Mechanical behavior of materials

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Partials Dislocations and Stacking Faults in FCC

Mechanical Behavior of Materials (Hindi)

Partial Dislocations and Stacking Faults in FCC

Namaskar phir se swagat karta hoon aapka is course mein jiska naam mechanical behavior of material hai isko hum hindi mein padhenge abhi tak hum strain hardening ke baare mein jaan rahe the aur dislocations ke motions ke baare mein jaan rahe the usi ke sandarbh mein aaj hum jaanenge ki stacking faults kya hote hain yeh hum FCC crystal mein dekhte hain aur partial dislocations ka kya role ho sakta hai strain hardening ke prati to abhi jaante hain pehle ki stacking faults kya hote hain FCC mein to pehle FCC structure ko dekhte hain hum to ek mera FCC structure yaani mera cubic structure hai aur cubic structure mein mere paas kuch atoms is tarah se hain to yahan par kuch maine atom mark kar diya ye isko main origin ek atom mark kar raha hoon aur kuch atoms main is tarah se mark kar raha hoon jahan pe yeh atoms corners pe hai aur yeh atoms mere face centers pe hai to yeh ek mera ek 111 type plane hai aur dusra ek 111 type plane agar main mark karunga to kuch is tarah se atoms rahenge corners pe aur face centers pe to isko bhi hum mark kar sakte hain isko maine kuch red color se mark kiya aur ek atom yahan pe corner pe to yeh ye yeh mera FCC structure hai aur yeh mere saare jo structure jo bana hai yeh mere 111 plane se bana hai yeh different colors isliye mark kar raha hoon kyunki aapko pata chalenge ki ye jo atoms hai yeh different 111 planes par hai ya stacking hai stacking yaani inki sanrachna is tarah se ek ke upar ek

yeh rakhe hue 111 planes hai agar main kuch is tarah se rakhunga to mujhe ek FCC structure milega aaiye jaante hain ki 111 planes hai kya to yeh planes humein isliye study karne hain kyunki humne dekha tha ki slip system jo hai mere FCC mein yeh hota hai slip jo hota hai wo 111 plane pe hota hai aur along $a/2\langle 110\rangle$ direction pe hota hai yaani {111} family of planes pe hota hai aur yeh $\langle 110\rangle$ direction ke along hota hai to yeh mere different 111 planes hai to aaiye jaante hain kaun se kaun se mere 111 planes hai to yeh mera burgers vector ho gaya is direction par to humne dekha tha shortest lattice translation jo vector hai FCC mein yeh mera $1/2\langle 110\rangle$ hai aur yeh mera burgers vector hoga aur ya slip direction hogi.

To mark karte yeh mera jo pehla plane hai blue plane yeh is tarah se mark kiya maine yeh jo atomic arrangement se is plane pe yeh maine A layer mark ki hai yahan pe usi tarah se red mein jo mark hai wo meri B layer hai aur C jo mein mark hai wo meri C layer hai abhi is atomic arrangement is ko main kuch is tarah se dekh raha hoon jaise agar main A layer mein mark karunga to mere paas ye A yaani ye ek type ka 111 plane hai aur yeh jo plane hai yeh close packed hai yaani truly close packed plane hai aap dekhenge ki saare atoms agar main hard sphere model consider kar raha hoon to saare atoms ek dusre ko touch ho rahe hain abhi iske agar humein direction mark karoon slip direction to slip direction meri kuch is tarah se hogi yahan pe $1/2\langle 110\rangle$ yaani center to center jo distance hai atoms ka wo jo shortest lattice translation vector hai ye meri $\langle 110\rangle$ direction hogi jaise yahan se aur yahan tak main mark karunga is atom se is atom ke center tak ye bhi meri $\langle 110\rangle$ direction hogi abhi jaante hain ki iske upar ye mera 111 plane hai aur main kuch is tarah se dekh raha hoon is ye jo plane hai ya ye jo direction hai ye meri 111 direction hai agar main diagonal direction se is structure ko dekhunga to mujhe 111 plane kuch is tarah se dikhai denge abhi main yeh jo B atom hai yeh kuch yeh teen atom hai inke beech mein jo jo cavity hai ya jo space bani hai yahan par mera yeh B atom ya B atomic B atoms ya B layer par jo atoms hai wo reside karenge ya rahenge rukenge to ye meri B position hogi B atomic layers ki position hogi mere A atomic layer pe to isi tarah se yeh meri B atomic position se maine bataya ki ye jo spacing hai yahan pe aur yahan pe ye meri B atomic planes pe jo atoms hai unki positions hai ye usi tarah se C atom mera kuch is tarah se rahega to ye jo stacking hai stacking yaani ye jo parat bani hai yaani A ke upar B B ke upar C isko hum stacking kehte hain aur yeh ek stacking FCC mein peculiar stacking hai yaani ek vishesh stacking is tarah se agar hum karenge atoms is tarah se agar rachenge ek dusre ke upar to humein FCC structure milega kuch is tarah se to meri saari ABC ABC stacking is tarah se maine dekhiye FCC mein mark kar lete mere B atoms kuch is tarah se maine bataya ki is tarah se atomic position se to agar main yahan par dekhunga to yeh jo position hai yeh meri B atomic position hai aur yahan pe bhi meri B atomic position hogi aur yahan par bhi ek B atomic position hogi to is tarah se kuch meri B atomic position hai aur C atomic position agar main dekhunga to C atom mere B atoms ke jo center wala jo cavity hai ya space available hai wahan pe wo rahega C atom C atom yaani yahan pe C layers pe jo atoms hai wo yahan pe rahenge B ke beech mein to is tarah se kuch meri stacking hoti hai FCC mein 111 planes ki aur main is planes ko kuch upar se aise dekh raha hoon agar diagonally main yahan se dekh raha hoon ye meri $\langle 111\rangle$ direction hai to mujhe stacking milte hai ABC ABC yahan par agar main is tarah se kuch stacking karunga to mujhe FCC structure milega agar aap physical metallurgy ki koi bhi kitaab uthayenge to aapko kuch is tarah se aur ek stacking mil sakti hai AB AB to yeh stacking mujhe milti hai HCP crystal structure mein to abhi ke liye hum jaanenge ki mere paas yeh ABC ABC stacking hai jo FCC mein hai aur iska mahatva kya hai hum jaanenge slip mein to abhi hum dekhte hain ki yeh slip kis tarah se hota hai uske liye humein jaanna padega ki yahan pe partial dislocation aur Thompson tetrahedron ke construction ke dwara isko hum is tarah se jaante hain.

