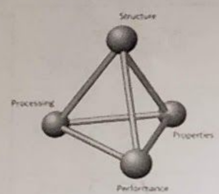
MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 3

MAC IDs of Present Team Members

kimd102 channa2

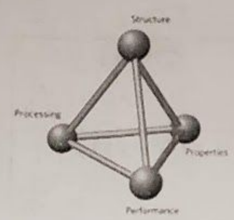
demelk2 wunderj

Implant Component: Liner

Fill in the Materials Selection table below related to the **Structure** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank.

Material	Structure					
	Class	Atomic Arrangement	Interatomic Bonding Classification			
HXPLE (Highly cross-linked UHMWPE)	Polyethylene	Crystalline + amorphous cross-linked	covalent			
Zirconium Dioxide (Zirconia)	Ceramic	(Allotrophic) Tetragonal and monoclinic crystal	covalent			
Silicon Nitride	Ceramic	Crystalline	Covalent			

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 03

MAC IDs of Present Team Members

kimd102 channa2

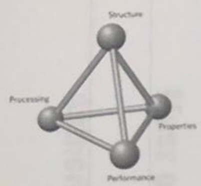
demelk2 wunderj

Implant Component: Liner

Fill in the Materials Selection table below related to the **Properties** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank. **You should use the same candidate materials you identified on Page 1!**

Material	Properties						
	Elastic Modulus	Ultimate Strength	Toughness, Fracture (brittle/ ductile)	Wear	Corrosion Resistance	Bio compatibility	
Highly crosslinked UHMWPE (HXLPE)	≈648 MPa Lowest	50.2 MPa Lowest	Ductile	Good	Good	Good	
Zirconia	205 GPa	800-1500MPa Highest	Can be brittle	Good	Good	Good	
Silicon Nitride	300GPa Highest	≈400MPa	brittle	Very good	very good	very good	

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 03

MAC IDs of Present Team Members

demeik2 | channa2
kimd102 | wunderj

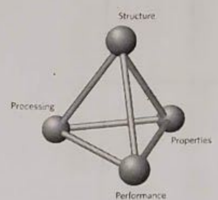
Implant Component: liner

Fill in the Materials Selection table below related to the **Processing** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank. **You should use the same candidate materials you identified on Page 1!**

Material	Processing					
	Coatings	Drug delivery options	Corrosion Resistance		coating effect	
XPLE	PMPC	N/A	cross linked, low wear rates	reduced free radicals from cross-linking	similar effect to natural cartiledge.	
Zirconia	PMPC	N/A	if used as base for coating it improves corrosion resistence	metal free reduces risk of metal particles being released.	" "	
Silicon Nitride	PMPC	N/A	can be enhanced by adding coatings.		" "	

MILESTONE 4 – DETAIL DESIGN

(Detail Design Page 4 of 5)



Team Number: 3

MAC IDs of Present Team Members

kimd102	channa2
demelk2	wunderj

Based on the tables on the previous pages, your team will consider Highly crosslinked UHMWPE (XLPE) and Zirconia as potential materials for this component.

Explain why you selected these based on their structure, properties, processing or performance?

Highly cross-linked UHMWPE (XLPE) has good wear properties due to the crosslinking, and by surface-treating XLPE with PMPC which lubricates the surface, the liner can have even longer wear cycles. Also, unlike UHMWPE, XLPE produces less wear debris which can cause osteolysis.

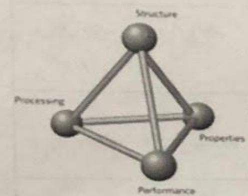
Zirconia has high elastic modulus and ultimate strength which would prevent the liner from failing easily. Under high stress, its phase transformation which increases the volume stops crack growth.

For the whole design:

Comment on why the materials selected for all components makes the most sense ***for your patient:***

Our patient, Djimon Hounsou, prefers to stay active as he has been playing a variety of sports since he was young, despite his groin pain. As a result, the liner has to have good wear properties that is able to withstand high usage. XLPE surface-treated with PMPC has excellent wear rate and low friction, while creating minimal wear debris that can cause osteolysis. Our patient weighs 80kg, which would create high stress on the implant when playing sports. As a result, Zirconia which has high elastic modulus and ultimate strength, and unique allotrophic property to stop crack growth, would be a suitable material for the liner.

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 3

MAC IDs of Present Team Members

channa2 | wunderj
demelk2 | kimd102

Implant Component: Femoral Stem (i.e. the load-bearing component)

Titanium alloy (TiO_2)
Hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$)

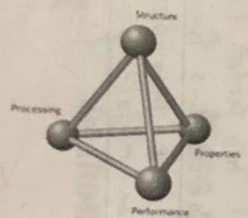
Fill in the Materials Selection table below related to the **Structure** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank.

