Mechanical behavior of materials

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Week-6

Lecture-27

DislocationMotion:Glide, Cross SlipandClimb

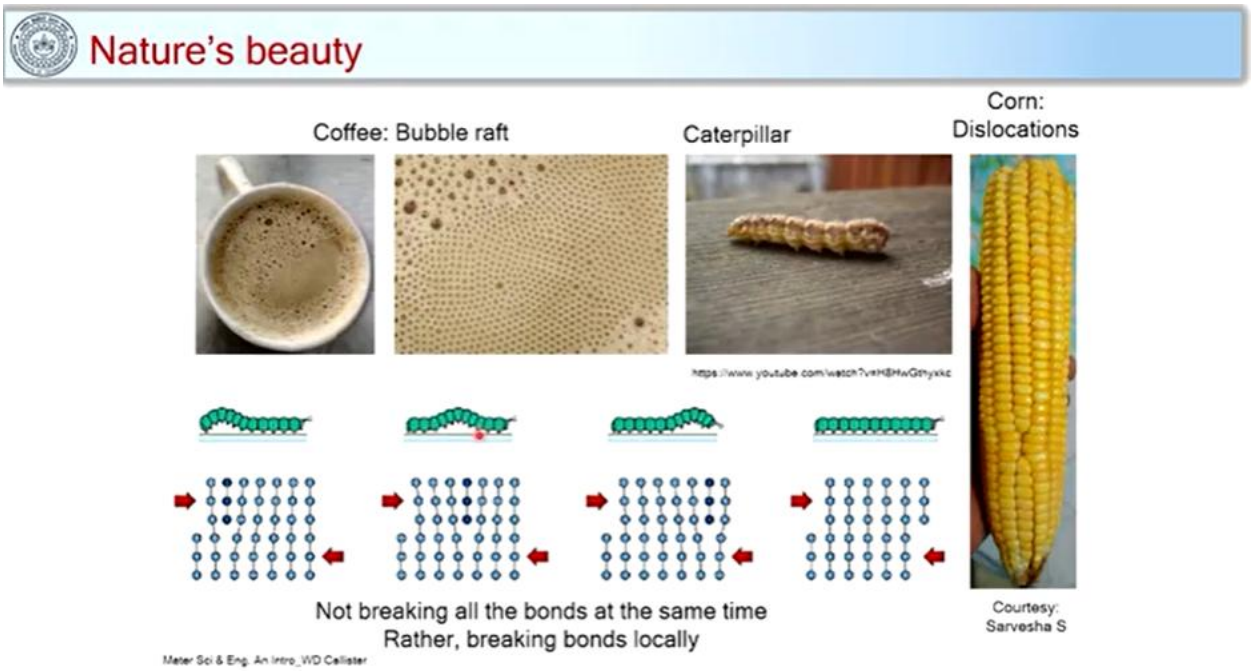
Dislocation Motions: Glide, Cross-Slip and Climb

Namaskar phir se swagat karta hoon aapka is course mein Mechanical Behavior of Material jo hum Hindi mein padhenge. Last part mein humne dekha tha ki Peierls-Nabarro stress kya hota hai. To humne dekha tha ki stress hai jo hamare dislocation ko ek mein move karne ke liye zaroorat hai. Abhi hum jab yeh stress apply karte hain to hum apne dislocation ke motions kya ho sakte hain kaun si kaun si motions possible hai dislocation ki yeh dekhenge. To yahan par slide mein maine likha hai Glide, Cross-Slip aur Climb. To abhi glide ke glide yeh shabd humne suna hai glide humne slip ke baare mein bhi dekha tha. To abhi dekhte hain ki kuch cheezein jo nature mein humein dislocation se correlate karne mein madad karegi jaise ye maine ek baar aapko bola tha ki Bubble Raft ke baare mein aap dekhiyega. To agar aap kabhi coffee ka froth dekhenge to kuch is tarah se mujhe bubbles milenge. To ye bubbles mein aap dekhenge ki kuch defects aapko milenge yani bade bubbles milenge to yeh substitutional atoms ki tarah kaam karte hain kuch vacancy ki tarah jahan par bubbles nahi hai woh yani wahan par vacancy hongi. Aur yahan par aap dekh payenge ki kuch dislocations bhi aapko dikhenge agar aap acche se observe karenge to. Abhi dislocations dekhne ke liye aur ek interesting cheez aap dekh sakte hain ki kabhi kabhi corn mein jo makka hota hai usme kuch is tarah se structure milta hai. To aap dekhenge ki mera extra half

plane hai yahan pe aap yahan pe bhi extra half plane hai to aap dekhenge ki yahan pe ek dislocations taiyar ho rahe hai yahan pe. To yeh mere corn ke dislocations ho gaye.

Jab main dislocation ke motion ki baat karta hoon specially slip ki baat karta hoon tab yeh ek example hamesha diya jata hai yeh caterpillar jo movement hai. Yeh jo caterpillar hai iska jo movement hai yeh mere slip ya glide ka ek uttam udaharan hai. To aap dekhiyega ki caterpillar kis tarah se move ho raha hai to ye schematic dwara is tarah likha gaya dikhaya gaya hai. Agar main dekhunga ki ye mera plane hai extra plane to aap dekhenge ki ye caterpillar ke jo pair hai yahan par is tarah se uthe hue hain jaise jaise extra half plane is tarah direction mein move ho raha hai yani main bol sakta hoon ki dislocation is direction mein move ho raha hai stress ke ek stress jab isko apply karte hain tab. To aap dekhenge ki caterpillar ka jo movement hai is tarah se ho raha hai yani main dekhunga ki yahan pe making or breaking of bonds ho raha hai aap dekhenge ki yahan pe bonds ban tootenge locally aur banenge bhi. To is tarah se hum dekhenge yeh jo extra half plane hai is tarah se move ho raha hai aur aage aap dekhenge ki yeh caterpillar ek unit move hua hai to yahan pe bhi hum dekhenge ki yahan pe surface step ek ho gayi hai. To is tarah se jo glide hai ya slip hai edge dislocation ka is tarah se hum samajh sakte caterpillar ke movement ki tarah.

Abhi jante hain ki glide aur slip hoti kya hai. To humne yahan par dekha ki yahan par breaking of bonds locally ho raha hai aur yahan par saare bonds ek tarah toot nahi rahe hain yahi humne dekha tha ki kuch bonds kuch hi bonds toot rahe hain yahan par aap dekhenge ki yeh jo iske kuch pair hai woh zameen par chipke hue kuch hi pair jo hai woh hawa mein uthe hue hain. To yahi concept hai jab dislocation move hota hai lattice mein to kuch hi bonds toot-te hain aur saare bonds yahan par toot-te nahi hai to humein bahut saari energy nahi chahiye small energy chahiye dislocation ko move karne ke liye.