Dislocations and stacking sequence in FCC

{111}

$\frac{a}{2} < 110 >$

$\frac{a}{2} < 110 >$

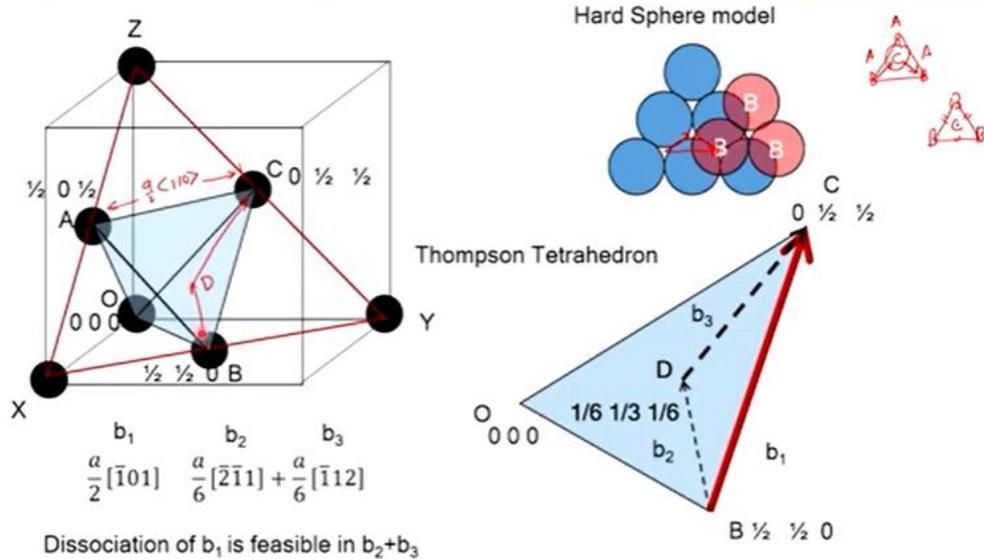$\{111\}\frac{a}{2} < 110 >$

..ABCABCABC... stacking sequence
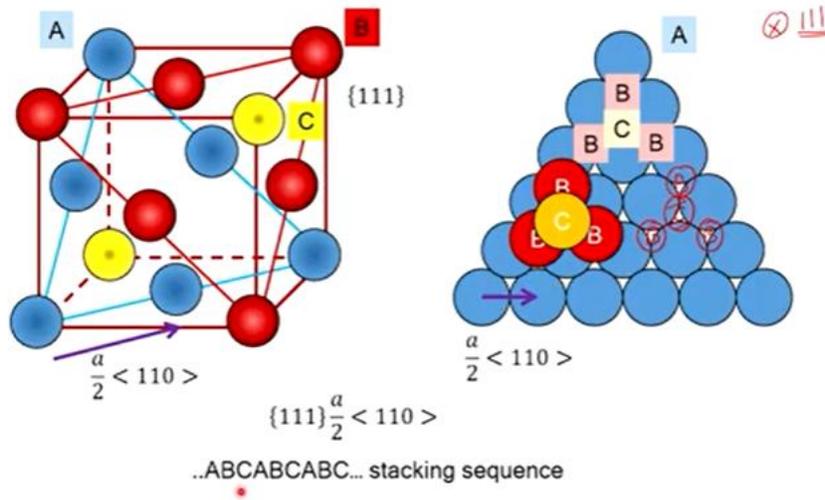
Yeh mera FCC structure hai yahan pe maine ek 111 plane mark kiya hai yahan pe is tarah se to yeh 111 plane mark kiya hai to aap dekhenge ki agar mera atom slip ho raha hai yaani ye ek plane hai ye A plane hai aur yeh B plane hai aur main hard sphere model consider kar raha hoon to aap dekhenge ki ye B plane kuch is tarah se mark tha ye mera A plane hai aur ye jab slip hota hai to ye B atom position maine bataya ki yahan pe B atom positions kahan pe hai kuch is tarah se aur is A layer pe kuch is tarah se hai to jab ye slip hoga to yaani translation hona chahiye kuch burgers vector ke dwara to ye B atom apne B position pe hi jaana chahiye to maan lete hain ki B atom kuch is tarah se slip ho raha hai is tarah se glide ho raha hai yahan se yahan tak to yeh jo distance hai isko bhi mark kar lete hain yeh jo distance hai B se B tak yeh tha mera $a/2\langle110\rangle$ par abhi hum dekhenge ki yeh jo atomic layers hai ya yeh slip kuch is tarah se hote hain phir se dekhenge yeh yahan se yahan jayenge aur yahan se yahan jayenge to kuch is tarah se hum dekhenge pehle to atom yahan se yahan glide ho raha tha abhi jo atom ek layer hai B layer hai wo A layer pe kuch is tarah se glide ho gayi yaani seedhe yahan se yahan tak na jaate hue yahan se ye split hoga yeh dislocation ya is tarah se mujhe kuch is tarah se movement milegi B layer ki mere A layer pe to isko hi hum slip kehte hain atomic planes ka movement ek dusre ke upar fisalna isko hum slip kehte hain to mujhe slip direct nahi mil rahi hai mujhe slip kuch is tarah se jaake mil rahi hai aur humne dekha tha ki yeh jo position hai meri yeh meri C position hai hum dekh sakte hain ki mere paas ye position is tarah se the aur uske upar mere paas B position the kuch is tarah se aur inke upar ek C position thi to aap dekhenge yahan par yeh jo B layer hai wo kaise glide ho rahi hai B se B to glide ho rahi hai par wo C layer ke through ja rahi hai kuch is tarah se ja rahi hai is tarah se fisal rahi hai abhi hum isko hi jaanenge partial dislocations ke dwara to main is structure mein kuch atoms yahan par maine remove kar diye clarity ke liye to abhi hum sirf yeh atoms consider karenge aur kuch is tarah se construction karenge humne kya kiya ye origin wala ek atom hai aur yeh jo teen face centers pe jo atoms hai inko humne connect kar diya aur yeh jab hum connection karenge is humein ek tetrahedron milega us tetrahedron ko kehte hain hum Thompson tetrahedron to ye ho gayi meri construction Thompson tetrahedron ki to ye maan lete hain ki humne iske ye points vertices kuch is tarah se mark kar liye O A B aur C iske agar main coordinates kuch is tarah se mark kar loon X Y aur Z direction to mere paas kuch iske coordinates A point ke (1/2,0,1/2)

aayenge origin ka to (0,0,0) rahega B ka (1/2,1/2,0) rahega aur C ka (0,1/2,1/2) rahega to ye maine coordinates mark kar liye abhi jaanenge hum is construction ke dwara kis tarah se yeh jo slip hai isko hum samajh sakte hain.

