

# FABRICATION OF POLYMERIC NANOTUBES FOR DRUG DELIVERY APPLICATIONS

PURE

Student(s)

Alp DUMAN  
Alp Kaan KUTAY  
Aylin ALPAN  
Ece ÖZDEMİR

Faculty Member(s)

Gözde İNCE  
Ali TUFANI  
Mehmet Can ZEYBEK

## ABSTRACT

Initiated Chemical Vapor Deposition (iCVD) is a deposition system that uses monomer vapor instead of any other technique that enables conformal coating and eliminates any disadvantage from other deposition techniques. Due to these advantages iCVD coatings can be used for biomedical applications. Coating AAO templates with P(MAA co-EGDMA) creates pH responsive nanotubes. Depending on the pH of the environment these coated polymers swell or shrink. Swelling enables loading of the targeted molecules to nanotubes. Shrinking results in stress induced release of the loaded molecules. This conclusion can be used for making drugs reach their targeted area more effectively.

Keywords: iCVD, pH Responsive Coating, Polymeric Nanotubes, Controlled Release

## OBJECTIVES

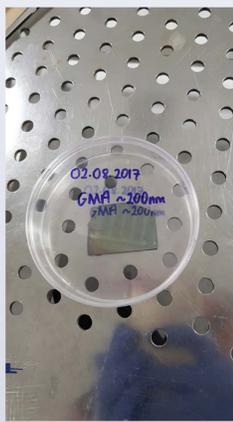
- Learn to use the iCVD system. Read articles, research on internet and practice on lab to improve knowledge and practice.

- Produce a conformal coated substrate with any monomer.

- Produce a conformal coated nanotube with P(MAA co-EDGMA) monomer.

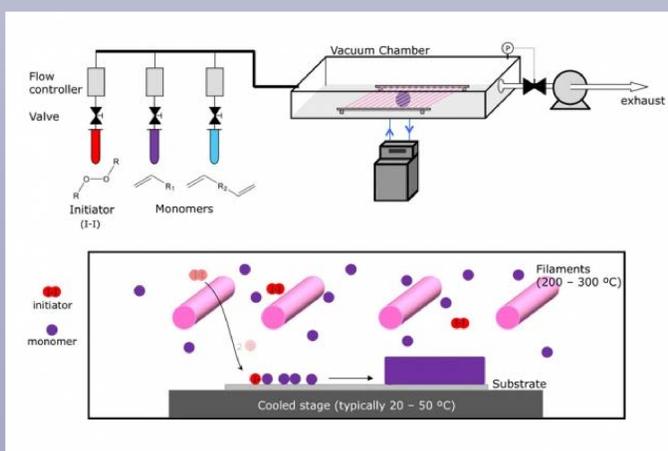
- Load the nanotubes with any molecule of choice.

- Unload the nanotubes with response to pH stimuli.



## PROJECT DETAILS

iCVD is a technique that enables the fabrication of chemically well-defined thin polymeric films on complex objects with micro and nano-scale features. This technique is different from other techniques as it uses an initiator to start polymerization process. Alongside the initiator, monomer and nitrogen are also introduced. Monomers are separately heated so that they can vaporize. Once their vapors propagate from their jars to the chamber the initiator thermally decomposes, thanks to pre-heated filaments, to form radicals but monomer vapor is not affected. Monomers and free radicals adsorb on the substrate and thus initiate free-radical polymerization. The low energy cost of iCVD holds advantages over other CVD methods, as the process can be conducted at a low temperature.

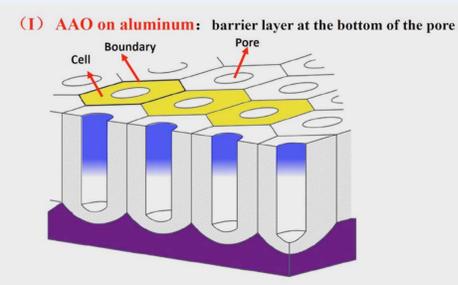


Kinetics behind iCVD were modeled and the most important result is after the iCVD processes are finished it gives us stoichiometric polymers with no observable crosslinking on the surface of the film. To get this result monomers and the initiator must adsorb on the substrate. If substrate temperature is kept at significantly lower temperature than of the chamber it can be seen that initiator radicals and monomer vapor indeed adsorb. Actually deposition increases with lower substrate temperatures.

## PROJECT DETAILS

A good and practical way of checking the process is by looking at the  $P_m/P_{sat}$  of monomer vapors;  $P_m$  being partial pressure of the monomer and  $P_{sat}$  being condensation pressure of the monomer vapor. Taking this value between 0.1 and 0.8 provides us with deposition. Taking it too low means that there is not enough monomer concentration and taking it too high results in condensation of the vapor. After initiation at filament temperature and adsorption, propagation occurs at the substrate temperature and polymer thickness can be observed real time. Termination of the polymer chains occur accordingly to  $P_m/P_{sat}$  value.

For iCVD, a practical model is available regarding temperatures, pressures and  $P_m/P_{sat}$  values of everything mentioned above. With this model usable monomers with the system increase rapidly and thus so do application areas of iCVD.



AAO template is placed together with substrate in iCVD for coating purposes. This coating will make the pH responsive nanotubes. Substrate is there to ensure AAO template is coated right. Coating is made with low  $P_m/P_{sat}$  to make the coating as conformal as possible. iCVD process is done as mentioned above with respective  $P_m/P_{sat}$  and P(MAA co-EDGMA) monomers. When coating is finished AAO template is held in HCl solution for a day to isolate the nanotubes. These nanotubes now have conformal coated polymer that swells at high pH and shrinks at low pH. Swelling is due to deprotonization at high pH. This creates a negative charge at the tip of the polymers so molecules push each other away. Shrinking occurs because of protonization of the polymer and it resets to its original state.

Because of the swelling effect, volume of the nanotube increases and extra volume can be used to store molecules of our choosing; in this application intended drug. Now there is swelled molecule holding the intended drug. When this nanotube reaches an environment with low pH it relaxes back to its original state but it is filled with drug in it. While decreasing its volume, the polymer exerts pressure onto the drug. This causes the drug to burst release due to stress.

## CONCLUSION

All of this loading and unloading effects were tried using molecular dye and environment of pH 4 and pH 8. Nanotubes were able to absorb 8% percent of the released dye. Roughly 50% of the intended drug was released from the nanotubes.

This shows us;

- This system can modernize drug usage. Today's drugs rely on taking high dosage of drug and diffusing it through the whole body to have effect on the targeted area. This might cause some harmful side effects.
- With pH stimuli drugs it is possible to take lower dosage of drugs but have the same effect on the targeted area, maybe even better.
- It is possible to load more drugs with increased nanotube number. Process is open to improvements.
- Stimuli effects other than pH can be researched to widen the targeted areas of human body.

## REFERENCES

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