To abhi glide of dislocation dekhte hain slip yane to humne dekha tha ki do dislocations humne dekhe the ek Edge aur Screw. To iske liye pehle hum ek kaam karte hain yahan pe Edge dislocation ke liye ek line mark kar dete hain ye meri dislocation line hai dono ke case mein hum dislocation

line yahan par mark kar diye. Yeh mera crystal hai aur Burgers vector jab mark karunga Edge dislocation ke liye to yahan par yeh meri tangent vector hai ya dislocation line hai aur yeh jo Burgers vector hai Edge dislocation mein ye perpendicular hona chahiye to yahan par maine Burgers vector is tarah se mark kiya hai. Abhi yahan pe maine mark kiya hai yeh jo Burgers vector hai kuch is tarah se parallel mark kiya hai ye dislocation line ke liye aur abhi main kya kar raha hoon abhi main kuch stress apply kar raha hoon shear stress apply kar raha hoon is tarah se. To agar jab main shear stress apply karunga to mujhe deformation kuch is tarah se milna chahiye yani ye jo condition hai yani mujhe ek slipped crystal milega slipped part milega aur ek unslipped part milega ye mera output hai in dono motions ke dislocations ka. To mujhe shape change jo mil raha hai Edge dislocation jab move hoga aur Screw dislocation jab move hoga to mujhe yeh shape change mil raha hai.h

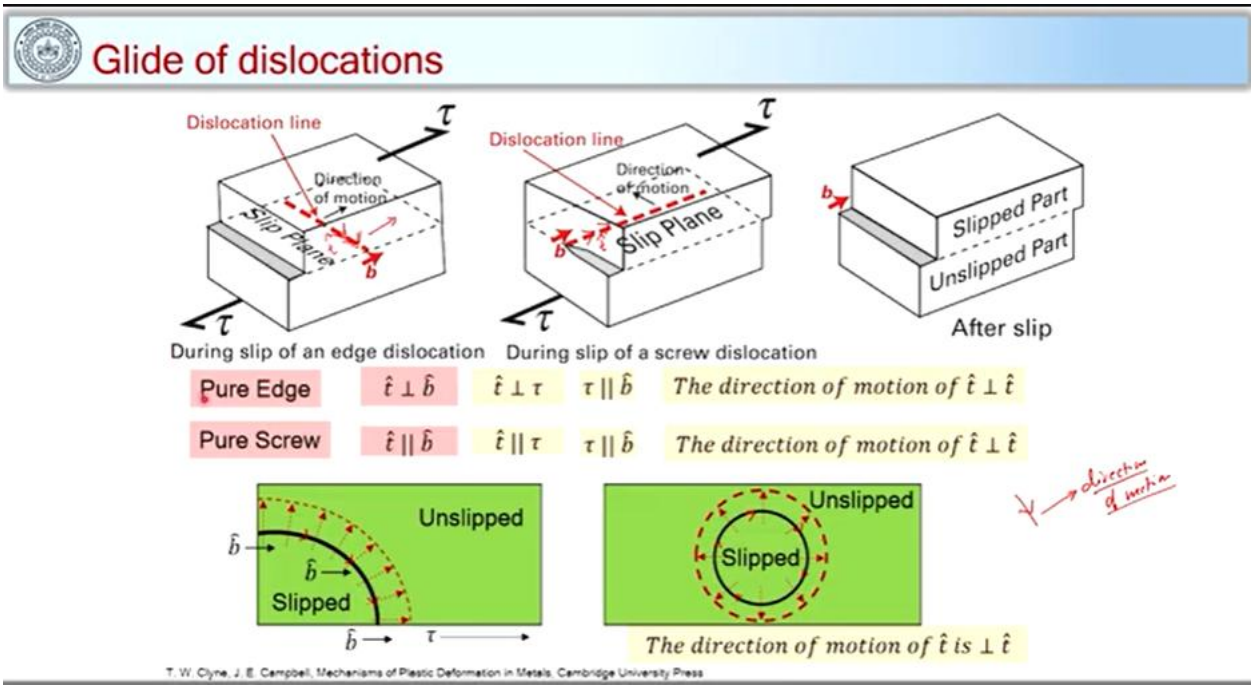
To aaiye jante hain ki yeh dislocation kis tarah se move hona chahiye. To jab maine yeh shear stress apply kiya to aap dekhenge pehle case mein jab hum Edge dislocation ki baat karte to Pure Edge ki baat kar raha hoon main. Pure Edge ke liye kya definition hai jo tangent vector hai woh perpendicular hona chahiye mere Burgers vector ke saath. To tangent vector yahan pe hai yeh mark kar lete hain yeh mera tangent vector hai is direction mein. Yeh aap dekh sakte hain ki yeh perpendicular hai mere Burgers vector ke saath aur ek cheez hum likh sakte hain jo stress humne apply kiya is tarah se likh sakte hain jo tangent vector ke saath yeh stress kaisa hai agar stress is tarah se tangent vector is direction mein hai to yeh stress perpendicular hai mera tangent vector ke saath. Aur aap dekhenge ki yeh jo stress hai yeh parallel hai mera Burgers vector ke saath aur direction kya hogi meri tangent vector ki aap dekhenge ki dislocation is tarah se move ho raha hai agar yeh Burgers vector hai to Burgers vector ki direction mein move ho raha hai. To aap dekhenge yeh jo dislocation hai main is tarah se keh sakta hoon ki The direction of tangent vector or direction of dislocation is perpendicular to the tangent vector. Yani aap dekhenge mera tangent vector is direction mein hai yahan pe hai aur iska movement is direction mein ho raha hai to mere tangent vector jo hai uske perpendicular direction mein mera movement hota hai dislocation ka. Yeh ho gaya mera Edge dislocation.

Abhi hum dekhte hain Pure Screw dislocation to Pure Screw dislocation mein ye relation hai jahan par tangent vector parallel hai mere Burgers vector ke saath. Yahan par bhi mark kar lete hain tangent vector hum. To tangent vector agar hum mark karenge to yeh tangent vector is tarah se hai aur aap dekhenge ki jagah agar tangent vector parallel hai Burgers vector ke saath to yeh jo tangent vector hai yeh parallel ho jayega mere shear stress ke saath jo maine external stress apply kiya is tarah se. To ye parallel ho jayega. Agar aap ye condition dekhenge to jo shear stress hai woh bhi parallel ho jayega mera Burgers vector ke saath. Agar aap dekhenge ki yeh jo dislocation hai yeh kis direction mein move ho raha hai yeh is direction mein move ho raha hai yahan pe mark kiya hai The direction of motion yeh jo dislocation ka. To agar ye is direction mein move hoga to yeh slip is tarah se hoga yahan par step mujhe is tarah se milna chahiye iska output bhi. To yahan par bhi aap dekhenge ki jo direction hai dislocation motion ka yeh perpendicular hai mera tangent vector ko. To yane Direction of Dislocation Motion is Perpendicular to its Tangent Vector. Yeh dono case mein bhi hum dekh sakte hain yahan par bhi hum dekh sakte hain ki jo dono case mein humein dislocation motion kis tarah mil rahi hai Pure Edge ya Pure Screw mein yeh mil rahi hai jo hamara tangent vector hai uske perpendicular. To koi bhi dislocation rahe Edge rahe Pure Edge rahe Pure Screw rahe yeh condition hamesha satisfy hogi.

