Mechanical behavior of materials

Dr. Niraj Mohan Chawake

Department of Materials Science and Engineering

Indian Institute of Technology, Kanpur

Week-8

Lecture-38

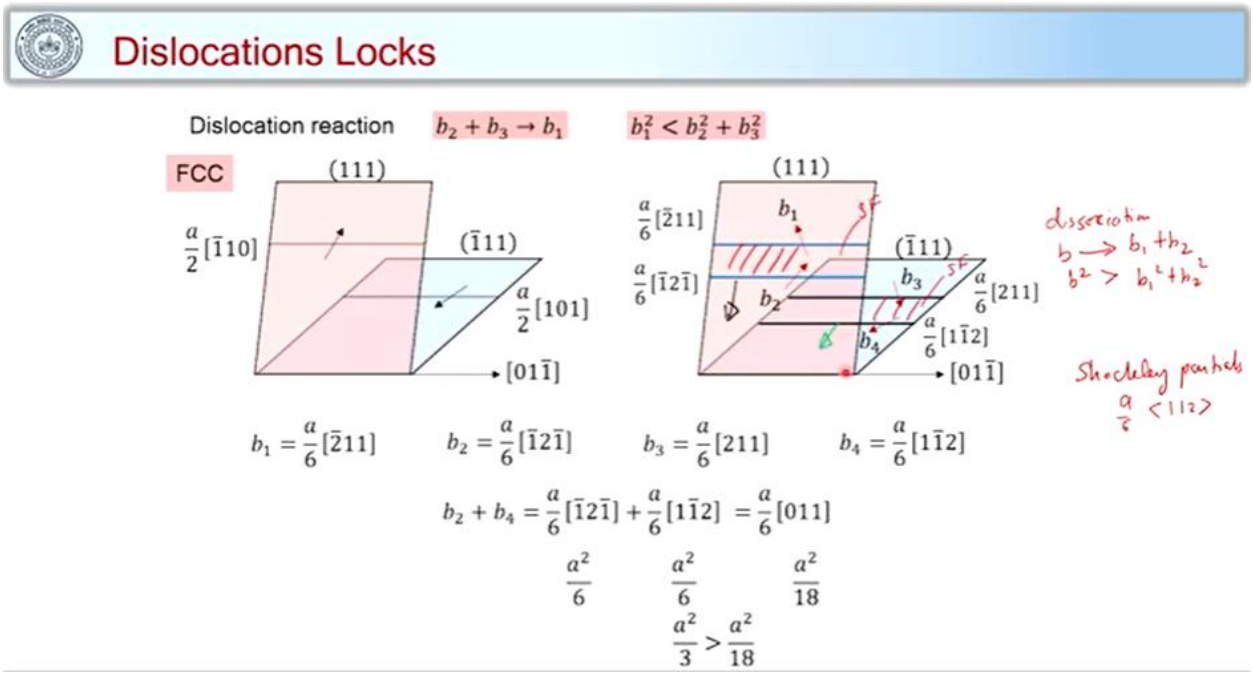
Dislocations Locks: Lomer- Cottrell Lock

Namaskar ka swagat karta hoon is course mein mechanical behavior of material jo ki hum hindi mein padhenge last part mein humne dekha tha ki ek perfect dislocation do partials mein split hota hai aur kuch stacking faults taiyaar hote hain is part mein hum jaanenge ki dislocation reactions ki wajah se kuch dislocation locks taiyaar hote hain aur unhi lock ke baare mein is part mein hum jaanenge to dislocation reactions ki jab main baat karta hoon yaani jab do dislocation combine hoke ek dislocation banata hai to yeh kab sambhav hai jab mera b_1^2 yaani yeh jo product jo hai dislocation reactions ka yeh b_1^2 yeh kam rahega $b_2^2 + b_3^2$ se to yeh energy criteria hai yaani yeh jo b_1^2 hum isliye kar rahe hain kyunki hum bata rahe hain ki mere energy jo rahegi dislocations ki yaani mere b_1 ki jo energy rahegi dislocation ki woh kam rahegi b_2 aur b_3 ke dono ko combine karke bhi jo energy aayegi usse kam rahegi tab jaake yeh dislocation reaction sambhav hai abhi hum jaante hain ki yeh kis tarah se hote hain to isliye bhi hum consider karte hain fcc material aur fcc material mein main consider kar raha hoon ek plane jo ki $(\bar{1}11)$ is tarah se maine ek plane consider kiya hai aur ek dusra plane consider karta hoon (111) agar aap crystallography dekhenge to in dono plane ka jo intersection hoga woh yeh jo intersection hoga iski direction hogi $[01\bar{1}]$ to

