NTNU

Norwegian University of Science and Technology

Course: TPK5100 – Applied Project Management

Project: 3D modeling and printing of Nano-surfaces

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Introduction:

Engineers and architectures use 3D modeling for different purposes like Hollywood blockbuster uses 3D modeling for special effects, to cut costs, and to speed up production. The main objective of this project is to make 3D models of nano surfaces and 3D print the nano surfaces into visually focusable scale. Basically, nanoscale surfaces are 3-dimensional surfaces often sketched in literature like papers, presentations, and textbooks. These 3-dimensional surfaces are difficult to understand with a 2-dimensional representation because material surfaces have variations at a very small scale.

We wanted to provide physical(visual) representations of nano surfaces not only for educational purposes but also for marketing purposes. Our vision is that the models we are producing could be useful for universities, to help students get a better understanding of the material lectures, or to illustrate effects of different surface coatings produced by manufacturers for potential customers in the industry. We are also considering different types of materials, where we compare the different surface treatments. We are modelling the representations with a 3D printer, using existing microscopy images of the materials.

As our primary goal was to prove that 3D printed specimens can be used to physically show differences between surfaces, we need to source images of similar materials of the same scale.

Deliverables:

- To be able to 3D model nano surfaces.
- To be able to 3D print the nano surfaces into visually focusable scale.
- Framework development for future works.
- Database for 3D model storage and accessibility.

Process:

- Selection of research material.
- Selection criteria.
- Selection of 3D modelling software/techniques.
- 3D printer availability and skills requirement.
- 3D printing of modelled surfaces.
- Finalizing samples.
- Framework development for future modelling and printing of such materials.
- Feedback from academia/industry, if possible.

Applications:

- Teaching environment: to represent surface morphology.
- Industrial environment: to demonstrate effects of coatings to potential customers.

Outlook development:

- To produce an outlook of the project including mistakes and suggestions

Benefits:

- Framework for peers and academia to obtain/develop more such samples
- Use in academia for teaching/understanding purposes

- Use in industry for demonstration to customers.
- Learning of new skills/techniques by the group members.

Framework:

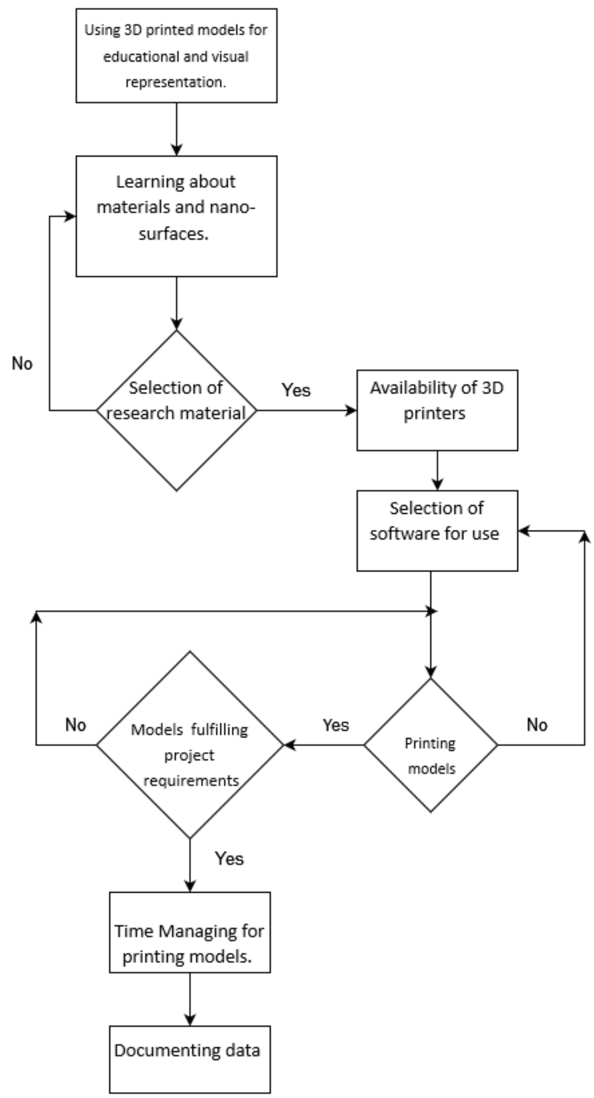


Figure 1: Framework

Roles and responsibilities:

All group members are from different fields, bringing different sorts of expertise and skillset.

- Muhammad Farhan, Civil Engineering background, is used to 3D modelling of building structures.
- Hammad Ali, Chemical Engineer, well versed in knowledge of nano surfaces.
- Muhammad Naseer ud din, Electrical Engineer, familiar with working of 3D printer.