Abhi jante hain isko aur ek example leke yeh hum Glide ki baat kar rahe hain glide yani jo dislocation motion hai us slip plane mein kaise move kar raha hai kis direction mein move kar raha

hai iski baat kar rahe. To yeh mera paas ek dislocation line hai aur iska Burgers vector main define kar deta hoon is tarah se kuch is direction mein. To yeh dislocation line main agar is tarah se mark karunga to tangent vector mera kuch is tarah se jayega aur Burgers vector ki jab main baat karunga to mere Burgers vector to inherent rehte hain yani woh change nahi honge uska magnitude aur direction nahi change hoga to Burgers vector yahi rahega saare points pe saare location pe. Yahan par aap dekhenge to yahan par jo dislocation hoga yeh jo dislocation hoga yeh mera Screw dislocation hoga aur yeh jo dislocation hoga yeh mera Edge dislocation hoga yahan par aap dekhenge ki tangent vector perpendicular hai Burgers vector ke saath aur yahan par aap dekhenge ki tangent vector hai parallel hai Burgers vector ke saath aur yahan par mujhe mixed nature milega. To jab main mujhe yeh understanding ho gayi hai ki jo dislocation motion hai woh hamesha tangent vector jo motion hai woh hamesha is tangent vector ko perpendicular hoti hai. To agar maine shear stress kuch is direction mein apply kiya hai yani Burgers vector ke along to mere mujhe ek slip region milega aur ek unslipped region milega par is jab main shear stress increase karunga to is dislocation ka motion hoga aur motion kis direction mein hona chahiye motion is direction mein hona chahiye. Motion hamesha hoga Perpendicular to the Tangent Vector. Yani agar main local yahan pe tangent vector draw karunga to us point pe jo dislocation ka motion hoga woh perpendicular hoga. To agar yeh mera dislocation glide kar raha hai ya slip kar raha hai is slip plane pe to woh kis tarah se move hoga woh is tarah se move hoga jo mera next position hoga dislocation ka woh is tarah se aayega. Yani aap dekh pa rahe honge ki yeh dislocation jo hai iska ek tangent vector hai aur yeh jo motion hai dislocation ka woh perpendicular hai iske tangent vector ke saath.

Aur ek example dekhte humne loops dekha tha loop yani kya hota hai humne bataya tha ki dislocation ending on itself ya dislocation woh khud par khatam ho raha hai shuru bhi hota hai uske upar hi khatam hota hai usko hum loop kehte hain. Ye agar main Glide Loop maan ke chalta hoon to agar yeh loop main maan ke chal raha hoon to ye slip part hai andar ka aur yeh unslipped part hai. Agar hum tangent vector dekhenge iska to mark kar lete iska tangent vector to yeh mera tangent vector ho jayega dislocation ka tangent vector aur dislocation line vector is tarah se hoga. To yahan pe iska motion kaise hoga agar main shear stress yahan pe apply kar raha hoon to iska motion hoga perpendicular to its tangent vector to kuch is tarah se yani har ek point pe agar main nikalunga to yeh dislocation is tarah se kuch move hoga aur hum dekhenge ki agar stress hum apply kar rahe hain to yeh dislocation jo motion hai woh is tarah se hoga aur yeh loop increase hoga apna size badhayega. To is tarah se kuch hamara dislocation ka motion hota hai yani yahan par main Glide ki baat kar raha hoon ya slip ki baat kar raha hoon to aapko ek hamesha yaad rakhna hai ki Direction of Motion of Dislocation woh kya rahega hamesha uske tangent vector ko perpendicular rahega hamesha woh perpendicular rahega. To agar mera tangent vector is tarah se samjhe agar mera tangent vector is tarah se hai to uska motion usko perpendicular rahega yeh mera direction of motion rahega dislocation ka. Yeh ek yeh kisi bhi dislocation ke liye lagu hota hai woh Edge ho Screw ho ya Mixed ho.

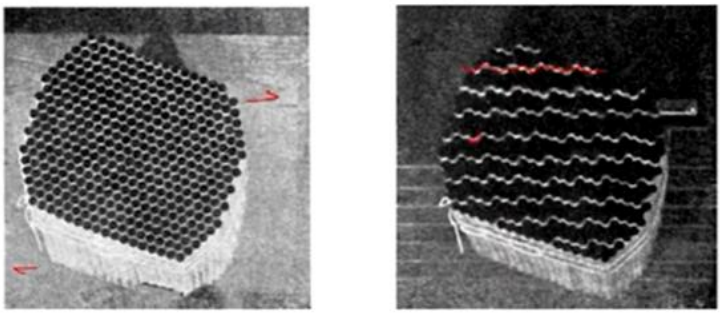


To yeh Glide of dislocation ho gaya abhi hum dekhte hain crystal structure ke saath kya glide hona chahiye. To humne dekha tha ki FCC, BCC aur HCP mein slip direction kya hoti hai FCC mein close yahan par humne dekha tha ki close packed direction slip direction hoti hai aur major jo close packed planes hote hain woh slip planes hote hain. To humne dekha tha ki slip systems kya hai crystal structures ke saath. To aap dekhenge ki mere paas FCC mein ek hi slip direction hai yani ek type ki slip direction hai aur ek type ka slip plane hai. Par BCC mein mere paas ek slip direction hai par mere paas do teen slip planes hai jaise {110}, {112} aur {123} humne discuss bhi kiya tha. Aur HCP mein bhi waise hi hai mere paas ek slip direction hai ek type ki slip direction hai $\langle 1\bar{2}10 \rangle$ type ki ye close packed direction hai HCP mein aur mere paas various slip planes hai jaise (0001) ye basal plane ho gaya $\{10\bar{1}0\}$, $\{10\bar{1}1\}$ ye depending on jo hamari conditions hai deformation conditions ke uske hisaab se ye slip planes change honge.

To ek interesting observation dikha jata hai BCC ke case mein yani yahan pe ek maine Pencil Glide karke mark kiya hai to aap dekhenge ye mere paas pencil ka ek stacks hai aur yahan pe agar ye stack ko main kisi shear force apply karunga maan lete hain maine is tarah se kuch shear force apply kiya hai ye stacks ko to aap dekhenge ki yahan par is tarah se kuch mujhe deformation mil raha hai yani yeh jo glide ho raha hai planes ka ya slip ho rahe planes yeh kuch is tarah se zigzag way se isko hi hum kehte hain Pencil Glide. Aap dekhenge ki agar yahan par yeh jo lines hai main isko mark kar leta hoon agar yeh jo lines hai yahan par ek line hai yahan pe ek line hai yahan pe ek line hai yahan pe ek yeh particular planes dikha rahe aap dekhenge ki yeh jo direction change ho rahi hai yeh particular planes yahan pe dikha rahe hain isko hi hum kehte hain Pencil Glide yani pencil ki tarah slip ho raha hai isliye hum isko kehte hain Pencil Glide. Yeh Taylors ka ek illustration tha pencil ke stack ko leke.