To maine abhi ek plane consider kiya yahan par is tetrahedron ka Thompson tetrahedron ka O B aur C yahan par maine O B aur C is tarah se mark kiye aur yahan par uske coordinates bhi mark kiye humne dekha yeh jo B aur C hai yeh meri yeh is Thompson tetrahedron mein ye jo saare jo direction hai ya saare jo edges hai yeh meri burgers vector hai yaani yeh saare $a/2\langle 110\rangle$ type wale vectors rahenge to yeh saare saare jo edges hai is Thompson tetrahedron ki kuch is tarah se rahenge abhi humne yahan par dekha ki yeh jo hai slip jab hota hai B layer ka A layer ke upar to ye burgers vector se translation hona chahiye to main maan leta hoon ek B position hai yahan pe aur C position hai ye bhi meri ek burgers vector hai yaani yeh bhi distance jo hoga wo $1/2$ $a/2$ $a/2$ 110 hoga to yeh jo distance hai wo B aur C ka yeh $a/2$ 110 type hoga to mera jo slip ho raha hai wo B se C C hona chahiye par agar yahan par humne dekha ki kuch humein is tarah split mil raha hai yaani jab hum glide karenge to yeh kuch C position pe jaake phir C position se B position pe aa raha hai kuch is tarah se humne dekha yahan par to isko mark kar lete hain yahan par hum dekhenge ki C position jo hai yahan par B layer mein koi atoms nahi the to yeh jo split hoga is vector ka kuch is tarah se hoga aur yahan par humne mark kar liya kuch is tarah se is tarah se split hoga to agar hum yahan pe dekhenge to mere atoms se B atom kuch is tarah se ja raha hai beech mein aur yeh kuch is tarah se ja raha hai C position pe agar hum geometry dekhein to yeh jo C position hai wo is triangle ki centroid hai yahan pe humne centroid mark kiya centroid position hai to yeh jo position humne mark ki yahan pe yeh exactly centroid pe hai to yeh jo point hai ye mera D point hai yahan pe maine D point mark kar liya aur agar ye centroid hai to humein pata hai ki centroid jo is vector ko split karega 2: 1 mein ratio mein split karega aur jo distance hai wo centroid se wo vertices ka equal rahega is direction mein agar main is [sangeet] mein dekhunga to ye to equilateral triangle ho gaya aur ye jo C position hai wo exactly centroid position aapko milegi aur agar D agar centroid hai to uske coordinates main is tarah se nikaal sakta hoon $(a/6,1/3,1/6)$ to $a/6$ $1/3$ aur $1/6$ abhi hum iske mujhe saare coordinates pata hai to main vectors nikaal sakta hoon to main is tarah se nikaalunga isko main b_1 Keh raha hoon isko main b_2 Keh raha hoon aur isko main b_3 Keh raha hoon to main kuch is tarah se dekh paa raha hoon ki yeh jo dislocation hai b_1 Yeh do vectors mein split ho raha hai b_2 Aur b_3 To b_1 Jo hai wo vector summation hai b_2 Aur b_3 Ka to main b_1 Kuch is tarah se nikaalunga b_1 Mera aa jayega agar aap nikalenge isko to ye $a/2[\bar{1}01]$ aayega aur b_2 Aayega mera $a/6[\bar{2}\bar{1}1]$ aur b_3 Aayega $a/6[\bar{1}12]$ aap karke dekh sakte hain to agar main B to C agar consider karunga to ye $C - B$ ke coordinates karunga to mere paas b_1 Ka vector aa jayega aur humein pata hai ki hum isko likhenge lattice parameters ke hisaab se to hum main usko $a/2[\bar{1}01]$ likh sakta hoon to agar main dekhunga ki yeh sawal ek simple aata hai ki yeh b_1 Is do vectors mein kyun split hona chahiye to abhi hum dekhenge ki yeh mera dislocation hai agar dislocation split ho raha hai ya dissociate ho raha hai b_2 Aur b_3 Mein ye humne dekha tha ye kab hota hai jab iski energy b_1 Ki energy b_2 Ke energy yaani is path ki energy jo hai yaani b_1^2 Jo hai $b_2^2 + b_3^2$ Se bada ho tabhi yeh possible hai tabhi yeh sambhav hai to yahan par hum dekhenge ki yeh b_1 Ki energy agar hum nikalenge aur b_2 Aur b_3 Dono ki individual energy nikalenge to hum humein dekhenge ki dissociation yeh b_1 Ka possible hai b_2 Aur b_3 Mein to isiliye yeh jo slip ho raha hai wo direct yahan se yahan na hote hue wo is process se ja raha hai yaani mera B atomic layer jo hai wo C position pe aayega aur C position se mere B position pe aayega to iske wajah se kya hota hai hum yeh dekhenge to yeh jo vector hai b_2 Aur b_3 Ye mera partial dislocations hai aur yeh jo b_1 Hai ye mera perfect dislocation hai perfect dislocation kyun hai humne dekha yahan pe B se C ja raha hai

to main ek lattice translation se ek lattice position se dusre lattice position to ye mera lattice translation vector hai isliye ye mera perfect dislocation hai agar D position pe hum dekhenge to yahan pe actually koi atom nahi hai ya to isiliye ya is plane mein koi actually atom nahi hai to isliye hum isko partial dislocation kehte hain abhi jaante hain ki iske wajah se kya hota hai uske wajah se ek stacking fault taiyaar hoga isko hum samajhte hain.

