 shows the illustration of the original tests. The results on the movement of dislocation breaking-away from impediments such as the additives [17,18] and also the defects due to X-ray irradiation [19,20] with the oscillatory stress has been reported by the strain-rate cycling tests combined with ultrasonic oscillations. Applying ultrasonic oscillatory stress to a plastic deforming crystal, a stress decreases and $\Delta\tau$ appears as illustrated in Figure 1. When the strain-rate cycling between the strain rates was conducted keeping the stress amplitude constant, τ_v, the stress change due to the strain-rate cycling is $\Delta\tau'$. The $\Delta\tau'/\Delta\ln\dot{\varepsilon}$ has been made an estimate as the strain-rate sensitivity of flow stress, which is termed λ here.

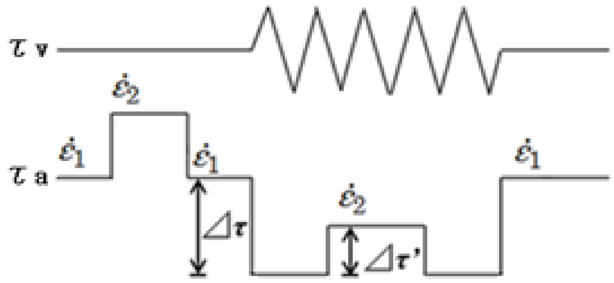

Figure 1: Change of applied stress, τ_a , by the strain-rate cycling between two strain rates, 1.1×10^{-5} s^{-1} and $5.5\times10^{-5}s^{-1}$($\dot{\varepsilon}_1 < \dot{\varepsilon}_2$) , in the middle of superposition of ultrasonic oscillatory shear stress, τ_v.

Relation of Strain-Rate Sensitivity to Stress Decrement

Δτ vs. λ curve looks like a flight of stairs, which has two bending points and two plateau places. Figure 2 shows the Δτ vs. λ curve at 77 to 263 K for NaBr:Li⁺ (0.5 mol%) [21]. The value of Δτ at first bending point (τ_p denoted in Figure 2) refers to the additive ions in the crystals, since first bending point does not exist on the Δτ vs. λ curves for nominally pure NaBr crystal within the same low temperatures and strains [21]. The value of τ_p tends to be lower at the higher temperature and disappears near atmospheric temperature such as 263 K, as shown in Figure 2. τ_p depends on temperature, also the density and the type of impediments such as point defects [22,23].

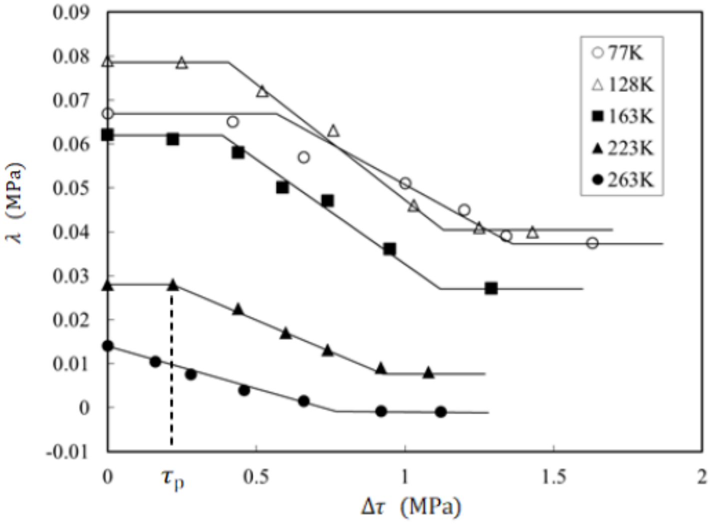

Figure 2: Stress decrement (Δτ) vs. λ for NaBr:Li⁺ (0.5 mol%) at 77 to 263 K [21].

The Δτ vs. λ aspect is considered to represent the oscillation effect on the free flight motion of the dislocation on a slip plane during plastic deformation [18]. Additive ions and a few forest dislocations are regarded as main impedimenta to the slip motion of dislocation here. Applying oscillation with high stress amplitude to the crystal, the λ value begins to decrease with increasing Δτ. Some point defects stop acting as obstacles in the region at Δτ beyond τ_p. Second plateau place appears on Δτ vs. λ curve by the oscillation with still higher stress amplitude. At this place, only forest dislocations are expected to act as obstacles to the dislocation slip. Furthermore, the activation energy for the break-away of a dislocation from additive ion has been obtained by analyzing the data on the basis of Δτ vs. λ curve [21].

Conclusion

The original strain-rate cycling tests combined with ultrasonic oscillations clear up the weak point of many different methods. The aspect of the Δτ vs. λ curve obtained from the original method is considered to represent the movement of the dislocation which glides forward breaking-away from the forest dislocations and additive ions on the slip plane in ionic crystal.

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Conflict of Interest

No conflict of interest.

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