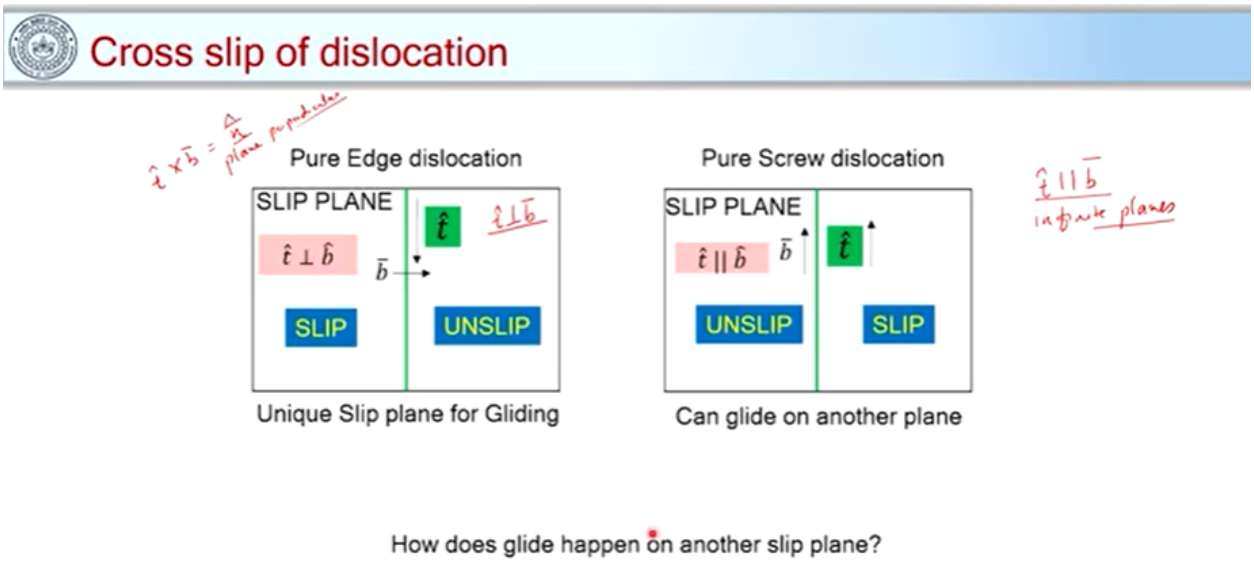
Glide: Crystal structure

Structure	Slip direction	Slip planes
fcc	<110>	{111}
bcc	<111>	{110}, {112}, {123}, pencil glide*
hcp	$<11\bar{2}0>$	(0001), $\{1\bar{1}00\}$, $\{1\bar{1}01\}$



Taylor's illustration of shearing a pack of pencils. The direction of shearing is fixed (parallel to the pencils), but shearing can occur on any plane. From G. I. Taylor, *Proc. Roy. Soc.*, v. 62 (1926).

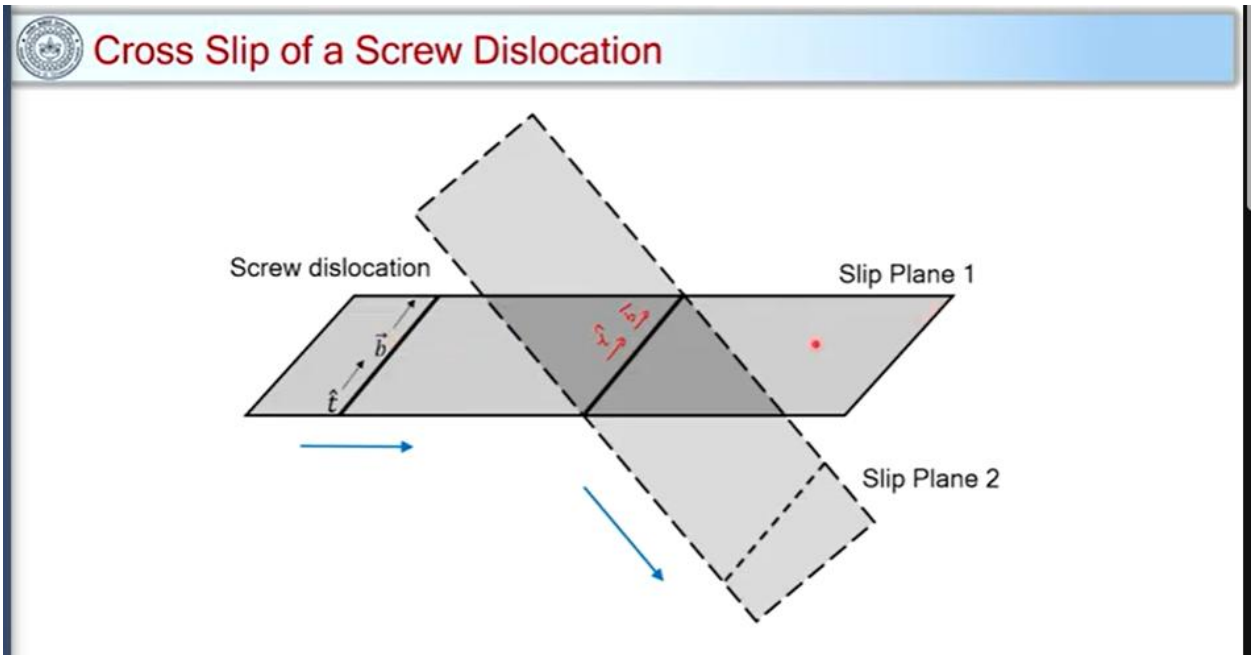
Abhi hum dekhte hain ki Cross-Slip kya hota hai dislocation ka. To dislocation ka cross slip kab hota hai ye pehle hum janenge. To ye agar main Pure Dislocation ki baat Pure Edge dislocation ki baat karunga to yahan pe mere paas pure jab maine slip plane ki baat ki to mere paas ek tangent vector hai agar main Edge Pure Edge baat karunga to yahan pe jo Burgers vector hai woh hamesha perpendicular rahega is tangent vector ko ye mera definition hai Pure Edge dislocation ka. Agar aap dekhenge jo t is perpendicular to b yani t jo b ko perpendicular hai to yeh dislocation line bifurcate karegi slip aur unslipped region ko. Aap dekhenge yeh jo combination hai t perpendicular to b Burgers vector yeh sirf ek hi plane mein possible hai kyunki aap dekh sakte ki do perpendicular vectors ek hi plane ko define ek hi plane mein define ho sakte hai ye geometric constraint hai mere Edge dislocation ka. Yani ek hi plane in dono vectors ko contained kar sakta hai yani saath mein rakh sakta hai. Dusra plane le sakte ho par us dusre plane mein aap ek to t tangent vector aayega nahi to Burgers vector aayega dono agar ek plane mein aane hain to mujhe sirf ek hi unique plane milega jo mujhe is tarah se agar main $t \times b$ nikalun to ek normal direction mujhe milegi. Agar main $t \times b$ nikalta hoon to mujhe ek normal direction milegi yeh jo normal direction rahegi yeh meri plane ko perpendicular rahegi ye humne dekha tha ye aap samajh bhi sakte product se. To Edge dislocation yeh kisi bhi mere ek hi slip plane mein ho sakta hai to yani iska matlab mera Edge dislocation sirf ek hi plane mein move ho sakta hai isko hum glide kahenge ya slip kahenge to yeh mera t perpendicular to b aur isliye main kahunga ki Unique Slip Plane rahega Edge dislocation ko Pure Edge dislocation ko glide karne ke liye yani is case mein Cross-Slip nahi hoga.



Hum jante hain ki Cross-Slip hota kya hai. Cross-Slip hum dekhenge abhi Pure Screw dislocation ko samajh ke. To maan lete hain mere paas ek slip plane hai agar main Pure Screw ki baat kar raha hoon to mere paas ye tangent vector hai ye mera dislocation line vector hai agar hum Pure Screw ki baat karenge to Burgers vector kya hoga isse parallel hoga yeh mere Pure Edge Pure Screw ki definition hai. To agar hum dekhenge yeh jo do vectors ek dusre ko parallel hai to ab main yeh dislocation line se jaane wale infinite planes draw kar sakta hoon ya kisi bhi direction se yani yeh jo yeh jo do vectors hai aap jaan sakte ho agar koi do vector parallel hai ek dusre se yani t yahan pe parallel hai b se to main yahan se lagbhag infinite planes draw kar sakta hoon kyunki ye parallel hai to ye yahan in dono mein se infinite planes main draw kar sakta hoon. To aap dekh payenge ki yeh jo Pure Screw hai isme koi restriction nahi hai ki ek hi slip plane pe ye move ho ye dusre slip plane par bhi move ho sakta hai. To yeh jo dislocation line hai unslipped aur slip region ko demarcate karti hai to yeh jo dislocation line hai yeh mere is plane mein bhi move ho sakta hai aur agar mere paas dusra kuch slip plane aa jayega woh usme bhi move karega hum dekhenge iske baare mein. To yeh kisi bhi dusre plane par bhi glide kar sakta hai inko koi geometric restriction nahi hai ki sirf ek hi plane mein woh contained rahe. To hum jaan pa rahe yahan pe ki jo Pure Dislocation hai woh sirf ek hi plane mein glide ho sakta hai par Screw Dislocation hai woh dusre plane mein bhi glide ho sakta hai. Aur jante hain iske baare mein ki yeh dusre plane mein glide kis tarah se hota hai usi ko hum kehte hain Cross-Slip yani ek plane se glide hoke dusre plane par shift hona change hona isko hum kehte hain Cross-Slip.

