Mechanical behavior of materials

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Lecture-39

Ordered Structure: Superlattice Dislocations and APBS

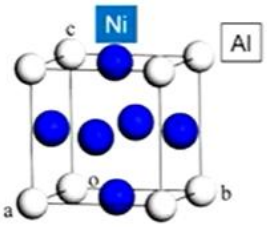
Namaskar ka swagat karta hoon is course mein mechanical behavior of material jisko hum hindi mein padhenge last part mein humne dekha tha ki strain hardening kaise hote hain dislocation locks kis tarah se hote hain is part mein hum jaanenge ki dislocation kya hote jab hamare paas ordered structure hote hain un dislocation ko hum super lattice dislocation kehte hain aur kuch defect hai jo surface defect hai jinko hum anti phase boundaries kehte hain aaiye jaante hain is part mein to yeh jo super lattice dislocation hote hain yeh humein milte hain intermetallic compounds jo ki hamare ordered solid solution hote hain yeh ordered solid solution tab taiyaar hote hai jab hamare paas ek koi chemistry rehti hai elements ki aur yeh jo dislocation hai ya jo bhi dislocation in ordered structure mein taiyaar hote hain yeh jo lattice hai hum inko kehte hain super lattice to yeh jo lattice mein jo humein lattice jo taiyaar hoti hai yeh hamara taiyaar hota hai ek long range order ke hisaab se to jaante ki jab hum super lattice dislocation ki baat kar rahe to pehle jaante hain ki intermetallic compounds kya hote hain to yahan par maine example diya hai Ni_3Al ye gamma prime phase hoga hota hai jiska structure $L1_2$ structure hai aap dekhenge ki yahan pe nickel jo hai woh face centers pe hai aur aluminium hai ye corners pe hai aap dekhenge ki aluminium ka position fixed hai yahan pe aur nickel ki position fixed hai nickel ki yahan pe lattice position fixed hai jo

ki face center hai aur aluminium ki yahan pe position hai wo fixed hai ye a corner pe hai aapko lag raha hai ki ye fcc jaisa structure hai par yeh fcc structure nahi hai kyunki yahan pe aap dekhenge ki mere aluminium se corners pe hai aur nickel jo present hai wo face centers pe hai to nickel ki ek alag lattice hai inko kehte hain sub lattice aur aluminium ki ek lattice hogi is lattice ko kahenge aluminium ki sub lattice to aap dekh paa rahe honge ki aluminium ki yahan pe sub lattice jo hai wo simple cubic type hai to hamare paas do sub lattice milke ek super lattice taiyaar hoti hai aur ye humein dikhta hai kab jab hamare paas ordered solid solution ya intermetallic compounds rehte hain to aap dekh paa rahe honge ki inki ek stoichiometry hoti hai Ni_3Al yahan pe maine mention kiya to aap agar count karoge number of nickel ke elements is structure mein to yahan pe teen aayenge aur aluminium ke number calculate karoge yaani equivalent number is unit cell pe to wo ek aayenge aur is type of structures ko hum kehte hain $L1_2$ structure.