aap ye physical metallurgy text book ya aap khud crystal structure draw karke dekh sakte hain ki do yeh jo plane hai yeh is direction ke along intersect ho hai abhi hum dekhte hain ki mere paas ek dislocation hai yeh $(\bar{1}11)$ plane par aur uski magnitude hai $a/2[011]$ aur yeh jo dusra plane hai ispe mera ek dislocation hai $a/2[10\bar{1}]$.

To abhi ye jo perfect dislocations hai humne dekha tha ki ye split ho sakte hain do partials mein to abhi in do dislocations ko hum split karte hain do partials mein yeh jo dislocations hai yeh wala dislocation is plane pe aur yeh wala perfect dislocation is plane pe to kuch is tarah se main split karta hoon maan lete hain main yeh jo do partial maine split kiye is dislocation ko isko main naam de raha hoon b_1 aur b_2 aur ab dekhenge ki is dislocation ko maine split kiya hai b_3 aur b_4 to humne dekha tha ki yeh jo yeh jo dislocation hai ye perfect dislocation jo hai yeh split ho sakta hai do partials mein ye kab split hota hai jab aap dekhenge to yeh dissociation ke waqt humne dekha tha yahan par dissociation ke liye kya aavashyak hai agar mera b dissociate ho raha hai yahan par main b_1 aur b_2 ke ismein to main likh sakta hoon jo b^2 hai wo greater rahega b_1^2 aur b_2^2 ko mila ke to aap dekhenge ki yeh jo dislocation hai iski energy jo rahegi woh badi rahegi yeh b_1 aur b_2 ke square ko agar main karunga aur iski jo energy rahegi unki combined energy se bhi iski energy badi rahegi to jaante hain ki b_1, b_2, b_3 aur b_4 hai kya to agar hum dekhenge to yeh dislocation ho gaye split is tarah se to b_1 ki value rahegi $a/6[\bar{2}11]$ aur b_2 ki value rahegi $a/6[\bar{1}2\bar{1}]$ b_3 ki value rahegi $a/6[211]$ aur b_4 ki value rahegi $a/6[1\bar{1}\bar{2}]$ ye jo saare hain ye mere shockley partials hai humne dekhe the ye mere shockley partials hai aur inki value rehti hai hamesha aur kuch is tarah se ye rehte hain is family se rehte hain wo $a/6\langle 112\rangle$ type ab dekhenge ki b_1, b_2 aur yeh jo dislocation hai $a/2$ ye mere $(\bar{1}11)$ plane pe rahenge hamesha aur b_3, b_4 aur yeh jo dislocation hai $a/2[10\bar{1}]$ ye mere (111) plane pe hain aap inka agar dot product lenge b_1 aur is plane ka to wo shunya aana chahiye aur b_2 aur is plane ka dot product lenge to bhi shunya aana chahiye aur iska is dislocation ka aur iska bhi lenge dot product to shunya hona chahiye iska matlab yeh hai ki yeh yeh dislocation aur b_1, b_2 mere is plane par hi hai aap cross check kar sakte hain isko.

