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COMSOL
CONFERENCE
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Modeling of Hydrogel-based Controlled Drug Delivery System for Breast Cancer Treatment



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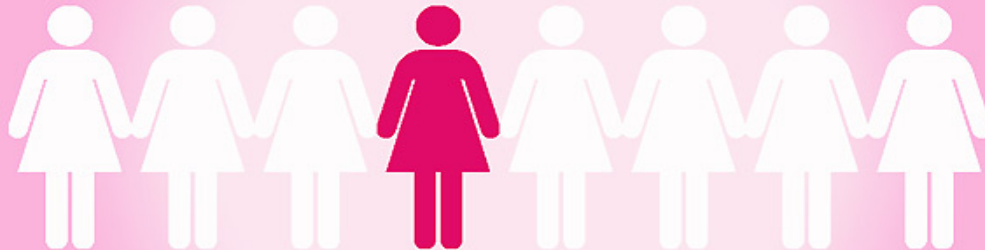


Background

- Breast cancer is the second leading cause of death among female cancer patients.

FBCOVERSTREET.COM

One In Eight Women Will Develop Breast Cancer In Their Lifetime



Early Detection Saves Lives.

Check Often

And Encourage Those You Love To Do The Same

Background

- It occurs by the uncontrolled reproduction of the cells which generates the milk tissue and milk channels.
- One of the every 8 women is diagnosed with breast cancer. (Lifelong: %11 risk)
- Breast cancer is the most frequent cancer.
- Frequency increases after 50 years of age.
- Rarely diagnosed in men (1 man to 150 women)
- %10 of breast cancer show genetic transition.

Background

- Risk Factor
 - Age above 50
 - Breast cancer in family
 - Early menarch
 - Late menopause
 - BRCA1, BRCA2 gen mutation
 - Oral contraceptive and HRT
 - Nulliparity
 - Giving first birth above 30 years of age
 - Using alcohol
 - Fatty foods and obesity

Background

- **Treatments for breast cancer**
 - Surgery
 - Chemotherapy
 - Radiotherapy
 - Hormonal therapy
 - Biological therapy



Background

- **Chemotherapy Drugs**
 - Methotrexate
 - Doxorubicin Hydrochloride
 - Fluorouracil
 - Docetaxel
 - Cyclophosphamide monohydrate
 - Cyclophosphamide
 - Paclitaxel
 - Tamoxifen citrate



Drug Delivery

- The conventional drug delivery methods include fast-acting responses via oral or injection delivery routes

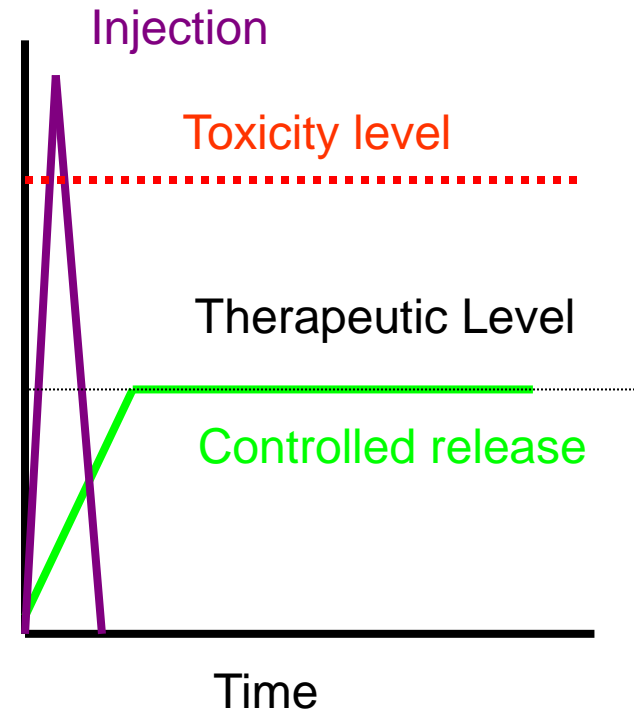
Problems associated with this approach

1. Reduced potencies because of partial degradation
2. Toxic levels of administration
3. Increase costs associated with excess dosing