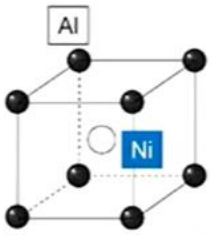
Yahan pe ek aur ek example humne diya hai yahan pe aap dekh paa rahe honge ki aluminium jahan pe hai ye ek corners pe hai aur nickel jo hai wo body center pe occupied hai is super lattice mein to aap dekh paa rahe honge yeh bcc jaisa structure dikh raha hai aur yahan pe yeh structure ka naam $B2$ hai to aap dekh paa rahe honge ki jo aluminium ki equivalent numbers hai is lattice mein wo one hai aur nickel ke bhi equivalent lattice jo equivalent numbers hai wo is lattice mein one hai aur aap dekh paa rahe honge ki jo aluminium ka sub lattice hai yeh simple cubic nature hai aur nickel ki beech jo sub lattice hai wo simple cubic nature hai to ye jo naam diye humne $L1_2$ aur $B2$ inko kehte hain strukturbericht designations aap iske baare mein padh sakte ho aur intermetallic compounds ya ordered solid solutions ke baare mein jaan sakte hain to abhi ye jo compounds ya stoichiometric compounds ya super lattice kab bante hain jab hum dekhenge ki jo energy hai jo bond energy hai meri a aur b atom ke beech mein ki wo kam rehti hai ek average energy ya a a bond aur b b bond ke beech ki jo energy hai combined energy unka average energy se bhi meri ye bond energy kam rehti hai tab aapko milega ki jo a atom hai woh prefer karega b atom ko aur tab jaake ordering hogi to aap yahan par dekh paa rahe honge ki is energy criteria ke wajah se aap dekhenge ki jo energy between unlike pair unlike pair yaani a aur b ke beech mein jo energy hai wo lower hai as compared to mere a a aur a aur b aur b ke beech mein yaani energy between like pairs tab jaake mujhe ye super lattice structures milte hain to abhi humne super lattice structures thode dekhe abhi hum dislocations ke baare mein jaante hain aur anti phase boundaries ke baare mein jaante hain.

Superlattice Dislocations

- Found in Intermetallic compounds
- Ordered solid solutions
- Stoichiometric compounds
- Superlattice = long range order



Ni_3Al: $L1_2$ structure

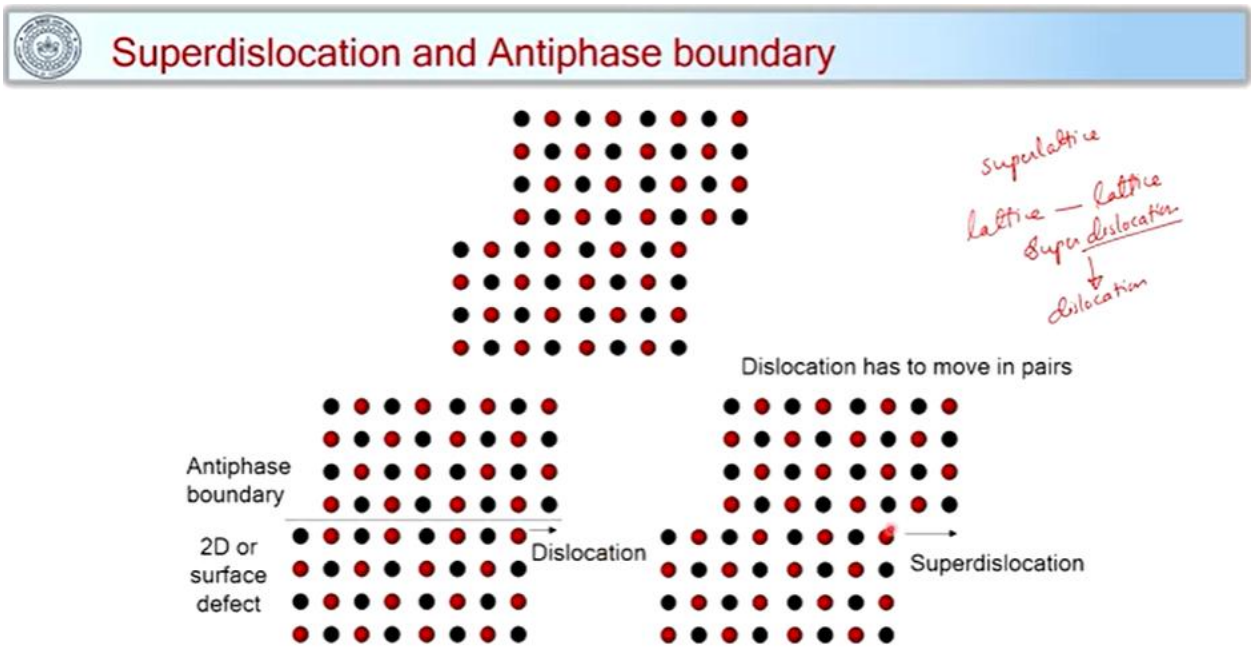


NiAl: B2 structure *"Strukturbericht designation"*

$E_{AB} < ½ (E_{AA}+E_{BB})$,
where,
E_{AB} - Energy of the unlike pair of atoms.
E_{AA}, E_{BB} - Energies of like pairs of atoms.