Communication plan:

- Weekly meeting after the class every Thursday.
- A group on Teams for file sharing.
- WhatsApp group for any urgent communication.
- Biweekly meetings on weekend in Gløshougen library regarding major working of project.

Scope:

- Educational purposes.
- Marketing purposes.

Group based evaluation of Initial planning:

Scale	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree
Team Response				√	

Details of data used (Materials, Modelling, Printing (Maker Space)):

Materials:

316 L Steel:

316L steel is a stainless-steel type often referred to as marine grade stainless steel. The 316L steel contains less than 0.03% carbon. This reduces the risk of carbon precipitation in the steel, making it a better option for welding. The steel also contains a considerable amount of Chromium (16-18%) and Molybdenum (2-3%). This gives the steel excellent corrosion resistance, strength and increased resistance to pitting, which makes it attractive in the industry. These surfaces were chosen as potential candidates for printing because the detailed measurements of the heights of the surface feature could assist in creating more accurate models.

Figure 2: FESEM images of steel soaked for 60 seconds in pH 3 bath of sulfuric acid and 3D printed model

Steel Surface Treatments by acid:

Steel was treated with three different acids 1. sulfuric, 2. phosphoric, and hydrochloric. After treatment with acid, a silane coating was applied to the steel. The idea is that silane coatings bond to the metal surface through covalent bonds of the form Metal-O-Si, and by treating the surface of the metal with an acid solution they can oxidize the surface and increase the number of oxides and hydroxides present for the silane to bond to.

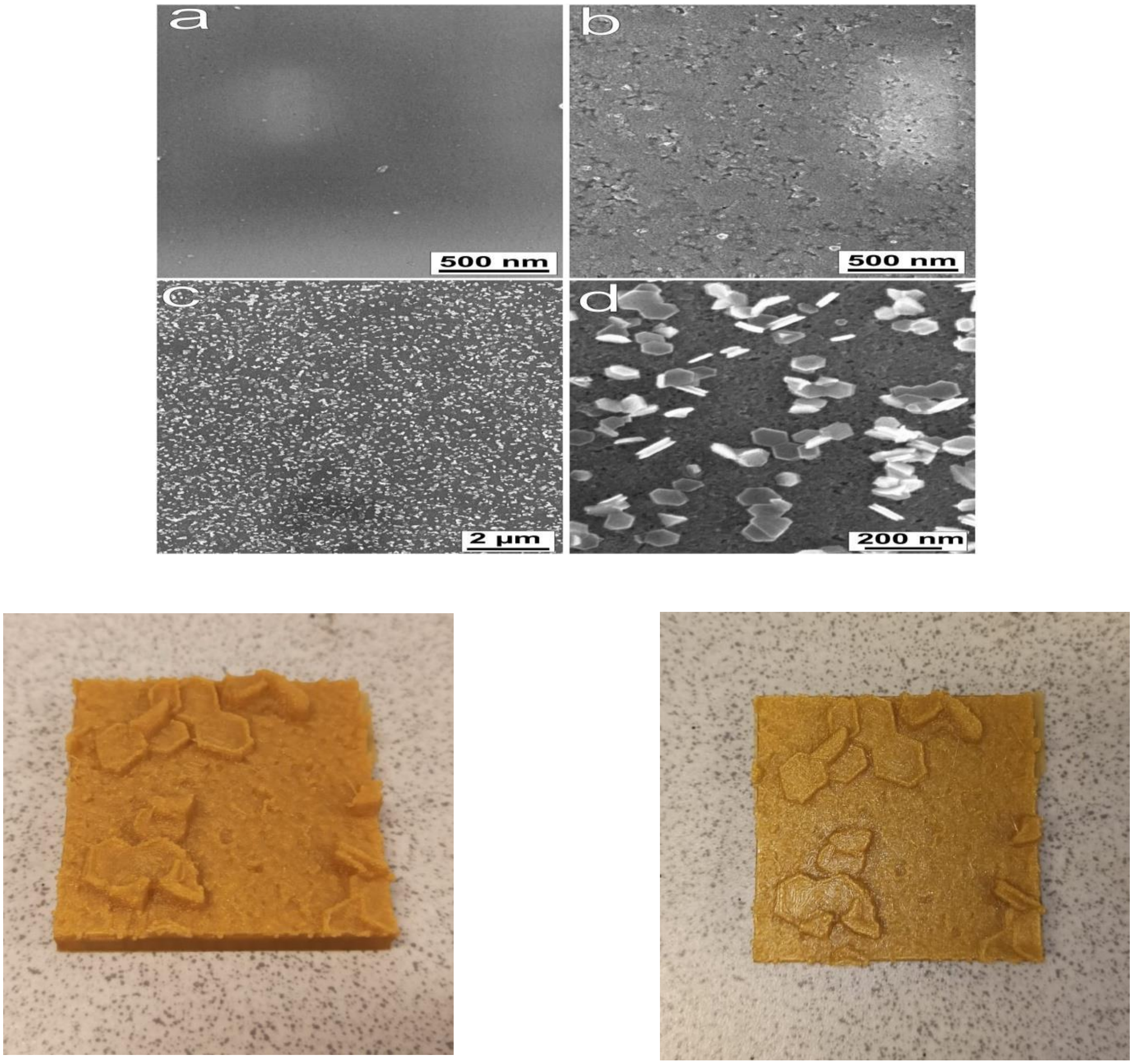


Figure3: SEM images of a Zn sample electrochemically oxidized and 3D printed models.