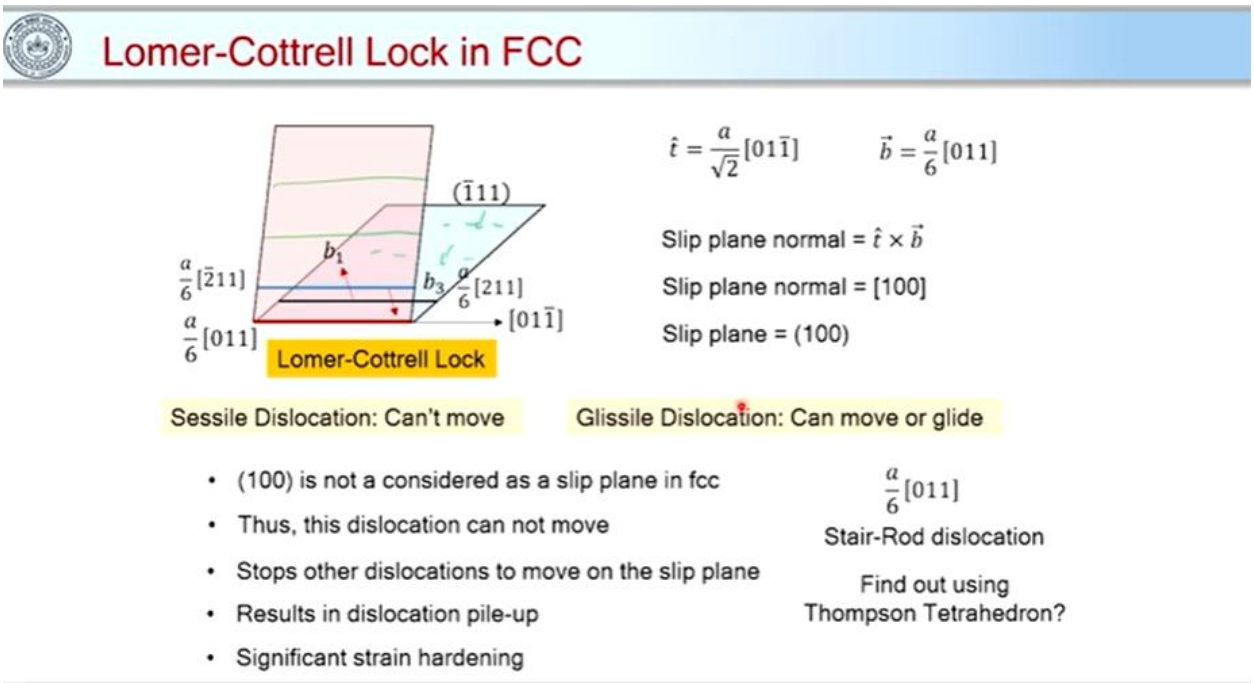
Abhi hum jaanenge ki mere maine is dislocations ko dissociate to kar diya do partials mein abhi agar maine kuch stress apply kiya hai is crystal pe to yeh b_1 aur b_2 move honge aur yeh jab move honge tab kuch is tarah se react honge ab dekhenge ki ye b_2 kuch is tarah se move hoga yahan par hum dekhenge ki ye jo beech wala jo hai wo stacking fault hai mera yahan pe bhi ek stacking fault hai aur yahan pe bhi ek stacking fault hai humne dekha hai agar main stress kuch apply kar raha hoon kuch is tarah se agar main stress apply kar raha hoon aur yeh b_2 is direction mein move hoga aur b_4 kuch is direction mein move hoga aur dono kuch yahan pe aayenge is direction pe yahan pe aake wo ek dusre ke saath react honge reaction kab possible hai humne bataya tha ki jab yeh jo in dono ka product jo rahega uski energy in dono ke energy se combined energy se kam rahegi to main in dono ko pehle react kar raha hoon to in dono ko main agar add karta hoon to mere paas value aati hai $a/6[011]$ ab inki hum energy nikaalte hain jaise b_2 ki energy hum nikalenge to square karenge inko to iski value aayegi $a^2/6$ aur iski energy aayegi ye bhi value aayegi $a^2/6$ agar iski energy nikalenge to ye proportional rahegi $a^2/18$ agar hum dono ka add karenge aur dekhenge ki isse yeh badi hai ya choti hai to humein pata chalega yeh jo product hai iski energy in dono ke combined energy se kam hai aur bahut kam hai to aap dekhenge ki yeh jo reaction hai ye possible hai ab is reaction ke wajah se kya hota hai jaanenge to hum ye to yahan pe dekh paa rahe hain ki mera b_2 aur b_4 yeh do partials hai yeh jab move honge tab yeh yahan pe react ho sakte hain ek dusre ke saath.