Partial dislocations & Thompson Tetrahedron

b_1 b_2 b_3

$$\frac{a}{2}[\bar{1}01] \quad \frac{a}{6}[\bar{2}\bar{1}1] + \frac{a}{6}[\bar{1}12]$$

Dissociation of b_1 is feasible in b_2+b_3

To mere paas ye ideal stack mere paas FCC mein ye A atom layer hai uske upar B atomic layer hai aur ek C atomic layer hai inke stacking se mujhe FCC structure milta hai to yahan par maine do stacking yahan par mark kiye yeh A stacking hai neeche mein uske upar meri B stacking hai to agar aap dekhenge yahan par yeh jo position hai yeh meri A stacking layer hai aur yeh meri B hai yeh jo region hai yahan par is plane par agar yeh mera ideal structure hai FCC ka to yeh B position ye continuous hoti yahan pe par yahan pe agar yeh atomic positions agar main consider karunga to actually mere paas B atomic position kuch is tarah se honi chahiye thi yahan pe meri B atomic positions honi chahiye thi to yahan pe dekhenge ki yeh atom position yahan pe shift hua hai color change kar leta hoon to yahan pe yeh B atom positions yahan se yahan change ho raha hai aap dekhenge ki yahan se yeh meri B atom position thi wo yahan se yahan change ho rahi hai yahan se yahan change ho rahi hai ya yahan se yahan change ho rahi hai to aap dekhenge ki yeh B layer yahan pe is direction mein move hui hai to aap dekhenge ki yeh jo position hai yeh meri C position hai aap agar dekhenge yeh jo C position hai agar main is tarah se mark karoon yahan par C hai yahan pe C aayega yahan pe C aayega aur ye yahan pe aayega to ye meri saari jo positions hai wo meri C positions hai saari positions yahan se aap dekhenge ye shifted hai yahan pe is is direction mein usi tarah aap dekhenge ki yeh yahan par aap dekhenge is direction pe to yeh jo positions hai to yeh main is tarah se keh sakta hoon yeh agar yahan se yahan shift hoti yahan se yahan shift agar ye atoms hote to yeh mere B positions aa jayenge actually yeh jo position hai jo maine arrow se mark kiye yeh saari meri B positions hai to yeh to sahi stacking hai yahan par is region par is region pe bhi sahi stacking hai meri yaani A ke upar B hai par yeh jo beech wali jo region hai yahan par aap dekhenge ki atoms yahan par shifted hai aur shifted kis direction pe yeh jo B atoms hai yeh shifted hai C position par yaani yeh yahan par yahan par kuch movement hai atoms ki is region mein to yeh jo position hai yeh meri C position hai to isko mark kar lete dusre color se yeh

meri hogi C position yeh to yeh jo region hai actually kuch is tarah se hona chahiye tha yahan par complete agar yeh ideal structure hota to yahan par ye complete plane jo hota yeh B atoms ya B atomic layer se bana hona chahiye tha par beech mein mera C atomic layer aa gaya to ye mera C atomic layer hai to yahan par ho gaya ye fault taiyaar ho gaya to yeh movements kuch is tarah se agar ye aap dekhenge ye B atomic layers humne bola tha ki yeh B atomic layers yeh fault isliye taiyaar hua hai kyunki B atomic layers is direction mein moved hai to is direction mein moved hai yaani C atomic positions pe aa gayi hai actually ye yahan se agar yahan move hoti to shayad se yeh fault nahi hota par ye partially moved hai partial dislocations ki movement ki wajah se ye yahan pe aa gayi agar isko phir se fault region ko nikalna hai to mujhe yahan se is atoms ko yahan tak move karna padega to tab jaake fault remove hoga par abhi ke liye to sirf ye yahan par is direction mein move hai to isliye yeh faulted region hai aur yeh mera agar ye perfect dislocation se move hota B layer A layer ke upar to koi fault nahi taiyaar hota par agar yeh partially moved hai to ek fault taiyaar ho gaya yahan pe aur aap dekh payenge yahan pe meri kuch dislocation lines maine mark ki hai yeh do dislocation line mark kiye aur mera jo displacement hai yahan par maine kuch is tarah se mark kiya is tarah se b_2 Aur b_3 Se to agar main b_2 Se move kar raha hoon mera atomic layers ko B atomic layer ko to mera fault taiyaar hoga agar main b_3 Se phir se wapas karunga to yeh fault chala jayega to ab dekhenge yeh b_2 Ko kehte hain hum Leading partial aur b_3 Ko kehte hain hum Trailing partial leading partial isliye kyunki jab main b_2 Se movement karunga tab yeh fault taiyaar karega agar main b_3 Se wapas move karunga is atomic layer ko is direction mein to yeh fault remove karega to isliye b_2 Leading partial hai aur b_3 Trailing partial hai aur yeh jo surface hai yeh surface yahan pe yeh plane hai to yeh surface ho gaya to isliye yeh 2D aur surface defect hai ya isko bhi planar defect bhi kehte hain to mera stacking fault jo hai wo ek planar defect hai abhi stacking fault kahan pe hai to yeh hai mera stacking fault jo do partials ke beech mein hai to partial dislocations ke beech mein leading partial aur trailing partial inke beech ka jo region hai isko hum stacking fault kehte hain ab ye stacking fault kis tarah se hai agar yahan pe agar dekhenge agar ye mera unfaulted region hai yahan pe koi defect nahi hai to aap dekhenge ki stacking meri C ABC ABC kuch is tarah honi chahiye thi yahan pe bhi meri stacking jo rahegi C ABC ABC is tarah se stacking honi chahiye aur yahan pe aap dekhenge yahan pe C aur iske baad A hai aur A ke upar mera phir se C aa gaya aur agar yeh faulted region ye unfaulted region ke upar agar hum dekhenge to yahan pe phir se C aayega to aap dekhenge ki kuch is tarah se C C ABC is tarah se faulted region taiyaar ho gaya mera to yeh ho gaya mera faulted region aur isi ko hum kehte hain stacking fault.