Nano flowers:

Nanoflowers are a new type of nanoparticle with a structure like flowers. It is gaining a lot of attention due to their simple preparation method, high stability and efficiency. Some of the applications that are found to be interesting are the use of nanoflowers as biosensors for detection of conditions like diabetes, Parkinson's, and Alzheimer's, as an aid for removal of dye and heavy metal from water and for gas-sensing.

In a study by Ishioka et al, zinc oxide crystals were grown and subsequently corroded by UV radiation. The authors first prepared a zinc substrate for ZnO crystal growth by subjecting it to submerged plasma discharge in ultrapure water. This created ZnO nano bumps, which then grew into cluster of nanorods called nanoflowers in the presence of UV light. By further irradiating the material, the authors induced corrosion on the nanoflowers. The surface appearance after each of these treatments can be seen in figure. We chose this material to model because of the large size of the nanorods, the unique appearance.

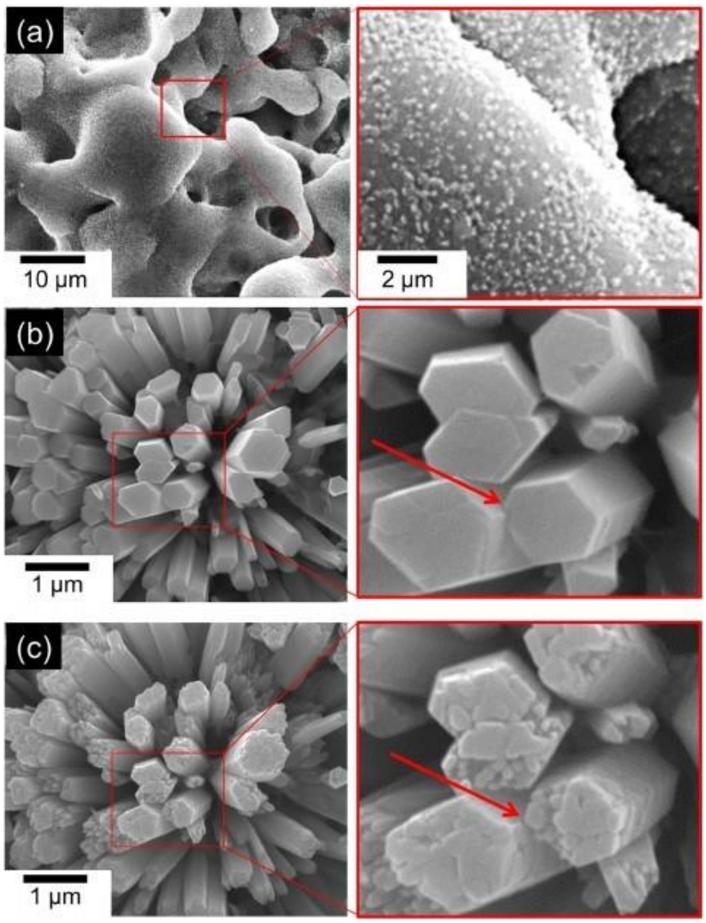
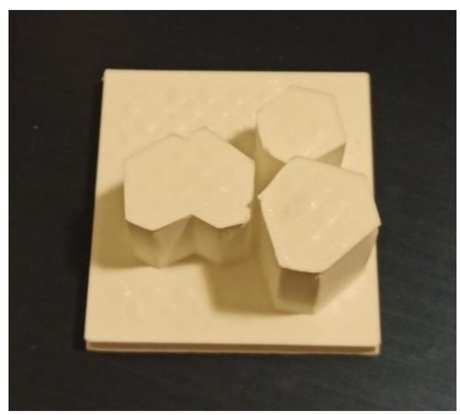
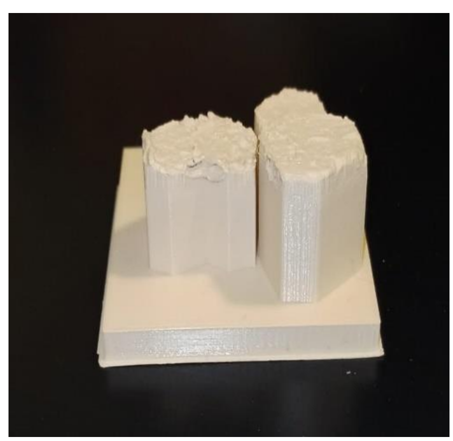


Figure 6: Scanning electron microscopy (SEM) images of the growth of ZnO nanoflowers

(a) Plasma- treated Zn substrate (b and c) Corroded nanoflowers





Product value:

The product has value in the industry and in academia. Both based on the usage of the product as before there were only 2-D models were available which didn't provide good information with flat surfaces but with 3-D models come into play it gets easier to show more information and it is more realistic to see models with one's eyes before it executes to real models.