Abhi humne dekha ki yeh do react hoke aap dekhenge ki b_1 aur b_3 yahan tak aa gaye aur b_2 aur b_4 react hoke ek dislocation taiyaar kiye $a/6[011]$ iski magnitude hai $a/6$ aur yeh burgers vector hai to iska tangent vector kya hoga to tangent vector mera is direction mein hona chahiye jahan par ye do plane intersect ho rahe to yeh mera tangent vector hoga is dislocation ka to yeh mera tangent vector hoga aur yeh jo vector hai to tangent vector ke liye hum unit vector nikaalte to iske direction mein unit vector jab nikalenge to yeh ho jayega $a/\sqrt{2}[01\bar{1}]$ aur burgers vector mera ye hai $a/6[011]$ to agar is dislocation ka ye mera ek dislocation hai jiska ek tangent vector hai aur burgers vector hai is dislocation ka agar mujhe plane nikaalna hai yaani kis plane par lie karta hai yeh agar nikaalna hai glide plane agar mujhe nikaalna hai to main kya karunga to main is plane ka normal nikaal sakta hoon normal kis tarah se nikaalunga agar main $t \times b$ karunga to is slip plane ka yaani yeh jo product aaya mere paas is burgers vector ke corresponding jo slip plane rahega uska ek normal main nikaal sakta hoon kuch is tarah se to ye jo slip normal hai ye mil jayega mujhe $[100]$ agar ye slip normal hai aur maine fcc crystal structure consider kiya hai to ye jo slip normal hai mujhe slip plane dikha de sakta hai to humne dekha hai ki agar ye mera indices hai miller indices mere normal ke plane normal ke to mera plane kuch is tarah se hoga to mera plane just main yahan par isko is plane ki tarah likh sakta hoon yeh mera (100) plane.