Controlled Drug Delivery

Goal of controlled drug delivery techniques:

1. Deploy to a target site to limit side effects
2. Maintain a therapeutic drug level for prolonged periods of time
3. Predictable controllable release rates
4. Reduce dosing frequent and increase patient compliance

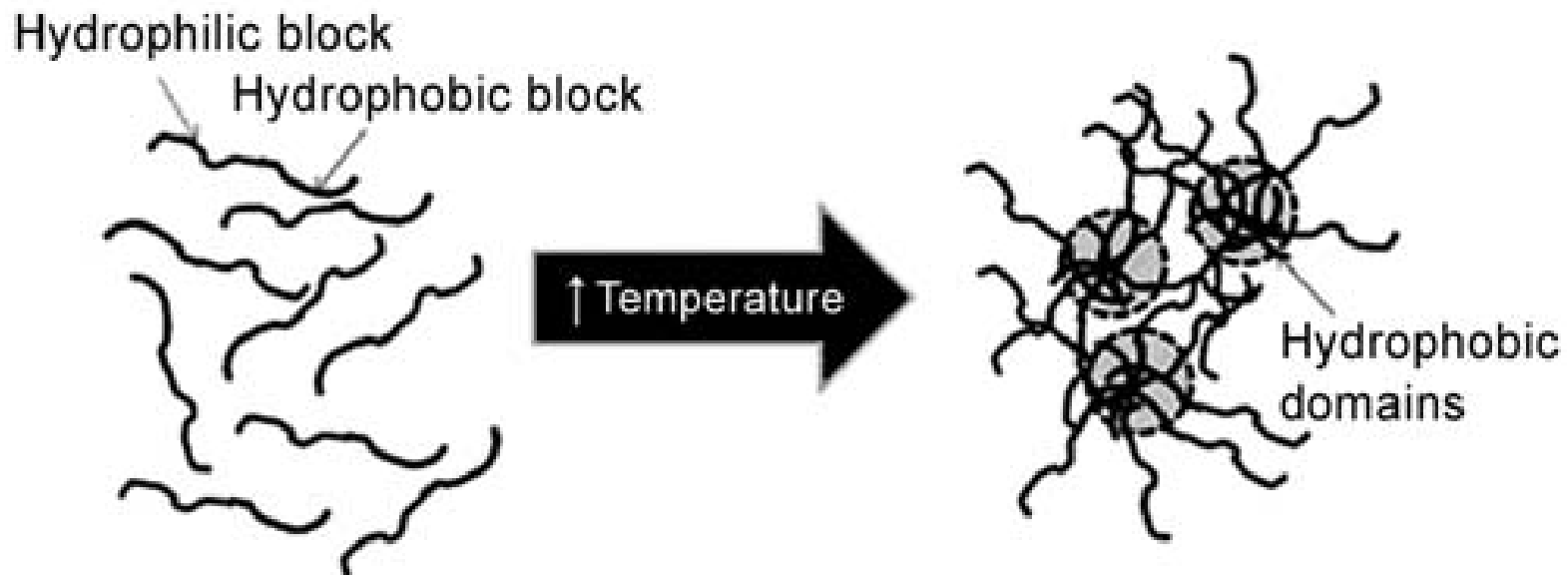


Hydrogels

- Polymeric hydrogel is a promising class of drug delivery systems with the controlled release behavior in the body
- **Definition:**
- Three-dimensional networks of hydrophilic polymer chains that do not dissolve but can swell in water
- In equilibrium, water can form more than 90% of hydrogel weight

Introduction

- In-situ forming Hydrogel
 - Mechanism of in-situ physical gelation driven by hydrophobic interactions