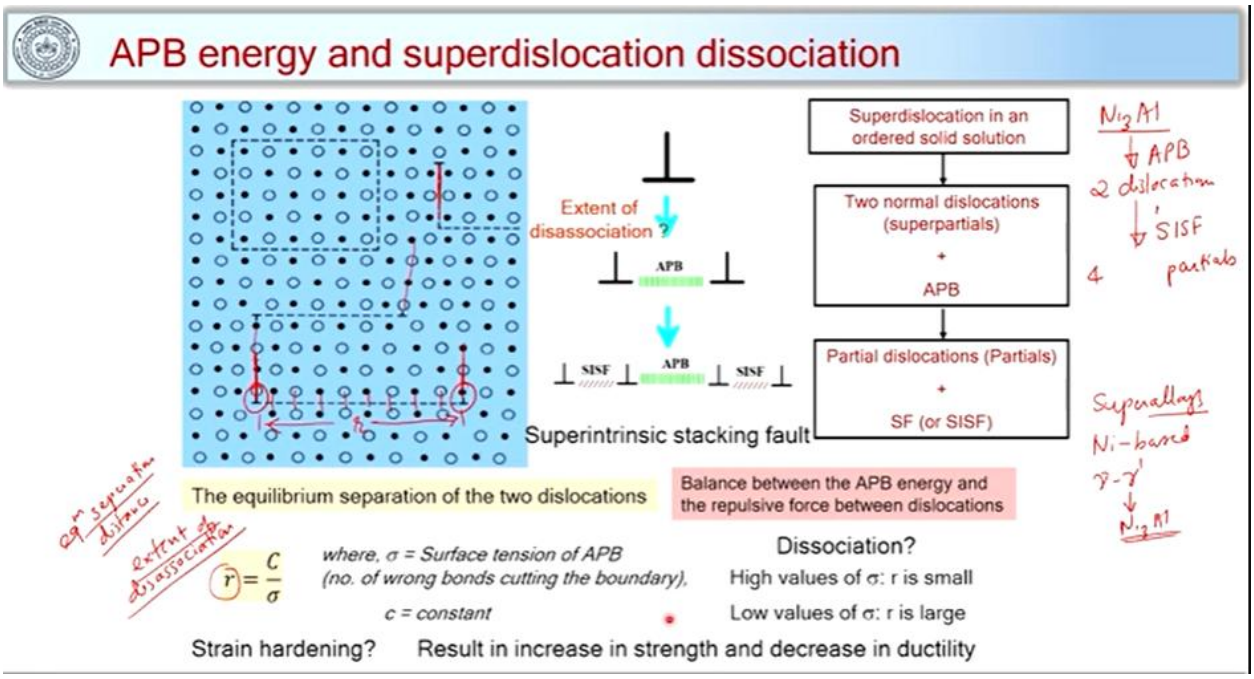
Maante hain mere paas ek defect free structure hai aap dekh paa rahe honge yahan par maine ordered structure ek kuch taiyaar karne ki koshish ki aapke paas red atoms aur black atoms ye points hai ye fixed hai yaani ek black atom ke surrounding mere red atoms hai ya ek red atoms ke surrounding mere paas ek black atoms hai to aap dekh paa rahe honge ki mere paas maine ek simple 2d ordered structure yahan pe taiyaar kiya hai abhi hum isko deform karenge deform karenge yaani humne dekha tha ki hum isko slip karenge agar main usko slip karta hoon to maan lete hain ek burgers vector yahan pe define kar lete to burgers vector mera kuch is tarah se hoga yaani shortest lattice translation agar hum dekhenge to shortest lattice translation red to red hoga ya black to black hoga to yeh mera shortest translation vector kuch is direction mein mujhe mil raha hai to agar main is upar ke part ko slip karta hoon niche ke bottom part se kuch is tarah se aap dekh paa rahe honge maine slip kiya hai yahan pe ek lattice distance hai to aap dekh paa rahe honge ki jaise maine ek unit move kiya yahan pe is direction mein to aap dekh paa rahe honge ki red atoms ek dusre ke upar aa gaye black atoms ek dusre ke upar aa gaye yeh coincide ho gaye to yeh jo dislocation tha woh ek uska ek nature hota hai aap dekhenge ki iske wajah se is ek movement ki wajah se mere paas ek boundary taiyaar hogi jahan pe aapke paas like like atoms ya yahan pe dekhenge red red atoms ya black black atoms ek dusre ke upar aa gaye to yeh ho gayi meri yeh jo energy configuration yahan pe aap dekhenge yeh highest energy configuration ho gayi yahan pe aur yeh boundary taiyaar hogi in do perfect lattice ke beech mein just ek translation ki wajah se abhi main jo hai yeh agar structure restore karna hai to main phir se ek baar slip karunga kuch is tarah se aur aap dekh paa rahe honge ki agar main ek complete lattice translation vector se move hota hoon to yeh structure yahan par jo anti phase boundary hai woh nasht ho jayegi mit jayegi aur aap dekh paa rahe honge ki yahan par ek displacement ho jayega surface pe is unit crystal par aur yeh jo structure hai woh retain karegi apni yaani jo faulted region tha wo mit jayega aur ye apna structure retain rahega to hum do scenario ye mark kar lete kuch is tarah se jab maine ek lattice resistance move kiya tha aur isko main kahunga dislocation is super lattice ke hisaab se aur yeh jo boundary hai jab main ek dislocation se move hua usko main kahunga ye jo boundary jo faulted region mera taiyaar hua kyunki ye humne 2d ismein dekh rahe hain to agar hum 3d mein dekhenge to ye ek area ho jayega aur yeh faulted area ho jayega isliye hum isko anti phase boundary is tarah