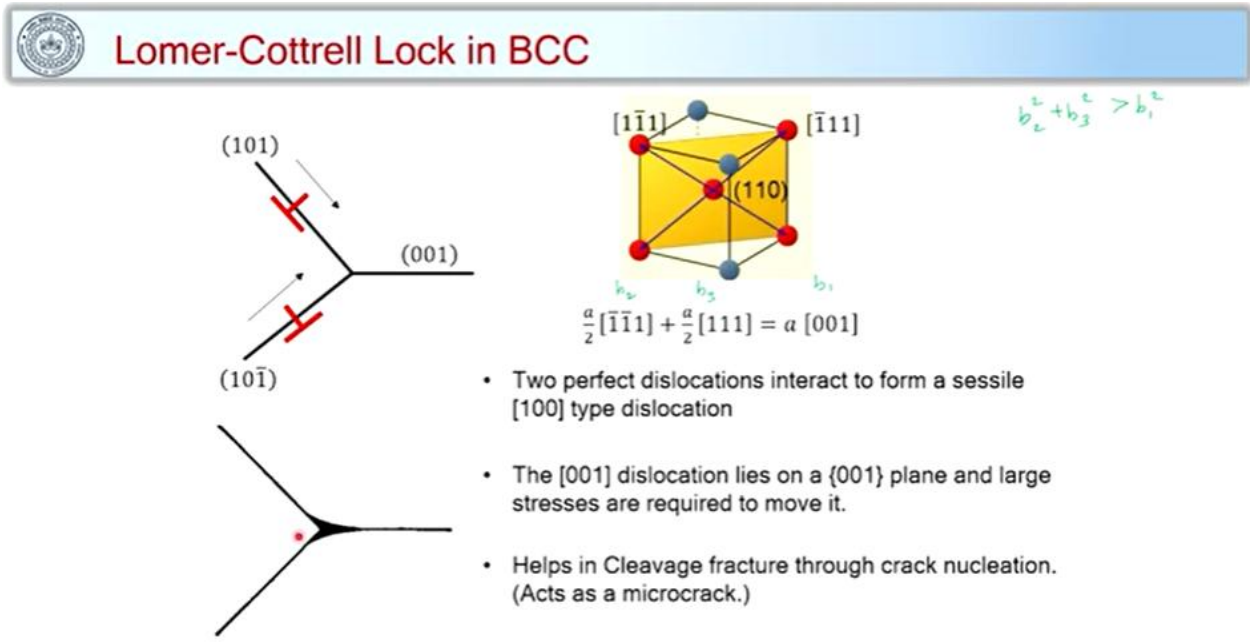
To yeh jo mera dislocation hai yeh kis plane par hai yeh mere (100) plane pe aur humne dekha ki fcc mein yeh mera slip plane nahi hai mera slip plane $\{111\}$ hota hai fcc mein to yeh jo dislocation hai yeh sirf is plane par hi move ho sakta hai aap dekh paa rahe honge ki yeh jo dislocation hai iska nature kya hai agar aap iska dot product lenge $t \cdot b$ agar lenge to aap dekhenge ki iski value shunya aa rahi hai to yeh mera ek edge nature taiyaar hoga aur edge dislocation sirf ek plane par hi move ho sakta hai jo ki yeh plane hai (100) aur yeh jo (100) plane hai yeh mera slip plane nahi hai fcc mein to isliye yeh dislocation is plane par aasaani se move nahi ho sakta aur yeh move hona bahut difficult hai to is kind of dislocation ko hum kehte hain sessile dislocation jo move nahi ho sakte jo force ke influence mein bhi move nahi ho sakte un dislocation ko hum kehte hain sessile dislocation aur jo dislocation move hote hain unko hum kehte hain glissile dislocation to agar yeh dislocation yahan par move nahi ho raha hai ya ruk gaya hai to iske wajah se yeh jo dislocation

hai ye partial dislocation yahan pe b_1 aur b_3 inka bhi movement is planes par ruk jayega to yeh dislocation in do dislocations ko bhi rok dega to yeh kyun rokega kyunki humne dekha hai ki dislocation ke around ek stress field hoti hai aur yeh stress field ek repulsive force taiyaar karegi b_1 aur b_3 ke liye aur isliye dislocation is planes par move hona ruk jayenge aur yeh move nahi honge to isi ko hum kehte hain lomer-cottrell lock to yaani hum keh sakte hain ki yeh jo dislocation hai lock ki tarah kaam kar raha hai jo dislocations hai ye do planes pe jo move ho ra hai in dislocations ke liye ek lock ki tarah kaam kar raha hai isliye hum kehte hain isko lomer-cottrell lock to iske wajah se kya hoga agar agar yeh dislocation allow nahi kar raha hai in do dislocations ko move hone ke liye ya koi bhi dislocation is plane pe move nahi ho paa raha hai to kya hoga dislocation pile up hoga yaani dislocation ka dislocation yahan par accumulate honge aur iski wajah se kya hoga strain hardening yaani material mera hard ho jayega isiliye lomer-cottrell locks ya dislocation locks kuch strain hardening karte hain mere material mein ab ek cheez main aapko exercise ke dwara dena chahta hoon yeh jo dislocation hai $a/6[011]$ isko hum kehte hain stair-rod dislocation aur is dislocation ko aapko plot karna hai humne thompson tetrahedron dekha tha last part mein to aap thompson tetrahedron draw kariye aur yeh dislocation kahan pe hai iska location aap find kariye to humne dekha tha ye lomer-cottrell lock fcc mein.