Stacking fault in fcc
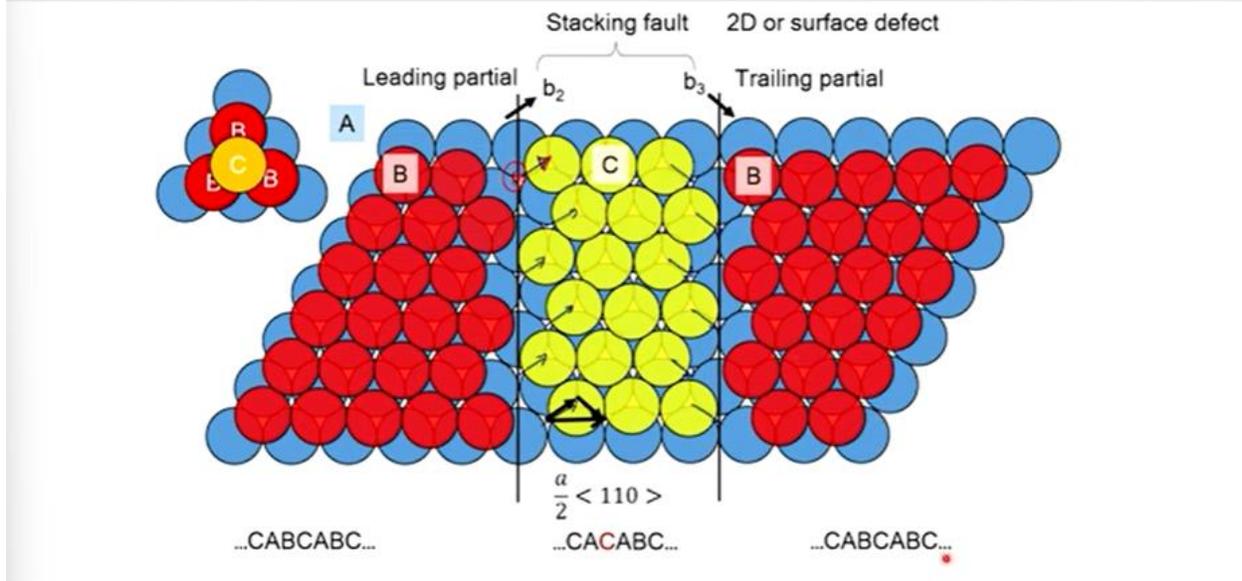
Abhi jaante hain ki stacking fault ke baare mein aur cheezein jaante hain to stacking fault kisliye taiyaar hua kyunki mera ek ye jo perfect dislocation tha ye do partials mein dissociate ho gaya in do partials ko hum kehte hain Shockley partials abhi ye dissociation kyun hona chahiye kyunki agar hum energy calculate karenge to kisi bhi dislocation ki energy hum calculate karenge humne formula dekha tha ki $\alpha G b^2$ Agar main iska square karunga yaani jo energy hai wo proportional rahegi b^2 Ke so iski energy aayegi $\alpha G a^2/2$ iski energy aayegi $\alpha G a^2/6$ aur iski energy aayegi $\alpha G a^2/6$ agar hum dono ki energy add bhi karte to humein yeh milti hai $\alpha G a^2/3$ jo ki choti hai ya kam hai is energy se $\alpha G a^2/2$ to yeh humne dekha tha ki dislocation dissociate kab hota hai jab yeh criteria hoga yaani b_1^2 Greater rahega $b_2^2 + b_3^2$ Se to isliye yeh split hoga par split hone ki wajah se ya dissociation hone ki wajah se mujhe ek fault mil raha hai wo hai stacking fault to yeh jo dissociation hai wo straight forward nahi hai to yahan par to meri energy bach rahi hai par hum dekh sakte hain ki agar hum energy balance karenge to yahan par agar meri energy kuch bach rahi hai dislocation ki to wo energy manifest honi chahiye aur create honi chahiye aur wo create hoti hai stacking fault ke dwara tabhi jaake mera energy balance hoga to yeh jo stacking fault hai wo jab yeh energy jab dislocation dissociate ho raha hai jahan yahan pe jo energy bachegi wo create karegi ek stacking fault ko aur stacking fault energy ka unit agar hum dekhenge isko hum represent karte hain γ_{SF} Iska unit hai milli joule per meter square yaani humne dekha tha ki ek surface defect hai to aur agar hum energy ki baat karenge us surface se associated uski rahegi energy milli joule aur normalize karenge uske area se to meter square to yeh rehti hai hamari stacking fault energy ki unit to aaiye jaante hain ki ye dislocation jab split hota hai b_1 Se ya dissociate hota hai b_2 Aur b_3 Mein to kuch is tarah se hota hai to maine dekha dikhaya tha ki yeh dissociation is tarah se hota hai ye mera leading partial hai mera trailing partial hai yahan pe ek mera faulted region rahega to maan lete hain inke beech ka jo equilibrium distance hai d isko maine is tarah se mark kiya hai aur maan lete hain iski jo length hai is dislocations ki dislocation ki line ki jo length hai usko main maan leta hoon L aur yeh jo region rahega yeh mera rahega stacking fault aur iski kuch energy rahegi associated usko main likhunga γ_{SF} Se yahan pe mark kar lete hain ye jo energy rahegi isse associated ye rahegi γ_{SF} To abhi main is jo partials hai main inko is tarah se decompose kar sakta