Hydrogel

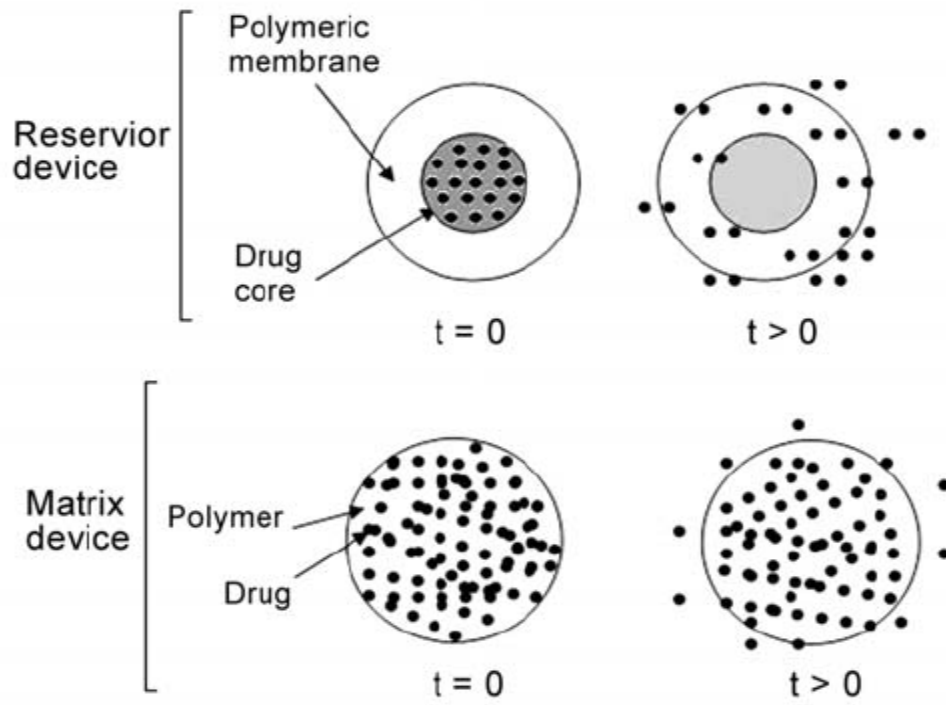
- **Advantages in Drug Delivery applications:**
 - highly biocompatible
 - Adjustable porous structure by controlling the density of crosslinking
 - loading of drugs into the gel matrix and subsequent drug release through the gel network
 - can protect the drug from hostile environment, e. g. the presence of enzymes and low pH in the stomach

Controlled System Types

- Drugs may be enclosed or immersed within a hydrogel and correspond to several different types of controlled release systems:
- **Diffusion-controlled systems**
- Swelling controlled systems
- chemically controlled systems
- environmentally responsive systems

Diffusion Controlled Systems

Schematic representation of diffusional controlled reservoir and matrix devices



Objective

- Introducing a new hydrogel based drug carrier for breast cancer treatment
- Modeling the diffusion release behavior of drug
- Evaluating the effective concentration of the drug needed in the hydrogel