To kuch is tarah se kuch lock hote hain mere bcc mein humne bcc mein dekha ki jo slip systems hote hain to mera slip plane mera $\{110\}$ hai aur slip direction hota hai woh mera $\langle 1\bar{1}1\rangle$ direction ke along hota hai to maan lete mere paas do slip planes hai ek (110) aur ek $(10\bar{1})$ to yeh do slip planes par kuch dislocation hai mere fcc mein aur yeh stress ki tarah stress ke influence mein kuch is tarah move ho ra hai ab jo aap dekhenge inka direction kuch is tarah se abhi hum dekhenge ki yeh jo dislocation se kuch is tarah se to is plane par main maan leta hoon yeh dislocation hai $a/2[\bar{1}\bar{1}1]$ aur is plane par maan leta hoon yeh hai $a/2[111]$ humne dekha ki ye mere burgers vectors hai dislocations ke kuch is nature ki tarah hote hain aur mere slip planes hai to jab yeh dono dislocations react karenge to mujhe ek dislocation milega aur uska burgers vector kuch is tarah se rahega $a[001]$ ab ye reaction kyun hoga yeh bhi aap verify kar sakte hain agar main yeh

isko maan leta hoon $b_2 + b_3$ ka square karke dekhunga to yeh mujhe milega bada milega b_1^2 se isko main maan leta hoon b_2, b_3 aur b_1 ye verify kar sakte to mere paas kuch ek resultant dislocation milega jiska magnitude hai a aur direction hai [001] aur yeh mera $a\langle 100\rangle$ type ka dislocation hai aur ye bhi mera sessile dislocation hai sessile dislocation isliye hai kyunki ye jo do planes intersect honge yeh jo dislocation lie karega yeh mera (001) plane pe lie karega aap dono ka yeh dono planes draw karke dekh sakte hain ki yeh jo plane aayega milega hum humein ye (001) plane milta hai to yeh jo plane hai ye mera slip plane nahi hai to yeh jo dislocation hai is nature ka [001] type ka jo mera lie kar raha hai (001) plane par isko move karne ke liye mujhe bahut jyada stresses ki zarurat hogi to yeh bhi jo dislocation taiyaar hoga yeh ek lock ki tarah kaam karega to mujhe bcc mein bhi lomer-cottrell locks milte hain aur is dislocation ki wajah se aap dekhenge agar yeh dislocation move nahi kar raha hai to aap kya iski wajah se kya hoga is region par yeh jo dislocation move nahi ho raha hai iski wajah se bahut saare stresses yahan par develop ho sakte hain aur yahan par ek crack develop ho sakti hai isko kehte hain cleavage fracture yahan par crack nucleate ho sakti hai because of large number of stresses yaani jo jyada stresses yahan par develop honge is dislocation ko move karne ke liye is plane par to yeh isko kehte hain cleavage fracture bcc mein is tarah se humein kuch is tarah se milte hain aur yeh jo sessile dislocation hai bcc mein ye act karta hai nucleation site for micro cracks to humein is part mein humne do locks dekhe ek fcc mein lock dekha hai aur ek lock humne bcc mein dekha hai ye locks kyun taiyaar hote hain kyunki hamare dislocation react hote aur aisa dislocation taiyaar karte jo aise slip planes mein rehta hai jo slip plane nahi hai mere material ke liye jaise fcc mein mere material ke liye {111} plane hai ya bcc mein {110} planes hai is planes par yeh dislocations nahi rehte aur yeh dislocations jo baaki ke dislocations hai unko rokte hain isliye inko locks kaha jaata hai to yeh jo dislocation lock hai yeh strain hardening mein bhi jyada mahatva rakhte hain aur strain hardening ko badhate hain.



Abhi ke liye yahan rukta hoon dhanyavad