To jante hain Cross-Slip kya hota hai screw dislocation ka. To maan lete hain mere paas ek slip plane hai aur ye slip plane yahan par ek Screw Dislocation hai kyunki humne dekha ki Screw Dislocation hi dusre plane par glide ho sakta hai mark kar liya yahan pe tangent vector aur Burgers vector. Maan lete ki ye is direction mein main force apply kar raha hoon ya shear stress apply kar raha hoon to is force ke application ke saath yeh jo dislocation hai woh is slip plane par move hoga isko main kahunga Glide ya Slip of a Dislocation. To maan lete hain is tarah se kuch glide ho gaya

mera ye dislocation ye yahan se yahan tak aa gaya. Abhi maan lete hain yahan pe koi obstacle aa gaya yani dislocation ruk gaya yahan pe iske liye iske motion ke liye rukawat ho gayi. To humne jaana hai ki yeh jo slip plane hai isme yeh jo slip plane hai aur yeh jo dislocation hai yeh dusre slip plane pe bhi Cross-Slip ho sakta hai agar maan lete yahan pe koi ek dusra slip plane hai is tarah se maan leta hoon main dusra slip plane hai to yahan pe aap dekhenge ki agar ye mera Screw Dislocation hai to yahi mera tangent vector rahega aur yahi mera Burgers vector rahega to ye jo dislocation hai woh is plane par bhi glide ho sakta hai to agar Plane 1 par koi rukawat aa gayi to yeh Plane 2 pe move ho sakta hai ya glide ho sakta hai kuch is tarah se to aap dekhenge ki kuch is tarah se yeh dislocation glide ho gaya to mera dislocation yahan par tha aur phir woh glide hoke Plane Slip Plane par glide hoke is Slip Plane 2 par aa gaya. To ye jo slip hai ek plane se dusri plane ki taraf isko hi Cross-Slip kehte hain. Yeh jo process hai Screw Dislocation ka ek slip se dusre slip plane pe glide hona isko hum Cross-Slip kehte hain.



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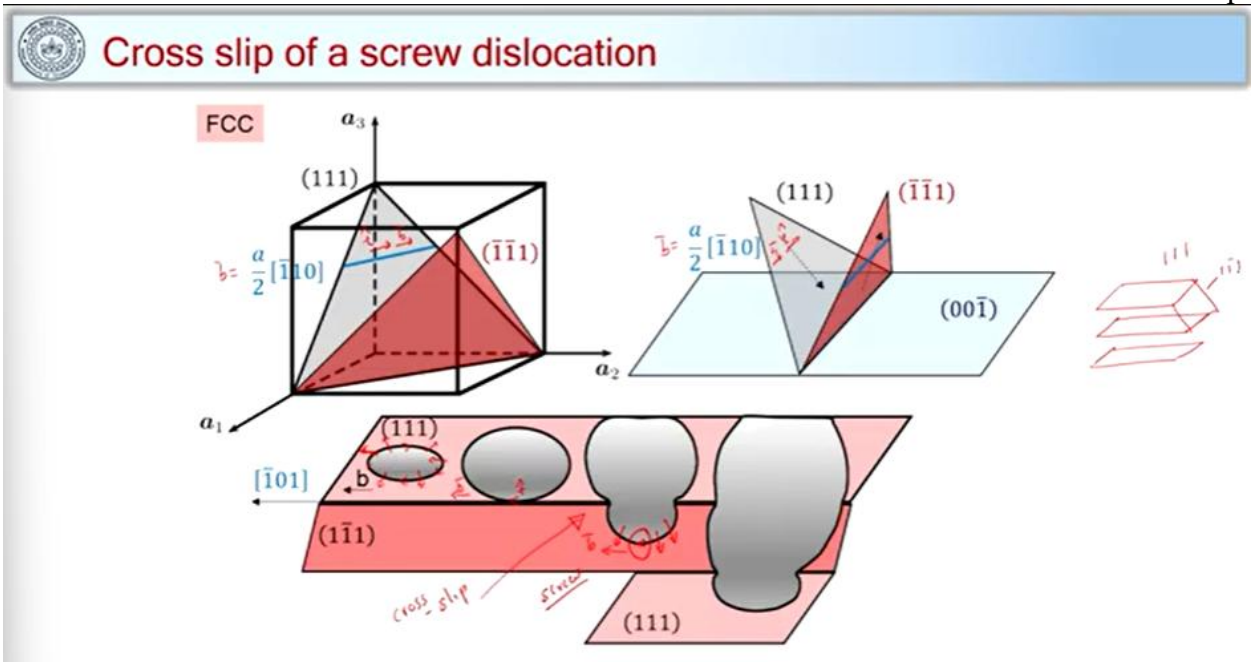
Aaiye aur thoda jante hain is Cross-Slip ke baare mein maan lete hain FCC structure hai mere paas ye crystal structure hai aur humne dekha tha ki FCC crystal structure mein jo {111} plane hota hai yeh mera slip plane hota hai glide plane hota hai aur humne dekha tha ki bahut saare {111} plane hote hain to ye ek tarah ka {111} plane hai ya (111) plane hai agar main $a_1 a_2 a_3$ aise mark kar raha hoon yahan pe aur yeh jo dislocation hai yeh mera dislocation woh dekha tha ki jo Burgers vector hota hai woh is direction mein hai maan leta hoon yeh jo direction hai yeh meri $a/2[\bar{1}10]$ hai yani main mark kar leta hoon yeh jo yeh jo hai yahan par mera tangent vector hai aur isi direction mein mera Burgers vector hai aur yeh yeh jo hai yeh mera Burgers vector ka direction aur magnitude hai. Maan leta hoon agar tangent vector is direction mein hai to yeh jo dislocation ho jayega yeh mera Screw Dislocation ho jayega to ye Screw Dislocation hai agar ye Cross-Slip karna chahta hai is plane se to hum jante hain ki ye Cross-Slip kaise hoga to aap dekhiye yahan pe main ek dusra plane draw kiya yeh wala red color ka yeh bhi dusra {111} plane hai yeh $(\bar{1}\bar{1}1)$ plane hai. To aap dekhenge ki crystal structure mein mere paas ye do {111} plane hai abhi is tarah se maante hain ki agar main kuch loading condition is tarah se hogi ki ye glide hoke yani

dislocation jo hai jo Screw Dislocation hai woh glide hoga is plane pe kuch is tarah se is tarah se hum dekh lete hain ye jo bottom wala plane hai yeh mark kar liya maine yahan pe (111) aur yeh ek mera yeh {111} plane hai yahan pe yahi condition main yahan par mark kar raha hoon aur yeh hai mera dislocation is tarah se bhi mark kar leta hoon yeh mera Burgers vector ho gaya aur yeh mera tangent vector hai is direction mein to Burgers vector bhi is direction mein hai mera Screw Dislocation hai is tarah se maine Screw Dislocation ko mark kar liya aur yeh dusra $(\bar{1}\bar{1}1)$ plane yane ek {111} dusre type dusre family ka yane is family mein dusra plane yeh maine mark kar liya. Abhi kisi force ke karan yeh dislocation move hota hai maan lete kuch is tarah se move hua woh yahan par aayega aur phir ye Cross-Slip jab hoga to Cross-Slip yani yahan par is {111} plane mein move hua tha ab ye is plane par aa jayega yani kuch is tarah se move hoga to mere jo movement hai dislocation ke woh kuch is tarah se is (111) plane par tha phir woh Cross-Slip hoke yane usne apna slip plane change kar diya yeh slip plane pehle (111) tha aur change kar karne ke baad ye aa gaya $(\bar{1}\bar{1}1)$ to is jo process ko hum kahenge is process ko hum kehte hain Cross-Slip of Screw Dislocation. To ye Cross-Slip ho gaya Screw Dislocation ka.