hoon kuch is direction mein is agar ye mere tangent vector hai to main kuch is tarah se split kar sakta hoon yeh ho gaya mera screw component b_2 Ka aur yeh mera ho gaya edge component yeh bhi yahan pe main isko b_3 Ko kuch is tarah se dissociate kar sakta hoon yeh ho gaya mera screw component kyunki ye parallel hai tangent line se aur yeh jo component hoga jo perpendicular hoga wo mera edge component hoga abhi aap dekhenge agar main screw aur edge components ki baat karunga to yahan par kuch force hoga force kaun sa hoga agar main is dislocation ko stationary maan raha hoon aur yeh dislocation move ho sakta hai to aap dekhenge ki yeh jo dislocation ki stress field rahegi yahan par yeh stress field ek force taiyaar karegi is dislocation ke upar aur wahi force ko maine kuch is tarah se likha hai to yeh force per unit length of dislocation hai aur yeh ho gaya mere edge components ke beech ka force aur yeh ho gaya mere screw components ke beech ka force to main kuch is tarah se likh sakta hoon aap dekh paa rahe honge ki yahan par jo screw component hai aur yahan par screw component hai dono opposite nature ke to inmein ek attraction hoga aur yeh jo hai yahan par yeh jo component hai aur yeh jo component hai yeh ho gaya mera edge component aur ismein ek repulsion hoga kyunki dono same nature ke abhi hum sirf glide force ki baat kar rahe hain yahan pe to glide force ki wajah se abhi sirf main edge aur edge component ke glide force ki baat karunga to aap dekh paa rahe honge yeh jo leading aur trailing partials maine taiyaar kiye yahan pe ek force of repulsion rahega between edge components kyunki screw components screw components ye cancel out karenge ek dusre ki stress field ko to abhi yahan ke liye main sirf consider kar raha hoon yeh jo edge dislocation hai yaani edge nature hai yahan pe leading partial ka aur yeh jo edge component hai trailing partial ka in dono ke beech ka to main kuch is tarah se likh sakta hoon ki force per unit length of dislocation mujhe pata hai aur mujhe dislocation ki length pata hai to main force calculate kar sakta hoon $F \times L$ to yeh repulsive force rahega aur yeh balance hona chahiye ek attractive force se to yeh jo jaise jaise in dono ka distance badhega aap dekhenge ki ye stacking fault ka area badhega aur stacking fault ka area agar badhega to stacking fault energy badhegi yahan pe to is stacking fault energy kya to material chahega ki stacking fault ya ya faulted energy na badhe yahan pe yaani ye region badhe nahi iska area badhe nahi yeh is tarah se force balance hoga to agar mere paas ye stacking fault energy pata hai material ki to agar main aur area is tarah se main calculate kar sakta hoon $L \times d$ aur is stacking fault energy ko main multiply karunga $L \times d$ area se to ek force mujhe mil jayega to yeh jo force hai wo ek attractive force dega to hum dekh rahe hain ki mere paas jo edge dislocation ke component hai edge components ke beech mein ek repulsive force hai aur jo stacking fault energy create hui hai uske wajah se ek attractive force taiyaar hoga kyunki material nahi chahega ki ek faulted region badhe to yeh do forces balance karenge aur yahi balance humne yahan par likha hai agar main usko solve karunga to mere paas ek kuch equilibrium distance aa jayega in dono partials ke beech mein yeh aa jayega F/γ_{SF} Aur agar main force nikalunga to force main kuch is tarah se nikaal sakta hoon $Gb_2b_3/2\pi$ aap isko calculate kar sakte hain do edge components ke beech mein ka force dono agar same slip plane par hai to to mere paas kuch is tarah se equation aa gaya aur main yahan par dekhunga ki γ_{SF} Versus d ka relation kya hai to aap dekh paa rahe honge ki jaise jaise γ_{SF} Badhegi waise waise ye jo d hai wo small hota jayega kam hota jayega yaani in dono ka distance kam hota jayega jaise γ_{SF} Material ki lower hai waise ye d badhta jayega to ye ek inverse relation humein mil raha hai to aap dekh paa rahe honge ki in dono ka distance do jo partials hai shockley partial hai inka distance equilibrium distance ghatega ya badhega based on γ_{SF} Yaani γ_{SF} Ki kya value hai uske upar to yeh stacking fault energy hamare cross slip ko affect karti hai humne cross slip ko jaana tha ki humne dekha tha ki screw dislocation cross slip hote hain to main kuch is tarah se likh paa raha hoon yeh meri yeh mera stacking fault yahan pe taiyaar hua hai aur yeh mere do partials hai aur yeh main baat kar raha hoon ek particular 111 plane pe aur yahan par

ab dekhenge yeh jo do partials hai yahan par is is tarah se jab milenge to yeh jo dislocation taiyaar hoga yeh mera perfect screw taiyaar hoga agar aap dono ko add karenge to aapko pata chalega yeh jo dislocation hoga mera perfect dislocation hoga perfect screw dislocation hoga aur yahan par hum dekhenge ki screw dislocation phir se split ho sakta hai kuch is tarah se to ye meri stacking fault ho gayi in dono partials ke beech mein humne dekha tha jo area rehta hai wo stacking faulted area rehta hai yeh jo process hai jahan par do partials dusre ko milkar ek perfect screw banate hain isko hum kehte hain constriction to constriction yaani kisi ko squeeze karke ya daba ke ek banana usko kehte hain constriction to yahan par mere paas ek perfect screw banega aur isko kehte hain constriction to perfect screw dislocation.

Stacking fault energy and separation of partials

Shockley partial

$b_1 \qquad b_2 \qquad b_3$

$$\frac{a}{2}[\bar{1}01] = \frac{a}{6}[\bar{2}\bar{1}1] + \frac{a}{6}[\bar{1}12]$$

$$E = \alpha G |b|^2$$

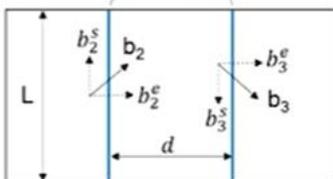$$\alpha G \frac{a^2}{2} \qquad \alpha G \frac{a^2}{6} \qquad \alpha G \frac{a^2}{6}$$

$$\alpha G \frac{a^2}{2} > \alpha G \frac{a^2}{3}$$

Dissociation of the dislocation in partials in not straight forward

Creation of Stacking Fault (SF)

Increase in energy due to SF: Stacking Fault Energy(SF)
: $\gamma_{SFE} = mJ/m^2$

Stacking fault (γ_{SFE})

$b_1 \rightarrow b_2 + b_3$

$$\vec{f} = \vec{f_e} + \vec{f_s} \qquad \text{Only glide force}$$

$$fL = \gamma_{SFE} L d$$

$$d = \frac{f}{\gamma_{SFE}} \qquad d = \frac{G\,(b_2 \cdot b_3)}{2\pi \gamma_{SFE}}$$