se kehte hain aur yeh 2d aur surface defect hai abhi hum dekhte hain ki dusra scenario kuch is tarah se tha hamare paas jab main ek super dislocation se move hua yaani main ek lattice translation vector se move hua yaani main red se red agar move hota hoon to usko main kahunga yahan pe super dislocation to yahan par humne do terminology dekhi hai ek super dislocation aur ek dislocation to super lattice mein mere paas super dislocation hote hai super dislocation kya hai simple cheez hai super dislocation ek lattice point se dusre lattice point ka agar main consider karunga to isko main kahunga lattice to lattice translation hi super lattice mein yeh hote hain super dislocation isko main kahunga super dislocation aur inke jo fraction hote hain super dislocation ke agar koi fraction mein hai jo lattice to lattice translation nahi hai to main unko kahunga dislocation to yahan par aap dekhenge maine dislocation kis cheez ko kaha hai maine dislocation ko kaha hai jab main ek translation move karunga par wo lattice to lattice nahi tha main red to black agar distance move karunga is atom pe to isko main kahunga dislocation to ye simple concept hogi meri super lattice aur super lattice dislocation aur anti phase boundaries to yahan par agar mujhe structure retain karna hai to aap dekh paa rahe honge ki dislocation ko yaani do dislocations ko pair mein move karna padega yaani ek baar ek translation phir dusra dusra translation tab jaake super dislocation hoga aur yeh structure mera retain rahega.