Abhi jante kuch is tarah se FCC agar material mein mere paas {111} plane hai maan lete kisi tarah ka {111} plane hai aur is {111} plane par mere paas ek dislocation loop hai aur maan leta hoon main iska Burgers vector is direction pe is dislocation loop ka to aap dekhenge ki saare jagah par ye dislocation Burgers vector jo hoga woh ek hi direction mein hona chahiye isi direction mein hona chahiye aur tangent vector mein mark kar raha hoon kuch is tarah se agar main tangent vector is tarah se mark karunga to aap dekhenge ki yeh jo nature hai yahan par yahan par jo nature banega yeh banega mera Screw Dislocation to aap dekhenge ki yeh jo loop hai agar main stress apply karta hoon to kis tarah se badhna chahiye move hona chahiye to kuch is tarah se woh badhega ya humne dekha tha ki yeh jo loop ka dimension hai woh badhega yani yahan par iske movement honge kis tarah se movement honge humne dekha tha ki perpendicular honge hamesha jis location ka movement is tarah se perpendicular hoga aur yahan par aap dekhenge ki yeh mera tangent vector hai abhi bhi aur yeh mera Burgers vector hai is tarah se aur maan lete ki mere paas aur ek dusra ek slip plane hai kuch is tarah se yeh ho gaya mera $(1\bar{1}1)$ yahan par yahi condition hum dekh rahe to yeh jo part hai mere loop ka yeh kya hoga yeh Cross-Slip hoga Cross-Slip kis tarah se hoga kuch is tarah se hoga yeh yeh jo direction hai meri yeh $[10\bar{1}]$ hai yahi direction hum maan ke chal rahe hain Burgers vector ke direction hai yahan pe aur yeh Cross-Slip hoga to kuch is tarah se Cross-Slip hoga aap dekhenge ki yeh jo part hai is dislocation is dislocation loop ka yeh Cross-Slip ho gaya kyunki yeh yeh Screw nature tha yahan pe to yahan pe yeh Cross-Slip ho jayega yeh Screw part agar aap dekhenge agar main stress phir se apply kar raha hoon to yahan pe dislocation motion hoga aur yeh jo loop hai kuch is tarah se aage badhega aur aap dekhenge ki yeh jo part hai yahan pe aage badhega kyunki hum mera yahan pe main tangent vector nikal leta hoon ye tangent vector kuch is tarah se hi rahega aur mera Burgers vector isi direction mein hai yahan pe bhi to ye dislocation loop ka motion is tarah se hoga aur yeh jo part hai jo Screw part hai Screw part hamesha Cross-Slip karega to aap dekhenge ki agar yeh mera $(1\bar{1}1)$ hai is jo part ye yahan par jo hua yahan par is part ko main kahunga Cross-Slip yeh jo event hua yahan par isko main kahunga Cross-Slip yeh jo event tha yeh Cross-Slip hai mera abhi yahan par bhi ek Cross-Slip hua hai to aap dekhenge ki yeh jo dusra plane maine draw kiya hai (111) yeh mere original jo primary plane hai (111) isse parallel hai to agar yeh Cross-Slip ke original plane mein aa raha hai agar hum dekhenge jab original plane ki jab main baat karunga to {111} plane kaise kis tarah se rahenge mere {111} plane is tarah se stack rahenge agar to yeh mere saare {111} planes hai agar main is tarah se maan raha hoon aur Cross-Slip hoke hum dekhenge ki is tarah se kuch dusra {111} plane tha yeh main maan

leta hoon $(1\bar{1}1)$ plane hai to mera loop yahan par tha loop cross hoke yahan par aa gaya phir ye phir ye mera original plane hai yeh cross hoke yahan pe aa gaya loop aur loop phir se yahan se move hoga is tarah se to yahi scenario maine yahan pe mark kiya hai to yeh dekhenge ki yeh jo process hai isko main kahunga Double Cross-Slip. Yeh mera Cross-Slip tha aur isko kahunga main Double Cross-Slip. Double Cross-Slip kya hota hai ki yani pehle Cross-Slip hoke phir se ek baar Cross-Slip ho par woh original ya primary slip plane pe ho raha hai us process ko main kahunga Double Cross-Slip.



Abhi hum Edge Dislocation ke baare mein janenge. To humne dekha tha ki jo Screw Dislocation hoga woh Cross-Slip karega par Edge Dislocation Climb process karta hai to Climb process hum janenge thoda aur detail mein hamare aage ke classes mein but yahan par hum thoda jante hain ki Edge Dislocation Climb yani kya hota hai. To yahan par hum dekhenge ki yeh mera Edge Dislocation hai yahan par marked hai aur jab main Edge Dislocation yahan par mark kar raha hoon to ye mera extra half plane hai aur ye mera slip plane hai to ye mera slip plane ho gaya is tarah se kuch maine mark kar diya. Jab hum Climb ki baat karte hain to Climb hota hai hamesha certain high temperature par high temperature yani temperature greater than $0.4T_m$ isko bhi likh lete hain hum to yeh milega mujhe greater than $0.4T_m$. T_m ka kya hai T_m yeh mera Melting Point hai alloy ka ya metal ka ye mera melting point hai yani $0.4T_m$ ke around ya upar mujhe Climb dikhta hai yani dislocation ka Climb dikhta hai yani Edge Dislocation ka Climb dikhta hai. To jante hain kaise hota hai to aap dekhenge ki at high temperatures kuch vacancies yani equilibrium concentration of vacancies rehte hain maan lete hain yahan pe kuch vacancy taiyar ho gayi to kya hoga is vacancy ki wajah se aur hum high temperature pe hain to kuch atoms diffuse honge to hum dekhenge ki kuch items yahan par jaise maan liya yahan se maine dekha ki ye items yahan par yahan diffuse ho gaya to aap dekhenge ki ye abhi mera extra half plane ho gaya aur phir se diffusion hoga to aap dekhenge ki yeh mera extra half plane hoga ye kuch atomic arrangements ho gaye aur aap dekhenge ki slip plane mera abhi yeh ho gaya initially mera slip plane yeh tha abhi diffusion aur vacancy create hua aur diffusion hua uske wajah se mera slip plane yahan ho gaya to aap dekhenge ki mera dislocation kahan move hua yahan par tha pehle initially phir woh above move hua isko kehte hain hum Climb Up isko kehte hain Positive Climb aur Climb Up. Yeh ho gaya