The primary goal of this project was to function as a proof of concept, and as such its applications are somewhat limited without significant refinement of the process. However, we include here an example of using these models in a teaching environment to help better describe the effects of surface morphology on surface properties. As nanotechnology is advancing in the field of education and teachers finds its difficult to explain to the students how real surfaces looks like so it will be a good opportunity to excel in this field and students would love to see the real models in their hands and see up close the effects and different models.

Nanomaterials have extensive and emerging applications in almost all modern industries like construction, textile, aeronautics, oil and gas, computers, and machinery etc. Commercial samples being prepared with nano surfaces to give a detailed view of how products can be affected with different things.

For instance, let's talk about steel surfaces being treated with different acids. Steel surfaces were treated with different acids to attempt to improve the protective properties of a subsequent silane coating. What

they found was that mild corrosion of the surface can increase surface are and improve the adhesion and function of the silane coating. However, extensive corrosion with significant changes in the surface morphology result in poor adhesion and large pockets beneath the coating, reducing its effectiveness. The picture compares these surfaces prior to coating, but the differences in the extent of the corrosion can be difficult to discern for a less experienced reader.

We feel that our printed models can give a better understanding of the differences between the surfaces. The model pictures above shows the models of the steel surfaces treated with sulfuric acid. From these pictures it is easier to see the extent of the corrosion and understand its effects on the coating. The sulfuric acid treated metal is a mostly flat surface, with short, widely spaced protrusions. The phosphoric acid treated metal, on the other hand, has an undulating surface, with deep, tightly spaced cavities. Since cavities beneath the surface of the coating play an important role in the effectiveness of the coating, it is much easier to tell from these two models that a coating on the sulfuric acid treated steel would be more protective. Figure 17: On the left is a model of the steel surface treated with sulfuric acid, and on the right is a model

of the one treated with phosphoric acid. This could be a beneficial teaching aid in, for example, a classroom environment, helping students to become more familiar with abstract concepts. In addition, these models could potentially be used within industry situations, demonstrating the effects of nano surfaces or coatings to potential customers.

Database:

The database is an important thing to hold up information for any project or product being produced or completed. Almost every company and organization have some sort of database for instance websites where they have information about the organization, details about their products and information about them working there.

As for our project, the scope of our project is to deliver a 3D printed model which is a tangible thing and not to develop a fully functional website or a database for our project. We have different options to give access to our models as it can be uploaded to a domain and or to have a specific server hosting information about our models.

As NTNU has a central drives system like blackboard and everyone can have access google drive easily so the preferred way for the group to upload information about the project is on google drive and then it can be shared with anyone wants to have information about the models or who wants to study about them. Moreover, the 3D printers that are being used are also at NTNU and it can be helpful to transfer data to printers just like we have printing setup from IT department at NTNU where we can send prints to central hosting system for prints and then we can use any printer at any campus to take out prints and copies. The models can be stored on SD cards for 3D printer workshop, and anyone can go and us them without any request and a domain can be made on internet to get those models if needed but the first route would be preferred for this project.

Link to database:

https://drive.google.com/drive/folders/1X3FfQmAzX05GXWdE0EY0bB5GbiW7t3tL?usp=share_link

Selection and comparison of modelling software:

The following software for the purpose of 3D modeling were considered:

- AutoCAD
- Revit
- Blender
- Nano CAD
- Solid works

We decided to go forward with SOLIDWORKS as it offers a more efficient and automated process of 3D modelling of nano surfaces. Originally it was planned to model structures manually using extrusions and cuts in the software, but a rudimentary process was configured which lets auto modeling of surfaces on to virtual models which saves time and resources. Some other software also supported 3D modeling of nano surfaces but lacked in supporting 3D printing.

Printing options accessibility and limitations

The prints were planned according to the availability of printers in Makerspace at NTNU. It was required to go through a printing course offered by NTNU to be allowed to use 3D printers. The machines needed to be booked in advance from the Make NTNU website. The samples under process needed to be monitored in the early phase to avoid errors, afterwards it did not need constant visual monitoring for the remaining printing process. Printing multiple models at once was also not feasible as it could increase the process time to more than 12 hours. Also, some models needed manual touch afterwards to cut and trim the edges and extrusions. Also, physical presence at multiple stages is also required at the printing facility. There are multiple printers of distinctive characteristics present in the printing space each with its own limitations.