γ_{SFE} Vs d

γ_{SFE} is higher d is smaller
γ_{SFE} is lower d is higher

edge components repulsive
SFE → attractive

Aaiye jaante hain iska effect kya hota hai cross slip pe aur humein cross slip ke liye sirf pure screw hi cross slip ho sakta hai humne padhai ki thi jab screw dislocation ke pure screw dislocation ki baat ki thi to aaiye jaante hain ki cross slip hoti kaise hai to yahan par main do partials mark kar raha hoon kuch is tarah se aap dekh paa rahe honge yeh hai mera perfect screw nature jo magnitude hai b ka wo perfect screw nature ka hai aur yeh mere partials hai aur inke beech mein jo ye jo energy rahegi is area ki isko kahenge stacking fault energy ab ye do partials yahan par meet ho gaye yahan par aap dekh paa rahe honge ki ye constrict ho gaye to yahan par jo nature banega mere dislocation ka wo perfect screw rahega to kuch is tarah se rahega to yeh mera tangent vector hai aur yeh mere partials hai yahan par split hai dissociated hai par is region mein aap dekh paa rahe honge ki ye constriction hoke perfect screw aur jab main ek third scenario agar main dekhunga ki to yeh jo part hai yahi part mera cross slip ho sakta hai to aap dekh paa rahe honge ki yeh part yahan pe is plane pe cross slip ho gaya yeh initially mere ye 111 plane pe tha aur yeh jo cross slip hua hai yeh hua hai $11\bar{1}$ Plane pe to yahan pe ye dekhiye yahan pe cross slip hua hai kuch is tarah se ye jo part hai screw ka yeh cross slip ho gaya yahan pe yeh meri tangent vector hai aur aage jaake ye jo screw part tha ye phir se split ho gaya mere do partials mein split isliye hona chahiye kyunki energy criteria hai humne dekha tha to hum dekh paa rahe honge ki yeh jo constriction laane ke liye kya criteria hona chahiye criteria simple hai yeh jo d hai ye ye depend karega mera γ_{SF} Pe to agar main kuch is tarah se agar γ_{SF} Meri lower hai to yeh d bada hoga to aap dekh paa

rahe honge ki agar yeh already agar γ_{SF} Higher hai yaani badi hai meri stacking fault energy jyada hai to yeh d small hoga aur mujhe kam force lagega in do partials ko paas laane ke liye aur constrict karne ke liye ya pure screw banane ke liye yahan se to aap dekh paa rahe honge ki γ_{SF} Mere cross slip ko jyada affect karegi aur humne dekha tha ye jab strain hardening ke baare mein dekha tha to mera jo stress hai wo is tarah se effect karega ya plastic strain par is tarah se depend hoga ye jo n hai mera strain hardening exponent hai abhi jaante hain kuch points jo stacking fault energy govern karte hain mere material ke baare mein to jo stacking fault energy hai wo depend karti hai mere material aur uske composition ke baare mein to ye depend karegi bonding aur composition se stacking fault energy yeh determine karegi yeh tay karegi ki meri cross slip hogi ya nahi hogi to aur cross slip hogi to uske wajah se strain hardening jo hai wo affect karega to jaise meri stacking fault energy badi hai to humne dekha tha ki jo separation hai equilibrium separation hai wo kam rahega aur kam rahega to cross slip aasaan ho jayegi aur cross slip aasaan ho jayegi to aap dekh paa rahe honge ki dislocation aasaani se dusre plane pe move ho sakta hai agar dusre plane pe aasaani se move ho sakta hai to jo work hardening rahega wo kam rahega aur jo exponent rahega wo bhi kam rahega lower work hardening humein exponential aur stacking fault jyada hai to aap dekh paa rahe honge ki constriction aasaani se taiyaar hoga agar stacking fault energy kam hai to aap dekh paa rahe honge ki constriction nahi hoga to yeh jo partials sirf ek hi plane par move honge ye dusre plane par cross slip nahi ho payenge to isliye jab yeh dusre plane par cross slip nahi ho payenge to humein sirf planar slip milegi jab mere paas low stacking fault energy rahegi ya mere paas high stacking fault energy rahegi to mere paas kuch wavy slip milegi is tarah se to mujhe is plane pe bhi slip milegi aur is plane pe bhi slip milegi cross slip ki wajah se to low stacking fault energy materials mere planar slip dikhate hain to aap jaan paa rahe honge ki stacking fault energy strain hardening ko acche se affect karta hai.


Abhi hum aage chalte hain aur stacking fault energy ke baare mein jaante hain to mere paas ek dislocation hai ye split ho gaya do partials mein yahan pe to aap dekhenge ki jo dislocation hai ye darshata hai kis kya darshata hai no slip aur fully slip region ko to aap dekh paa rahe honge ki yahan par mere paas yeh partials aa gaye aur inke beech mein jo area hai isko faulted region ye

stacking faults hai ye stacking fault hai mere yahan pe aur isko jo partials ke beech mein agar is tarah se darshaye isko hum kehte hain Extended Dislocation aur kabhi kabhi textbook mein is tarah se bhi likha jaata hai isko stacking fault yeh jo energy hai aur stacking fault ke jo ye hai ye jaisa bana hua hai isko hum kehte hain Stacking Fault Ribbon yeh bhi aap kuch research papers mein ya books mein kuch is tarah se aapko dekhenge yeh mere stacking fault ka representation hai to aaiye jaante hain ki mera jo perfect dislocation hai wo jab split hua yeh do partials mein split hua aur inke beech mein jo region hai yeh hai stacking fault to kabhi kabhi textbook mein kuch is tarah se bhi darshate hain complete symbol nahi dikhate kuch half T ki tarah dikhate hain to yeh bhi do partials darshate hain yahan pe to kuch material hum dekhte hain jaise stainless steel hai copper hai aluminium hai aur unki stacking faults energy dekhte hain to aap dekh paa rahe honge yahan pe stainless steels hai inki stacking fault energy likha hai 10 aur milli joules per meter square aur aluminium ki close to 250 yahan par likhi to aap dekh paa rahe honge ki jo jaise stacking fault energy meri badh rahi hai yahan pe stacking fault energy jaise badh rahi hai mera strain hardening exponent kam ho raha hai yaani γ_{SF} Badh rahi hai to n ki value ghat rahi hai aur aap dekhenge ki jo slip character hai yahan pe yeh slip character bhi change ho raha hai jaise humne dekha tha ki stacking fault energy kam hai to jo partials hai wo ek hi plane par move honge to isliye humein planar milti hai yahan par mid value hai stacking fault energy to humein planar aur wavy dono nature milenge aur yahan par humein wavy nature milenge to yahan par aap dekhenge ki jo stainless steel hai wo jyada strain hardening dikhayega as compared to aluminium jahan par stacking fault energy ki value mere paas jyada hai abhi jab hum stacking faults ki baat kar rahe the to stacking fault humne dekha tha ki mere paas ek ideal stacking hoti hai ABC ABC to yahan pe mere paas ek stacking fault maine taiyaar kiya hai yahan pe aap dekhenge yeh jo hai AB AB aur humne dekha tha yahan pe ek C layer yahan pe maine nikaal diye hai to mere paas jo fault hai wo AB AB kuch is tarah se hai aur yeh jo atomic arrangements hai play planes ki jo atomic arrangements hai AB AB stacking yeh humne dekha tha yeh hai yeh related hoti hai HCP stacking se to is type ke faults ko jahan pe aise kuch HCP fault faulted region milta hai us type ke stacking ko hum kehte hain Intrinsic Fault Intrinsic Stacking Fault aur is case mein hum dekhenge jahan par mere paas ABC AB AB aur yahan pe ABC A to aap yahan pe kuch AB AB ya AC AC stacking fault humein nahi milegi to yahan par jaise AC AC ya AB AB ya BC BC stacking fault nahi hai yahan par to yeh ho gaye mere Extrinsic Stacking Fault isko hum kehte hain Extrinsic Stacking Fault aur jahan par humein HCP ka structure ya HCP ka HCP se related stacking milte hai usko kehte hain hum Intrinsic Stacking Fault.