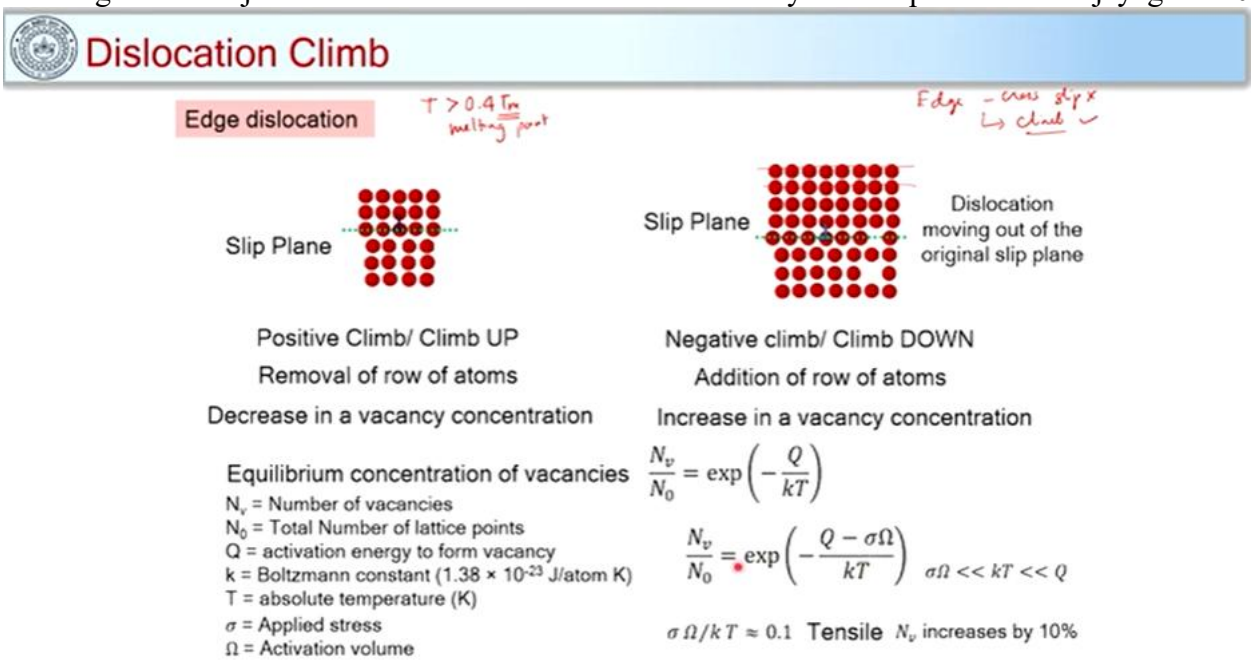
mera Edge Dislocation ka Climb Up aur Climb Down abhi aap samajh sakte ki agar Edge distribution Climb Up hota hai to Climb Down bhi ho sakta hai yani Positive Climb hai to Negative Climb bhi hai.

To aaiye jante hain ki Negative Climb hota kya hai. To maan lete hain mera dislocation hai yahan pe dislocation aap dekh payenge yahan pe extra half plane hai ye ne ise mark kar diya aur yeh mera slip plane hai yahan pe. To agar is tarah se kuch mera dislocation hai aur hum high temperature pe hai high temperature pe kya hogi vacancy taiyar ho gi to maan lete hain yahan par kuch vacancies taiyar ho gayi aur abhi atomic diffusion bhi honge kyunki hum high temperature hai pe hai to high temperature pe diffusion ek dominant mechanism hai to yahan par kuch aisa atomic diffusion ho gaye kuch atomic movements aur ho gaye aur aap dekhenge kuch is tarah se atomic arrangements ho gaye to aap dekhenge ki yahan par yeh jo plane hai yeh jo plane hai yeh mera extra half plane ho gaya aur aap dekhenge ki main keh sakta hoon ki mera dislocation Climb Down ho gaya aur yeh jo plane hai yeh mera slip plane ho jayega naya slip plane ho jayega. To yahan par main keh sakta hoon yeh Negative Climb hai ya isko kahenge Climb Down. To yeh Negative Climb aur Climb Down kehte hain ise. To hum Climb kis process ko kahenge Positive ya Negative Climb ko. To Climb isko kehte hain ki agar dislocation move ho raha hai kahan move ho raha hai apne original slip plane se out of the slip plane yani ye ye dekha agar yeh movement hai yeh mera original slip plane hai aur yeh move hua ye above tha yeh neeche aa gaya ye neeche tha yeh above aa gaya yani out of the slip plane but yeh jo slip planes hai ye parallel slip planes hai aap dekhenge ki dislocation ka movement hai parallel slip planes pe ho raha hai ya ye Climb Up ho raha hai aur Climb Down ho raha hai ye agar aap samjhenge is tarah se ye jo plane ye ek hi type ke planes hai. To yeh jo planes hai yani mera dislocation Climb Up aur Climb Down moving out is called Climbing of an Edge Dislocation. To yeh ho gaya mera Edge Dislocation ka Climb.

To humne dekha tha ki Edge Dislocation mera Cross-Slip nahi karta hai is dislocation hamesha Climb karega hum dekhenge ke baare mein isko summarize bhi karenge but yahan par hum Edge Dislocation hi Climb kar sakta hai yahan par hum dekhe dekhe the ki yahan pe Removal of Row of Atoms tha yahan par maine vacancy taiyar ki thi aur hum dekhenge ki yahan par jo atoms the yahan par jaake diffuse ho gaye the. To yahan pe Removal of Row of Atoms aur yahan par hum dekhenge Addition of Row of Atoms ya hum yahan par dekhenge ki decrease in vacancy concentration jo vacancy yahan par create hui thi jab Climb Up ho raha hai tab yahan par vacancy concentration meri decrease hui thi. Jab Climb Down hoga to aap dekhenge yahan par increase in vacancy concentration humne ek vacancy yahan par create ki thi aur yahan par dekhiye abhi jo vacancies taiyar hui yahan par do vacancies yahan par taiyar hui hai to hum dekhenge ki jab Climb Up aur Climb Down hota hai to yeh jo process hai isme vacancy concentration ghatega ya badhega. To yahan par yeh jo schematics hai aap aasani se samajh sakte ki vacancy concentration kis tarah se ghat-ta hai ya badhta hai.

Ab hum dekhenge ki yeh jo vacancy ki baat kar rahe the hum to yeh equilibrium concentration of vacancies hoti hai aap dekhenge ki vacancy ek defect hai jo temperature ke saath equilibrium concentration mein exist karti hai yani jaise jaise main temperature badhata hoon waise waise mera vacancy concentration badhta hai yeh aap is vacancy defect ke baare mein padhenge to aapko pata chalega. To kuch is tarah se hum likh sakte hain yeh jo thermal defect hai equilibrium defect hai to yeh meri number of vacancies ho gayi aur yeh mere total number of lattice points ho gaye mere crystal ke andar jo hai aur agar mujhe koi temperature pata hai aur mujhe yeh pata hai ki ek activation energy pata hai jo ek vacancy taiyar karne ke liye kya lagti hai to main nikal sakta hoon ki kisi bhi temperature par meri number of vacancies kya ho sakti hai is formula se main nikal