Project Schedule:

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Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish
1 Feren		1141	1141	0%	26-Aug-24	08-Jan-29
NEWPROJ-1 3D modeling and prinitng		50	50	0%	25-Aug-22	02-Nov-22
NEWPROJ-1.1 Initiation		31	31	0%	25-Aug-22	06-Oct-22
A1000	Topic Selection	21	21	100%	25-Aug-22	22-Sep-22
A1010	Scope Definition	26	26	100%	01-Sep-22*	06-Oct-22
A1020	Timeline acqusiton	5	5	100%	15-Sep-22	21-Sep-22
A1030	Academic requirement	5	5	100%	16-Sep-22	22-Sep-22
NEWPROJ-1.2 Planning		11	11	0%	22-Sep-22	06-Oct-22
A1040	Goals definition	5	5	100%	22-Sep-22	28-Sep-22
A1050	Data acqusiiton	5	5	100%	28-Sep-22	04-Oct-22
A1060	Software selection	5	5	100%	29-Sep-22	05-Oct-22
A1070	Prinitng technique selection	5	5	100%	30-Sep-22	06-Oct-22
NEWPROJ-1.3 Process		18	18	0%	06-Oct-22	31-Oct-22
A1080	3D modeling	6	6	100%	06-Oct-22	13-Oct-22
A1090	3D printing	5	5	100%	13-Oct-22	19-Oct-22
A1100	Framework Development	5	5	80%	19-Oct-22	25-Oct-22
A1110	Writeup	9	9	44.44%	19-Oct-22	31-Oct-22
NEWPROJ-1.4 Results		15	15	0%	13-Oct-22	02-Nov-22
A1120	Finalizing models	5	5	100%	13-Oct-22	19-Oct-22
A1130	Framework	1	1	0%	25-Oct-22	25-Oct-22
A1140	Report	1	1	0%	31-Oct-22	31-Oct-22
A1150	Video Presentation	3	3	0%	31-Oct-22	02-Nov-22
NEWPROJ-1.5 Closure		1	1	0%	02-Nov-22	02-Nov-22
A1160	Submission	1	1	0%	02-Nov-22	02-Nov-22
NEWPROJ-2 (New Project)		50	50	0%	25-Aug-22	02-Nov-22

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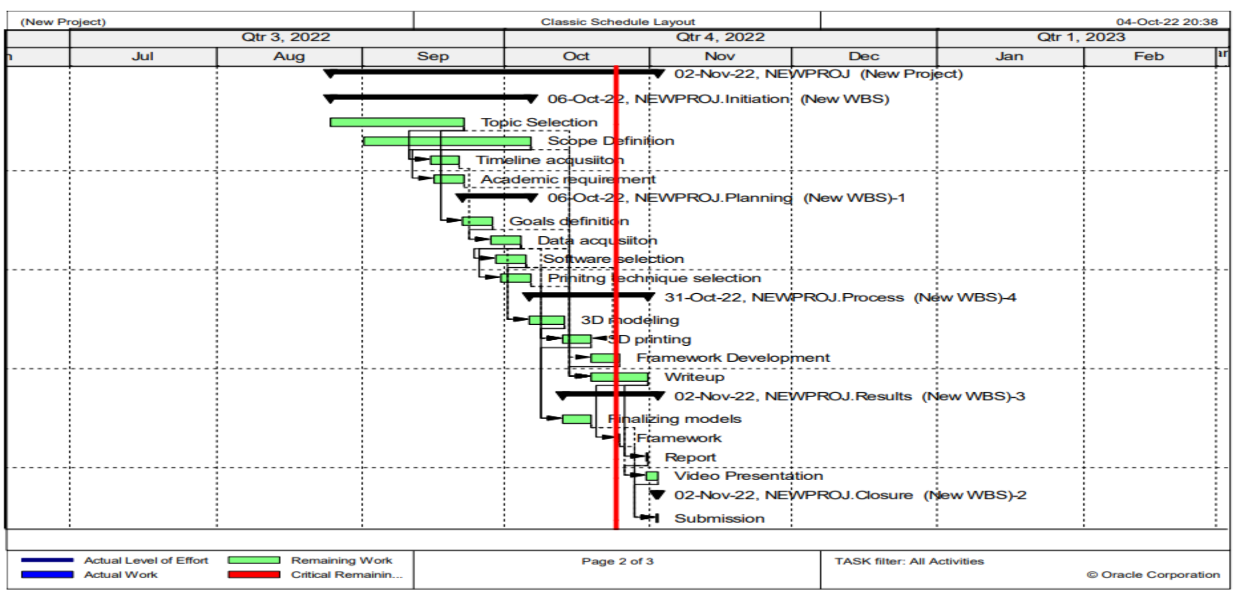
Gantt Chart:



Risk Analysis:

Risk type	Risk Description	Cause	Effect	Likelihood (3 most, 1least)	Severity (3 most, 1least)	Importance
Technical	Software expertise	complexity or inability to learn	redesign on new software	2	3	6
	Target material selection	too wide scope	redefining the scope of project	1	3	3
	Printing limitations	printers have different limitations for printing models	predetermining and evaluation	2	2	4
Resource	3D printing lab availability	lab may not be available all the time	reschedule before time	2	2	4
	Material availability	material and fillings for 3D printing	check before time	1	2	2
	Manpower	atleast one person	communicate well in advance	2	2	4
	Budget	material and fillings for 3D printing	provided by university	1	2	2
Safety	Material exposure	can be harmful to skin	usage of gloves	1	1	1
	Electronics	machinery and electricity presence	care and keeping max distance	1	1	1
	Ergonomic activity	complex activities	course in 3D printing undertaken beforehand	1	2	2
	must not chip/shatter	models are fragile	must be placed in containers	1	1	1
	Usage of sharp utensils for final touch	knife and sharp tools are used to carve the edges	usage of gloves and safety googles	2	2	4

Environmental Safety	Disposal of materials	incase breaks or wear out	recycle	2	1	2
	unsafe fumes production while 3D printing	printing process	safety equipment usage	1	1	1
	Usage of non toxic material	material selection	choose non toxic material	1	1	1
	Degradation of material	material selection	chose degradable material	1	1	1

Group based evaluation of Risk Analysis:

Scale	Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree
Team Response					√

Success factors:

Motivation:

Motivation plays the most vital role in the success of any project. In our case, the project required completion of tasks of varying magnitude and complexity and effort from everyone involved. As everyone was motivated, the division and premises of the workload became easier to handle.

Adequate project planning:

Time is of the essence; our project was time demanding and at the same time under time constrained. It required the group members to utilize time out of their schedule and allot it for the project.

Proper choice of project (Background expertise):

Having members from different expertise is a double-edged sword as the workload could require intake from different expertise or maybe the workload could be related to the same field but of high magnitude. In our case, each member was from different field I.e., Civil Engineering, Chemical Engineering and Electronics. It worked out for us as our chosen project required expertise from all these three fields.

Technology to support the project:

Our project required learning new software and techniques to produce the result. The work was distributed but everyone had a task which required them to either learn modeling or printing software. As everyone felt motivated to learn, the process became smooth.

Good coordination with stakeholders:

In any project where multiple individuals or disciplines have to corelate, and work together require a certain level of efficiency in terms of teamwork. In our case, everyone acted as a team player. Nobody tried to take the spot-light or ghost-light anyone. In our opinion, teamwork played the most crucial part in our project's success.

Agreed success criteria:

Clearly defining the project scope and requirement helped us in carving out a path forward. We finalized the objectives, timeline and our goals at the beginning of our project which helped us to stay on our schedule and produce results within the time frame.

Failure factors:

Degree of complexity (Machinery and software limitations):

There are multiple software available for 3D modeling but not each one of them supports modeling of nano surfaces and even out of the ones that do, some do not support 3D printing. It was mostly a trial and error and omission sort of process for finalizing our software and printing technique.

Degree of innovation (Uncertainty of result production):

Even if every task went according to plan, there was still some uncertainty in result production. It could be due to the printing limitations (lease printable sizes), unavailability of equipment or any other unforeseen circumstances.

Overburden:

Being students of full time Master's program, all the members had to cope with the workload of their primary courses as well as the additional workload of this project. In case, it was not managed well, it could have affected adversely on our project output.

Time limit:

Time constraint binds and limits the scope of our project. We had to learn new software, adopt new techniques and produce the results within a very constrained time. Neglecting this essential factor could have resulted in a very negative impact on our project's success.

Lessons learnt:

For any similar project it is essential to first identify the objectives and scope of the project because such projects contain a considerable level of uncertainty and ambiguity. The constraint of the time frame should also be considered before deciding on the type of project. Our advice is to formulate a project breakdown structure and develop a time frame, which in our case is in the form of a Gantt Chart. It would greatly help in staying on time and keeping track of the required and incoming activities. During our project we learnt that team effort and willingness to work were the major role players in the success of our project. From our experience, we would suggest using and include the expertise of each of the group members but at the same time ensure not to over burden anyone.