Aaiye jaante hain kuch schematics se yahan pe lattice humne nikali hui hai aur aap dekh paa rahe honge yahan pe yeh dotted jo line hai yahan pe yeh jo dotted line hai yeh meri anti phase boundary hai aap dekhenge ki like like atoms ek dusre ke upar overlap kar rahe hain ab is boundary ko main kuch is tarah se bhi represent karta hoon kar sakta hoon agar aap dekhenge ki ye boundary kab taiyaar hoti hai agar mere paas kuch dislocation hai agar aap dekh paa rahe honge yahan par mere paas kuch extra half plane yahan par maine insert kar diya aur yahan par aap dekh paa rahe honge yahan par dislocation ka symbol bhi yahan par mark kiya hua hai to yahan par agar main consider karunga ek dislocation hai to ye dislocation anti phase boundary yahan par generate karti hai ye yahan se clear ho jayega is is schematic se yahan par ek aap dekh paa rahe honge ki yahan par ek anti phase boundary taiyaar hui hai aur kuch is tarah se agar aap imagine kar payenge yeh mere extra half plane ho gaye yahan se to agar yeh extra half plane main yahan par insert karunga to aap

dekh paa rahe honge ki yahan pe ek anti phase boundary ya defect region main create kar sakta hoon iske pehle is dislocation ke pehle aap dekh paa rahe honge ki yahan pe koi anti phase boundary nahi hai jaise maine ek dislocation insert kiya yahan par ek anti phase boundary generate hui aur yahan par phir se dislocation insert kiya to yahan par is region par koi bhi ek anti phase boundary nahi hai ya koi bhi faulted region nahi hai to isi ka matlab hai ki agar mere paas do dislocations hai jahan se yahan par bhi is yahan par bhi aap dekh sakte ho ek dislocation ek extra half plane hai yahan pe aur ye ek extra half plane hai to agar mere paas do dislocations hai yaani yeh do dislocation milke mere paas ek super dislocation jab translate hoga tab jaake mera crystal structure defect free rahega par ek kis location se agar move ho raha hai to yahan par wo defect taiyaar karega jo ki ek anti phase boundary hai to yeh kuch is tarah se hai maine maine last slide mein likha tha ki dislocation has to pair this location has to pair and they have to move in pair ok yaani unko ek saath move hona hai to main kuch is tarah se likh sakta hoon yeh mera super dislocation ho gaya aur super dislocation jab ek hi dislocation se move hota hai to in dono is location ke beech mein mujhe ek anti phase boundary milegi yahan pe aap dekh sakte hain yahan pe kuch anti phase boundary hai aur jab let's say mere paas kuch fcc jaisa structure hai to ye dislocation split ho sakta hai to ye jab split hoga tab aap dekh paa rahe honge ki ye yahan pe faulted region taiyaar hoga agar ye partials main maan ke chal raha hoon ye agar dislocation yahan pe ye hai aur aur yeh do dislocations hai ye do partials hai to yahan pe mere paas ek stacking fault taiyaar hogi aur is stacking fault ko super lattice mein hum super intrinsic stacking fault kehte hain to mere paas kya scenario hai mere paas ek super dislocation hai jo ki ordered solid solution mein ya super lattice mein hai jo normal dislocations mein split hogi isko hum yeh bhi keh sakte hain isko hum super partials kehte hain aur mere paas kuch anti phase boundary aayegi uske baad agar yeh super partials partials mein dissociate ho rahe hain to mere paas ek super intrinsic stacking fault aayegi to ye ek similar concept hai jo humne fcc mein dekha tha yahan par wahan par stacking fault thi to anti phase boundary bhi ek faulted region hai aur jab yeh fcc structure rahega super lattice jaise hum Ni_3Al mein hum dekhe the Ni_3Al mein to is cases mein mujhe do ek do super partial yaani do dislocation normal dislocations milenge aur yeh do dislocations chaar super partials mein chaar partial dislocations mein convert honge to yeh chaar partial dislocations mein yahan pe convert ho sakte hain aur jab yeh convert hote hain tab mere paas yahan pe yahan pe jab yeh convert hote hain to mere paas ek anti phase boundary aayegi aur yahan pe mere paas ek super intrinsic stacking fault aayegi jo ki yahan pe maine mark kiya.