Material	Structure					
	Class	Atomic Arrangement	Interatomic Bonding Classification			
Titanium Alloy (Ti6Al4V)	Metal	Crystalline	Metallic Bonding			
Hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$)	Ceramic	Crystalline	Ionic Bonding (a calcium phosphate)			
Carbon nanofiber	Ceramic	Graphene Sheets	Covalent Bonding			

Known as the "workhorse" of titanium alloys (Titanium Alloy)

more biocompatible (more osseointegration) → increased cell adhesion/bone growth (Hydroxyapatite)

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 3

MAC IDs of Present Team Members

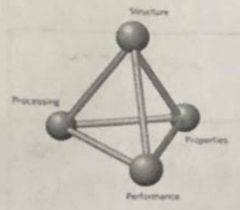
channa2 | wunderj
demelk2 | kimd102

Implant Component: Stem

Fill in the Materials Selection table below related to the **Processing** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank. **You should use the same candidate materials you identified on Page 1!**

Material	**Processing**					
	Coatings (or sprayed)	Drug delivery options	Corrosion Resistance			
Titanium Alloy	Can be coated with hydroxyapatite (helps promote osseointegration)	—	High			
Hydroxyapatite	Serves as a very good coating material	—	Good			
Carbon nanofiber	Serves as a very good/strong coating material	—	Good			

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 3

MAC IDs of Present Team Members

channa2 demelk2
kimd102 wunderj

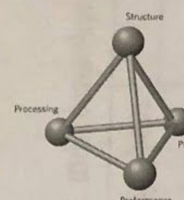
Implant Component: Stem

Fill in the Materials Selection table below related to the **Properties** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank. **<u>You should use the same candidate materials you identified on Page 1!</u>**

Material	Properties						
	Elastic Modulus	Ultimate Strength	Toughness, Fracture (brittle/ ductile)	Fatigue ~~Wear~~	Corrosion Resistance	Bio Compatible	Non-inflammatory, non-toxic
Titanium Alloy	120 GPa	1000 MPa Very strong due to high density & tensile strength	· higher toughness than pure titanium	Good fatigue strength (but low shear strength and poor wear resistance)	High	Yes	Yes
Hydroxyapatite	~80 GPa	~19 MPa	· brittle in nature · may be susceptible to cracks	Very closely represents the properties of human enamel (good fatigue strength)	Good	Yes	Yes
Carbon nanofiber	600 GPa (strong)	~27 GPa (stiff)	· carbon nanofibers enhance/improve toughness & strength	Good fatigue strength	Good	Yes	Yes

MILESTONE 4 – DETAIL DESIGN

(Detail Design Page 4 of 5)



Team Number: 3

MAC IDs of Present Team Members

channa2	wunderj
demelk2	kimd102

Based on the tables on the previous pages, your team will consider TiGAl4V and Hydroxyapatite as potential materials for this component.

Explain why you selected these based on their structure, properties, processing or performance?

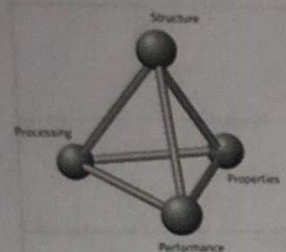
The crystalline structure of titanium alloys allows for a strong and hard structure, while still maintaining a low elastic modulus and reducing the potential for fracture. Because lower elastic modulus' reduce the effect of stress shielding in stems, choosing a titanium alloy, as opposed to other materials would be the better option. In addition, because titanium as a material is bio-compatible, non-toxic, non-inflammatory, and has a history of being used in implants reduces the risk of side effects & rejection by the body, making it safe to be implanted into our patient. In combination with a hydroxyappatite coating that is osteoinductive (encourages bone remodelling after implant), these are both great potential materials to consider.

For the whole design:

Comment on why the materials selected for all components makes the most sense ***for your patient:***

Our patient leads an active lifestyle, so having a titanium alloy with hydroxyapatite coating (both strong materials that do not fatigue easily) will help provide support from the stress Djimon may place on his hips (he is quite heavy at 80 kg). To add on, this titanium alloy is also low density, so will be lightweight for our patient, not interfering with his active lifestyle. The osteoinductive properties of hydroxyapatite also allows for his bone to continue to grow, rather than encouraging further bone degradation. The ceramic nature of hydroxyapatite also prevents metal-on-metal grinding, thus providing a long-term solution, since having multiple surgeries is not ideal considering our patient's age.