Reflection

First of all, we had to develop our project breakdown structure then formulate a timeline before starting the actual working on our project. Then, we discussed the challenges and the mitigation measures in order to overcome them. Afterwards, we evaluated different software to configure which one suited our product the most. Then we had to attend a introductory course in 3D printing at NTNU in order to gain access to the printing facility. All of us learnt to adapt to working in a diverse group for a common goal within a time constraint and facing a set of challenges. There was one prominent situation during our project where learning was critical to success of our project, as initially we intended to develop models during conventional method of making extrusions and cuts using cursor in the software but during researching, we came forward with a technique which let us to draw the models automatically. It was a risk that we took to spend our time searching for newer techniques instead of going with conventional methods, but it worked out in the end. This situation describes both the scenarios where learning (new automated techniques) and unlearning (not using conventional modeling methods) were critical for the success of our project.

Appendix:

1. Pre-report

Objectives

- To be able to 3D model nano surfaces
- To be able to 3D print the nano surfaces into visually focusable scale
- Framework development for future works

Process

- Selection of research material
- Selection criteria
- Selection of 3D modelling software/techniques
- 3D printer availability and skills requirement
- 3D printing of modelled surfaces
- Finalizing samples
- Framework development for future modelling and printing of such materials
- Feedback from academia/industry, if possible

Applications

- Teaching environment: to represent surface morphology
- Industrial environment: to demonstrate effects of coatings to potential customers

Outlook development

- To produce an outlook of the project including mistakes and suggestions

Benefits

- Framework for peers and academia to obtain/develop more such samples
- Use in academia for teaching/understanding purposes
- Use in industry for demonstration to customers
- Learning of new skills/techniques by the group members

Skills required:

- Fluency in 3D modelling software suitable for modelling nano surfaces
- Course required to be able to operate 3D printer in NTNU
- Learn to use 3D printer

Risk Assessment:

The risk assessment is based on the factors involved in the initial planning for the project work and it can be modified with time as the project progresses to completion. Initial factors showing risks are mentioned below:

Risks	Likelihood	Impact	Mitigation Actions	Impact after mitigation
Software usage for 3D modelling might be difficult to use	High	High	Needed to learn software usage can make it easy for modelling.	Low
Booking equipment for printing can take a long time	Low	High	Booking long before to have a spot before delivery deadline.	Low
Delivery time of models can be delayed	Low	High	It can be handled by taking booking time into consideration	Low
Resouces availability based on usage of 3D printers	Low	High	It can be handled by regular supply for printers	Low

Project breakdown structure:

(New Project) | Classic Schedule Layout | 04-Oct-22 20:38

Activity ID	Activity Name	Original Duration	Remaining Duration	Schedule % Complete	Start	Finish	Total Float
NEWPROJ (New Project)		50	50	0%	25-Aug-22	02-Nov-22	0
NEWPROJ.Initiation (New WB!		31	31	0%	25-Aug-22	06-Oct-22	0
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NEWPROJ.Closure (New WBS		1	1	0%	02-Nov-22	02-Nov-22	0
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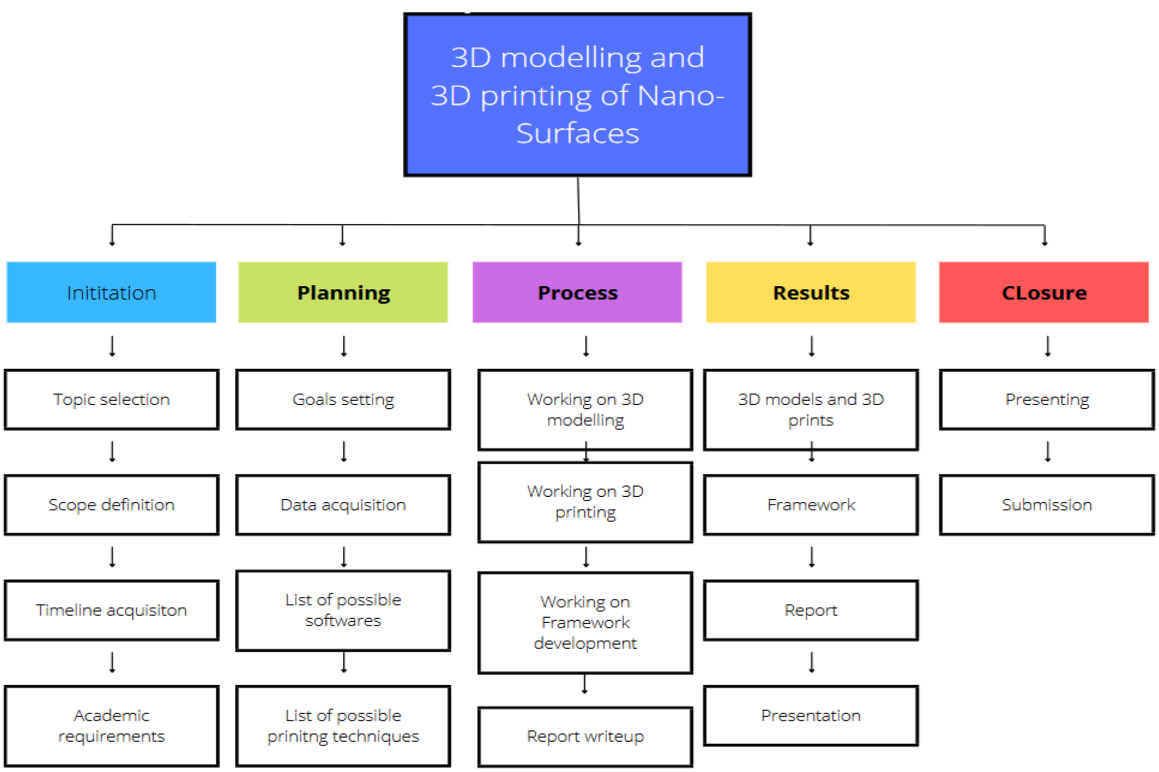
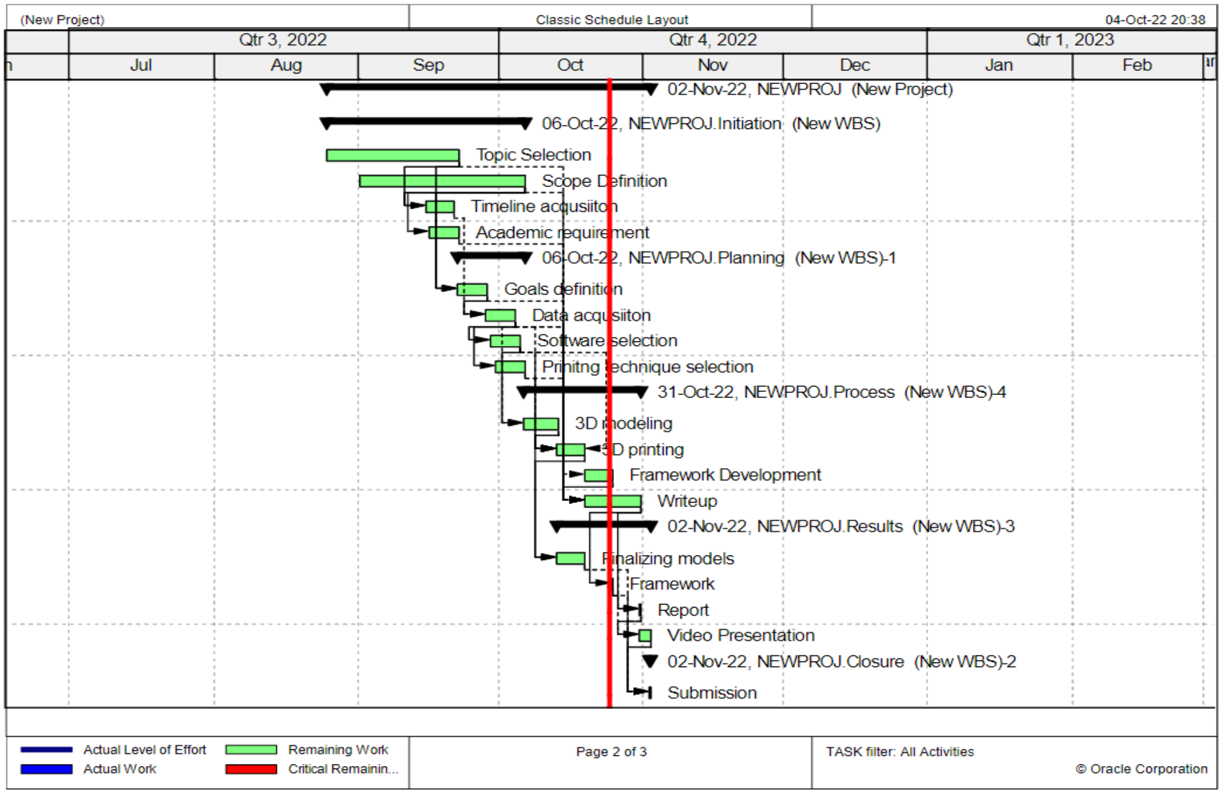
Actual Level of Effort | Remaining Work | Actual Work | Critical Remainin... | Page 1 of 3 | TASK filter: All Activities



Project schedule:



Success factors:

- Physical output (3D printed models)
- Framework development

Roles and responsibilities:

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2. Product Link:

   https://drive.google.com/drive/folders/1X3FfQmAzX05GXWdE0EY0bB5GbiW7t3tL?usp=share_link

3. Presentation Link:
   https://drive.google.com/file/d/1_MrhRCOZhAa8cqNX0h3kFZSDUxm8U-jK/view?usp=share_link