Aap dekh paa rahe honge ki jab faulted region hote hain tab dislocation ki movements difficult ho jaati hai agar mujhe dislocation ko move karna hai to aap dekh paa rahe honge ki in dono ko combine hona padega usi tarah se yahan par mere paas kuch faults hai to super partials ko combine hona padega tab jaake mere paas ek super dislocation taiyaar hoga to yeh extent of dissociation kitna possible hai jab hum dekhe the stacking fault ke liye to yeh do partials ke beech mein ek equilibrium distance tha to yeh super partials mein kitna equilibrium distance ho sakta hai wo depend karega ki meri anti phase boundary energy kya hai mere material ki to yeh separation of the two dislocations kuch is tarah se main likh sakta hoon ki balance between anti phase boundary energy and repulsive force between dislocations yeh wahi concept ki tarah hum isko samajh sakte hain abhi hum sab isko is tarah se likh sakte ki ek parameter determine kar sakte ki yahan par aap dekhenge ki yeh number of wrong bonds yahan par aap dekhenge ki yeh jo surface tension hai mere anti phase boundary ka wo determine karega ki mere number of wrong bonds kitne hain to yeh constant hai yeh jo r hai yeh number of wrong bonds mera determine kar raha hai to aap is tarah se dekh sakte ki jis tarah se yeh σ badhega yeh r jo hai yahan par likh lete r jo hai yeh mera extent of dislocation hai yaani kitna separation hai extent of dissociation ya equilibrium separation distance mere jo dislocations hai kitne dur reh sakte hain jaise mera ye ek dislocation hai ye dislocation hai inke beech mein ek equilibrium separation hoga jisko main r ki tarah mark kar raha hoon aur wo kis pe depend karega wo depend karega σ ke upar aur jo σ hai wo kis pe depend karega wo number of wrong bonds cutting the boundary yaani main agar ye bonds count karta hoon wrong bonds yaani 1 2 3 4 5 6 7 8 is tarah se agar mere paas number of wrong bonds hai us tarah se meri anti phase boundary energy jyada hogi aur is C ek koi bhi constant hai agar σ agar bada hai to aap dekh paa rahe honge yeh jo r hai woh ghatega aur σ kam hai to aap dekh paa rahe honge ki yeh jo r hai badhega to yeh stacking fault energy ki tarah hi kaam karti hai anti phase boundary energy jitni anti phase boundary energy badi utna separation kam jitni anti phase boundary energy jyada utna separation kam aur jitni anti phase boundary energy kam utna separation jyada to is tarah se hum samajh sakte hain to yeh abhi hum kyun likh rahe yaani dissociation is tarah se hoga jaise high value rahegi σ ki to r small rahega aur low value rahegi σ

ki to r large rahega to ye contribute karega mere strain hardening ko to aap dekh paa rahe honge ki strain hardening ko is tarah se contribute karta hai aur jab ye strain hardening ko contribute karega to wahan par meri strength badhegi aur ductility decrease hogi to aap dekh paa rahe honge super alloys mein jaise ek example yahan par hum dekh sakte super alloys mein nickel nickel base super alloys mein gamma gamma prime microstructure hota hai to ye gamma prime jo hota hai wo Ni_3Al ye ordered structure hota hai aap dekhenge ki yeh structure mere strength ko badhati hai to yeh short description tha mere super lattice ka aur super lattice dislocations ka humne super partials bhi dekhe partials bhi dekhe aur anti phase boundary bhi kya hoti hai aur inki wajah se mera material ki strength kis tarah se badhte yeh bhi humne is part mein dekha next part mein hum dekhenge ki bcc mein kya stacking faults hoti hai abhi ke liye rukta hoon dhanyavad