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 03

MAC IDs of Present Team Members

wunderj | demelk2

kimd102 | chang2

Implant Component: hip bone extension/acetabular cup

Fill in the Materials Selection table below related to the **Structure** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank.

Material	Structure					
	Class	Atomic Arrangement	Interatomic Bonding Classification	Porous architecture	bone growth on implant	Anistrophy
Tritanium	metal	crystalline	metallic	random, mimic cancellous bone	very high	Isotropic
Titanium Ti-13Nb-13Zr	metal	crystalline	metallic	mimic bone, less random,	low, needs coating	Isotropic
Tantalum	metal	crystalline	metallic	mimic bone, random, very porous	very high	Isotropic

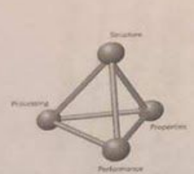
Acetabular cup/ bone extension:

Material							
	Elastic Modulus	UTS	Toughness/ Fracture	Fatigue	Corrosion resistance	Effect on bone density	Pore size
Tritanium (comparable to 3D printed titanium)	106-115 lowest of the three, minimal stress shielding	High strengths	Can depend on the cooling systems used	Similar to titanium alloys, so Ti-13Nb-13Zr will have a stronger resistance to corrosion	High corrosion resistance but can be susceptible to pitting and cracks	Strength and rigidity lies between titanium and tantalum, will allow for some bone density to be recovered and also a good fusion, good osseointegration and biocompatibility	100-700micrometers

Ti-13Nb-13Zr	79 GPa Lower than Cobalt chromium, will reduce stress shielding	945 MPa	20% higher fracture toughness compared to other titanium alloys	Higher fatigue endurance limit, equivalent to 10,000,000 cycles	Resistant to corrosion	Lower rigidity allows for better bone development and regrowth	>500micrometers
Tantalum	186 GPa	900MPa	Low mechanical properties can complicate load bearing aspects	Not much implant migration or loosening	Highly corrosion resistant	Very rigid implant allows for very good fusion however bone density could be compromised	400-600 micrometers Can be adjusted

MILESTONE 4 – DETAIL DESIGN

(Detail Design Page 4 of 5)



Team Number: 03

MAC IDs of Present Team Members

wunderj	denelk2
channa2	kimd702

Based on the tables on the previous pages, your team will consider Titanium 13Nb-13Zr and Tritanium as potential materials for this component.

Explain why you selected these based on their structure, properties, processing or performance?

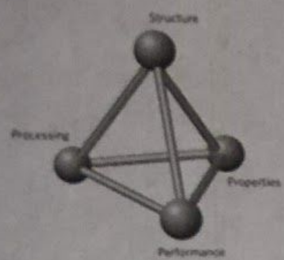
We selected these two potential materials since they both have very strong properties and won't break or fatigue easily. They also adhere to bone well and when titanium is coated they both allow bone to grow and heal fast. Both materials are strong, biocompatable and relatively easy to make and/or have the abilities to make them.

For the whole design:

Comment on why the materials selected for all components makes the most sense ***for your patient:***

Since our patient wants to live an active lifestyle the used materials have to not fatigue easily and last a long time. Both materials do not fatigue easily and are overall very strong, which is also important as we are trying to extend the hip bone down, so the material used must be durable and strong as to not break easily, just like real bone. These materials also allow the bone surrounding the implant to grow into and onto it, further securing it in place.

MILESTONE 4 – DETAIL DESIGN (MATERIALS SELECTION)



Team Number: 03

MAC IDs of Present Team Members

wunderj — channa2
kimd102 — demelk2

Implant Component: hip bone extension/acetabular cup

Fill in the Materials Selection table below related to the **Processing** of the material for at least 2-3 candidate materials that you will consider for this component. Note: You only have to fill in the parts you think are relevant, some may remain blank. **You should use the same candidate materials you identified on Page 1!**

Material	Processing					
	Coatings	Drug delivery options	Corrosion Resistance	manufacturing	effect of coating	environment for cell growth
Tritanium	doesn't need to be coated, already porous	N/A	high resistance, susceptible to cracks	additive manufacturing	doesn't get coated	osteoblasts present
Titanium Ti-13Nb-13Zr	needs to be coated	N/A	resistant	powder metallurgy	increase bone growth when has coating added to it	when has coating and osteoblasts present
Tantalum	Good coating material	N/A	highly resistant	naturally occurring electrolysis	increase bone growth when added onto implant	osteoblasts present