Change in the Burgers Vector of Perfect Dislocation Loops without Contact with External Dislocations

ARAKAWA Kazuto and MORI Hirotaro
(Research Center for Ultra-High Voltage Electron Microscopy)

Physical Review Letters, **96**, 125506 (2006)
▶ No. 20 in “100 Papers Selection” (p. 60)

The irreversible plastic deformation of crystalline materials is often governed by the generation and motion of linear defects, termed dislocations. Knowledge of the structure and dynamic processes of dislocations in a crystal is important for understanding the origin of the hardness and toughness of a crystal. These defects connect two parts of a crystal that are sheared on a plane with respect to each other by an atomic translation called the Burgers vector.

The Burgers vector of a dislocation is a major factor controlling the displacement field and the strain energy associated with the dislocation, moving direction, mobility of the dislocation, and so on. Dislocations always obey Kirchhoff’s law for the Burgers vector, according to which the total Burgers vector measured in a closed circuit enclosing single or multiple dislocation lines is always conserved even at their nodes. Furthermore, according to this law, the Burgers vector of a dislocation can change if it joins another dislocation or branches out.

In this paper, we presented a new process for inducing a change in the Burgers vector of nanometer-sized interstitial-type perfect dislocation loops—agglomerations of self-interstitial atoms on a habit plane—without contact with external dislocations in bcc Fe, upon high-energy electron irradiation or simple heating, by using in situ transmission electron microscopy (TEM). Two types of loops were formed upon high-energy electron irradiation—those with the Burgers vectors of 1/2<111> and <100>.

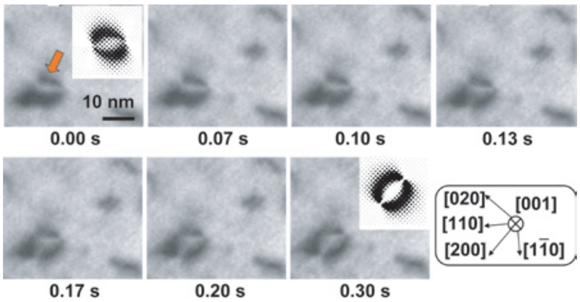

Fig. 1 Spontaneous change in the Burgers vector of a dislocation loop. The insets are images generated by TEM-image simulations for a loop (1/2[$\bar{1}$11](3$\bar{3}\bar{1}$)) with a diameter of 11 nm and that ([010](0$\bar{1}$0)) with a diameter of 10 nm.

The Burgers vector of the mobile 1/2<111> loops occasionally changed to that of another 1/2<111> loop without the coalescence of the loop with an external loop. Other types of the changes in the Burgers vector of loops, such as that from 1/2<111> to <100> and its reverse, occasionally occurred. Figure 1 shows an example of the transformation of a 1/2<111> loop to a <100> loop.

It should be noted that the 1/2<111> loops without stacking faults transformed although the energy of the system appeared to remain constant or to increase due to this change. The change in the Burgers vector of a prismatic loop without coalescing with external dislocations can be expressed as the nucleation and propagation of a proper shear loop, in which the habit plane is identical to that of the original prismatic loop and only the shear component exists in the Burgers vector inside the prismatic loop. Nucleation and propagation of a shear loop will also occur when external loops in the vicinity of a loop act as a source of considerable shear stress. On high-energy electron irradiation or simple heating, loops can appear or disappear near a marked loop due to the agglomeration of self-interstitial atoms and their glide motion; further, loops near a marked loop can extend or shrink by the absorption of self-interstitial atoms, small loops, or vacancies. In such a case, the shear stress at the position of the marked loop varies. If the stress accidentally reaches a critical value, nucleation and propagation of a proper shear loop will occur, resulting in a change in the Burgers vector.

Manmade Diamond Structure Opens Photonic Band Gap for Terahertz Waves

MIYAMOTO Yoshinari and CHEN Weibu
(Smart Processing Research Center, Joining and Welding Research Institute)

Journal of American Ceramic Society, **90**, 92-96 (2007)
▶ No. 22 in “100 Papers Selection” (p. 60)

Artificial crystals made of dielectric medium called photonic crystals can inhibit the propagation of electromagnetic waves or light with wavelengths corresponding to the periodic variation of dielectric constant by Bragg scattering and open photonic band gap. Many photonic crystals were made for infrared and visible optical range, however, there has been a little work on 3D photonic crystals with the feature of micron scale for terahertz frequencies (100GHz~10 THz). Development of terahertz wave applications is an emergent issue for bio imaging and risk management like remote detection of gunpowder, drugs, counterfeit IC cards besides advanced communication, physical and chemical characterizations.

Recently we have developed micro-stereolithography with companies to enable free-forming 3D micro or meso scale structures and its system is sold as the first commercial machine in the world since 2005. It can build complex micro objects layer by layer polymerization of liquid photo-curable resin with precise laser projection of two dimensional figures using DMD (Digital Micro-mirror Device) under CAD/CAM (Computer Aided Design and Computer Aided Manufacturing) system. Micro ceramic green parts are formed by using resins filled with nanometer sized ceramic particles. Dense micro ceramic components can be obtained by sintering these green parts.

Figure 1(a) is a micro diamond structure made of TiO_2 (~170 nm size, 40vol%) dispersed in resin. The lattice constant is 500μm. The structure is built layer by layer with 5μm in thickness like a natural crystal growth as seen in Fig.1(c) and (d).

The transmission spectrum along <100> direction shows a sharp band gap between 280GHz and 360GHz in a THz range as shown in Fig.2, where the transmission of incident waves goes down below 1%. Such diamond structure has a common band gap opened for all directions. Various micro ceramic devices like photonic crystals having cavities, channels, connectors, and other parts can be freely designed and produced by micro-stereolithography and successive sintering. The digital process which we named “Smart processing” can be linked to internet and applied to future remote and just-in-time manufacturing with saving energy and low environmental impact.

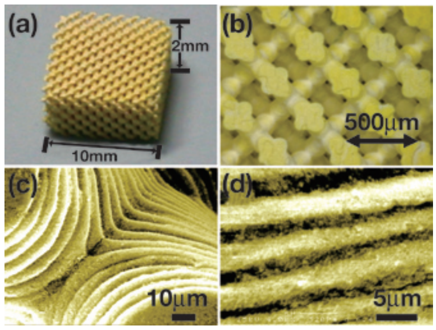

Fig. 1 (a) A micro diamond structure made of 40vol% TiO_2-resin with 8x8x4 unit cells. (b) Top view at (100) plane, (c) Cross linked part of lattice rods, (d) Side view of stacking layers.

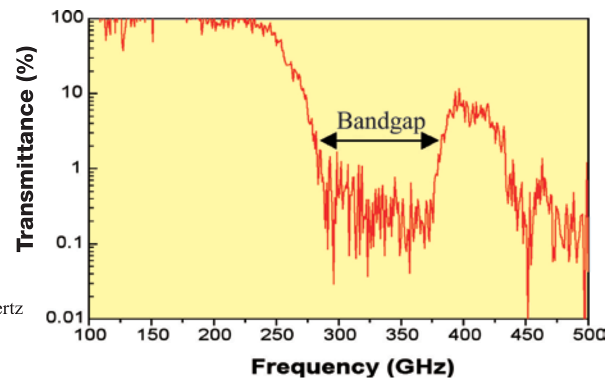

Fig. 2 Transmission spectrum of terahertz waves as a function of frequency.