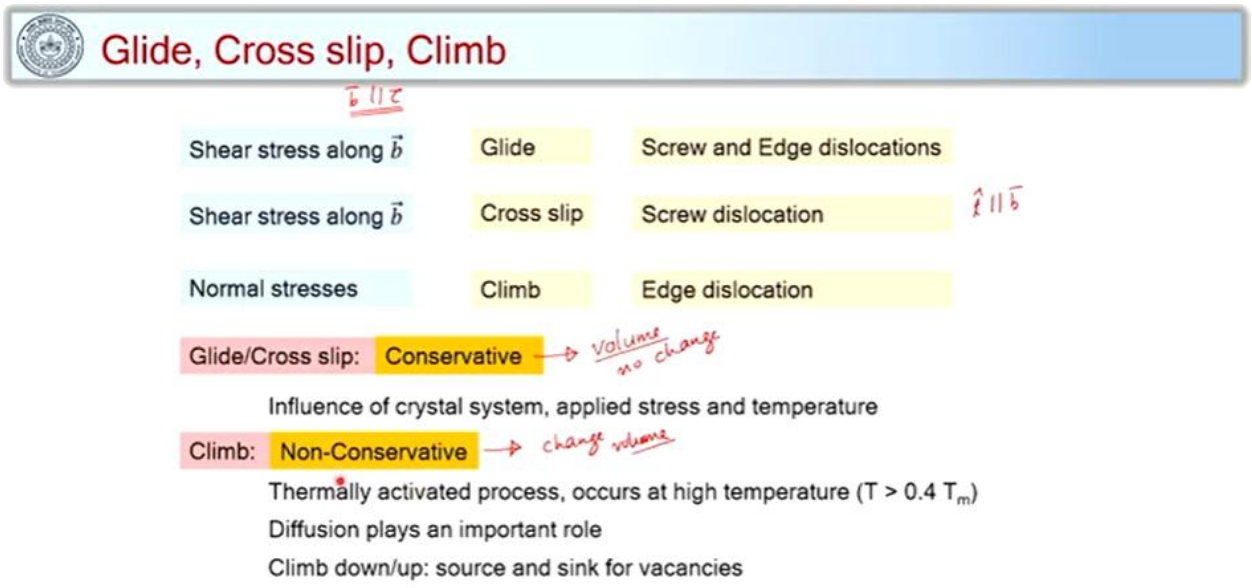
sakta hoon. Yeh ho gaya mera vacancy concentration kisi bhi temperature ke saath main is equations ke saath nikal sakta hoon. Aap dekhenge jab main stress apply karta hoon to ye jo vacancy concentration hai kuch is tarah se badhega aap dekhenge ki yahan pe ye jo activation energy hai ye agar main tensile stress apply kar raha hoon to ye jo stress hai is applied stress ke saath ek activation volume hoga yani jo volume activate hoga yeh mujhe help karega vacancy concentration badhane ke liye. To aap dekhenge ki par yeh jo $\sigma\Omega$ hai yahan pe sigma stress hai omega jo activation volume hai ye aap dekhenge ki ye much much smaller than kT aur much much smaller than Q hai ye condition yahan par main apply kar raha hoon iske baare mein hum baad mein padhenge par yahan par aap ye baat jaan lijiye jo ye jo hai activation volume jo hai Stress into Activation Volume ye jo product hai ye iska ratio agar main thermal energy ke saath lunga kT ke saath ye hum one hona chahiye close to 0.1 hona chahiye agar mera stress tensile hai to aap dekhenge ki jo number of vacancies hai yahan pe badh jayegi 10



Abhi hum summarize karte hain humne kya kya processes padhe the Climb, Cross-Slip aur Glide. To shear stress hamesha hoga along b direction to yahan par humein milega Glide. To humne dekha tha isko bhi hum likh lete ki humne hamesha dekha tha ki jo b jo hai agar woh parallel hai mere shear stress ke saath tabhi mujhe dislocation ka motion milta hai aap check kar lijiyega yeh part par jab shear stress along b hoga to mujhe Glide milega dislocation ka Glide aur dislocation Glide ke kis mein milta hai mujhe mujhe Screw mein bhi milta hai aur Edge mein bhi milta hai. Glide jab main baat kar raha hoon to yani movement of dislocation on slip plane yani kisi bhi slip plane pe dislocation ka movement isko hum kehte hain Glide. To mujhe Screw aur dislocation mein Glide milta hai yahan par same condition main apply kar raha hoon aur jab main Cross-Slip ki baat kar raha hoon tab mujhe sirf Cross-Slip milega Screw Dislocation mein Edge Dislocation mein Cross-Slip nahi milega iske liye kya zimmedar hai kyunki jo mera tangent vector hai Screw Dislocation mein woh hamesha parallel rahega Burgers vector ke saath. To main yahan yeh jo combination hai woh kisi bhi slip plane mein dislocation ko move kar sakta. Teesri condition hai agar normal stresses hai jo humne dekha tha ki tensile stresses se vacancy create ho rahi hai normal stress jab act kar rahe tab mujhe Climb milta hai Edge Dislocation ka. To Climb mujhe hamesha milega Edge Dislocation mein yeh dekhenge ki normal stress kis tarah se affect karta hai Climb

ke dwara hum baad mein dekhenge apne course mein hi aur yahan ke liye yeh summarize kar deta hoon yeh mere paas teen motions hai Glide, Cross-Slip aur Climb.

Abhi hum dekhenge Glide jo Cross-Slip hai woh kis kis par depend karegi woh depend karegi meri Crystal System par Applied Stress par aur Temperature par. Aap dekhenge ki jab crystal system let's say mere paas FCC tha to usme aasani se Cross-Slip hoti hai aur BCC mein Cross-Slip aasani se nahi hogi. To yeh depend karta hai mera crystal system, applied stress aur temperature ke saath. Climb jab hum dekhenge to Climb meri ye thermally activated process hai yani humne dekha tha ki temperature agar $0.4T_m$ se zyada hai to mujhe Climb milta hai to yani humne dekha tha ki diffusion yahan par Climb mein important role play karta hai. Humne dekha tha ki Climb Up aur Climb Down yeh act karega mere source aur sink of vacancy humne dekha tha ki vacancy concentration badhta hai ya ghat-ta hai jaise Climb Up ya Climb Down hota hai. To yeh jo process hai Glide aur Cross-Slip isko hum kehte hain Conservative Process. Yeh jo process hai Glide aur Cross ye do process hai isko hum kehte hain Conservative Process. Yeh jo process hai isko hum kehte hain Non-Conservative Process. Yahan par ye jo word hai Conservative ye textbooks mein is tarah se istemaal hota hai yani yahan par jo Conservative process hai yahan par jo volume hai woh conserved hota hai yani change nahi hota hai no change ye volume mera conserved hota hai jab mera dislocation motion hota hai. Yeh Non-Conservative yani yahan par change hoga volume aap is tarah se samajh sakte hain ki maine bola tha jab Climb hota hai tab Climb Down aur Climb Up hota hai to yeh vacancies ko generate karega ya annihilate karega to vacancy concentration ye ghatega ya badhega. Jab vacancy concentration ghat-te badhte tab aap dekhenge ki volume wahan par change hoga jab volume change hoga to isliye is process ko hum Non-Conservative kehte hain.



To abhi humne is part mein dekha teen processes isko summarize kar leta hoon main mere paas kaun se kaun se motions the dislocations ke. Dislocation ke motion se Glide, Cross-Slip aur Climb. Yeh mere teen process hai Glide aur Cross-Slip mujhe milte hain Edge aur Screw dono mein aur Glide mujhe mil Glide mujhe milega Edge aur Screw dono mein. Cross-Slip mujhe milega sirf Screw mein aur Climb mujhe milega sirf Edge mein.

Abhi next part mein hum janenge ki yeh jab dislocation motion hote hain to plastic strain kya develop ho sakta hai material mein. Abhi abhi ke liye yahan par rukta hoon. Dhanyavad.