Abhi hum jaante hain ki yeh jo stacking fault hai wo kaise nikalte hain to mostly experimentally yahan par main nahi bata raha hoon Density Functional Theory istemal log karte hain aur usse kuch ya gamma plot nikalte hain to aap dekhenge ki jab main ek A layer ko ya B layer ko A layer ke upar move karunga is direction pe $[1\bar{1}0]$ ya $[1\bar{2}1]$ direction mein move karunga to aap dekhenge ki energy plot taiyaar hoga yaani meri surface energy yahan par change ho rahi hai to is tarah se kuch darshaya to aap dekhenge ki agar main is position se is position pe ja raha hoon kuch is tarah se ek perfect position se perfect position par taraf ja raha hoon to yahan par koi fault nahi hoga yahan par aap dekhenge ki yahan par energy agar main is position pe aap move kar raha hoon mere B layer ko to yahan par highest energy hai aur yeh jo dark region hai yahan par lowest energy hai to aap dekhenge ki main is position se is position pe jaunga tab koi fault taiyaar nahi hoga par main yahan se yahan jaunga C layer pe jab main B layer ko move kar raha hoon tab aap dekhenge ki is position se jab meri B layer aayegi tab ek fault taiyaar hoga material mein to yeh ho gaya mera stacking fault ka measurement kuch is tarah se main karunga ki energy variation kya ho rahi hai us tarah se main nikaal paunga aur yeh main nikaal sakta hoon gamma plot se ye gamma plot

to yeh ho gaya mera stacking fault energy nikalne ka tareeka to is part mein humne dekha ki jo stacking faults hai wo taiyaar hote jab ek dislocation perfect dislocation split hota hai dissociate hota hai do partials mein aur do partials mein jab split hone ke process mein ek ek fault taiyaar karega aur yeh fault mere strain hardening ko bhi affect karta hai.
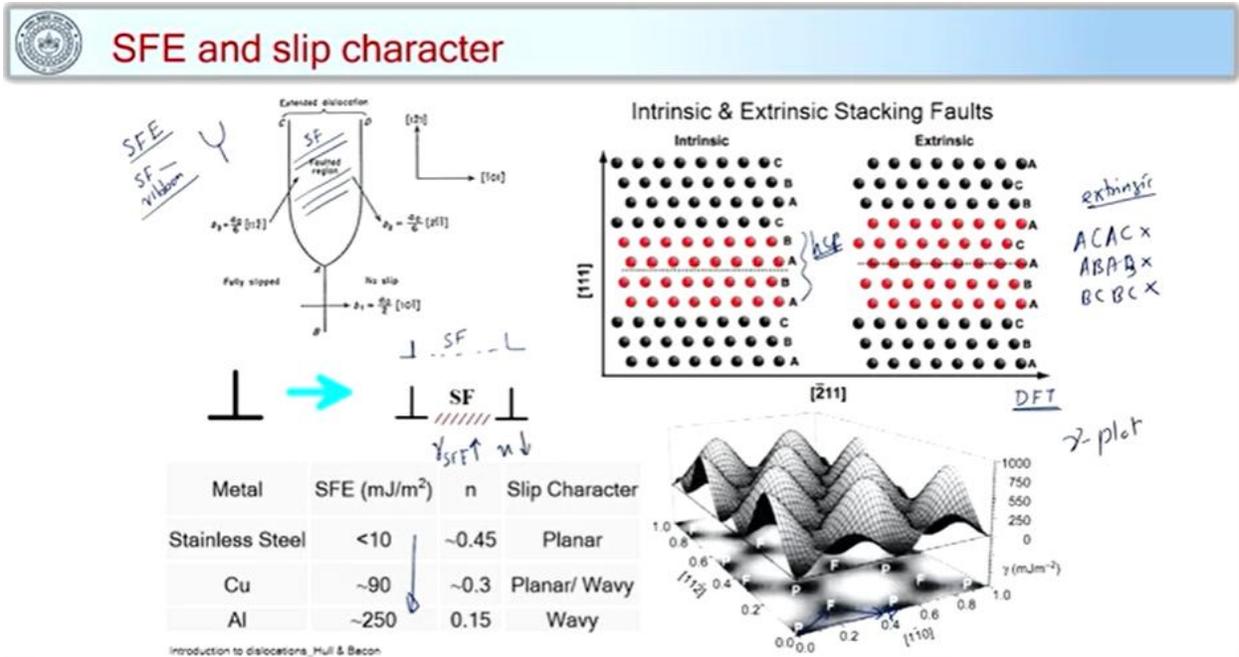
Yeh humne is part mein jaana next part mein jaanenge ki yeh jab dislocation split hote hain to unke wajah se locks bhi taiyaar hote hain un locks ke baare mein jaanenge unko kehte hain Lomer-Cottrell Lock next part mein humko iske baare mein jaanenge dhanyavad