Method

- Simpleware(ScanIP)
- COMSOL

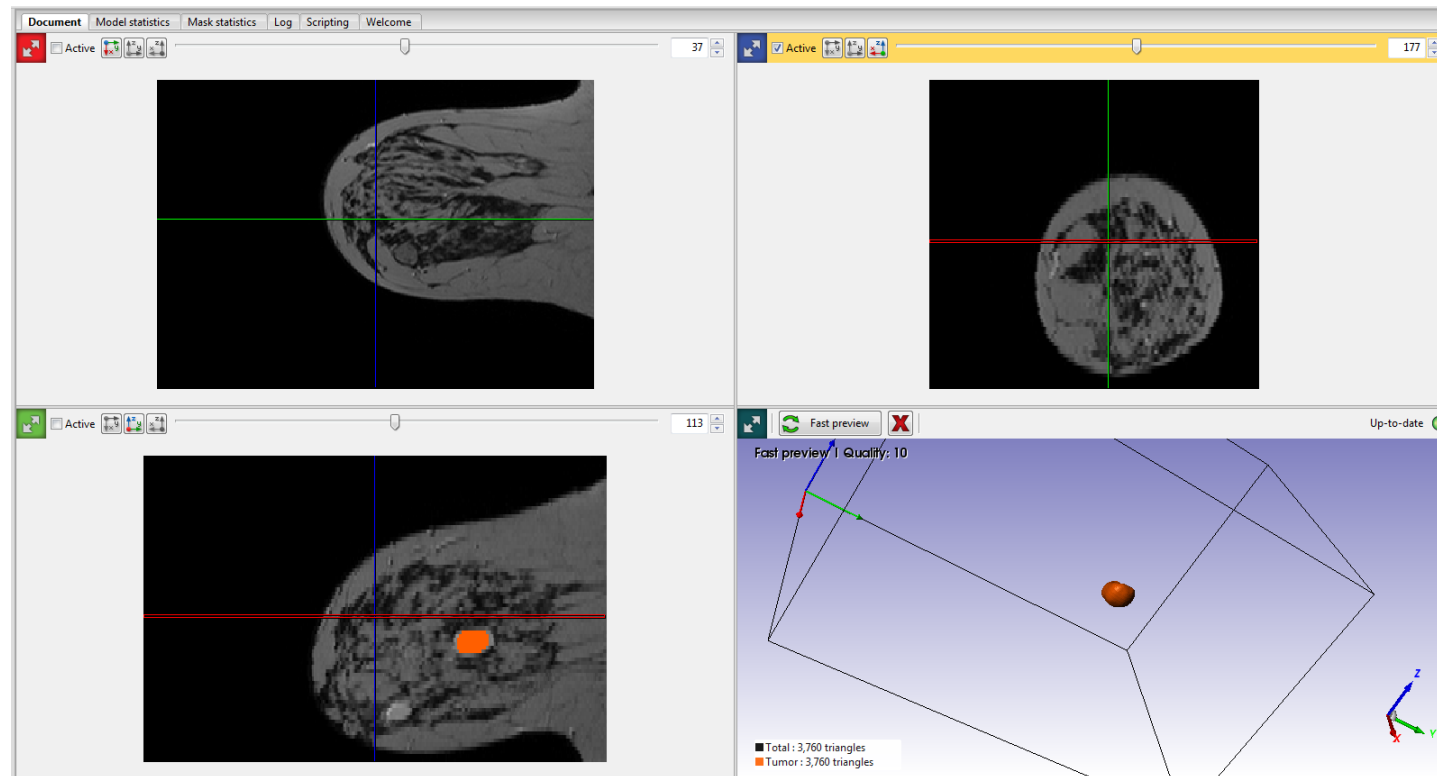


Method

- ScanIP used to generate mesh geometry.
- We used COMSOL as our method to simulate drug diffusion behavior.
 - Chemical Engineering Module

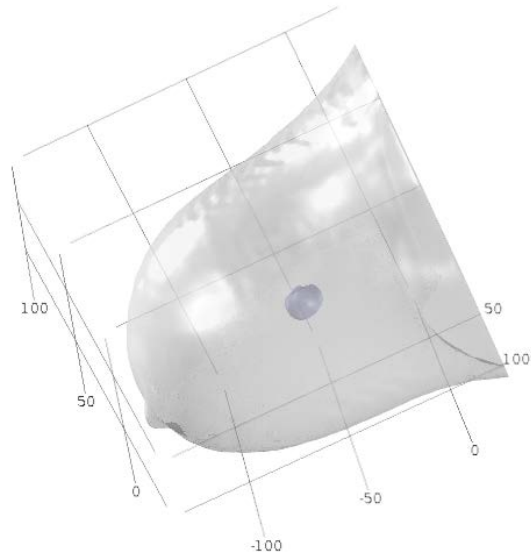
Method

- ScanIP

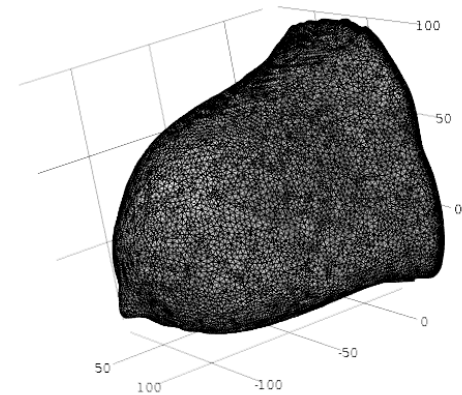


Method

- COMSOL



Geometry



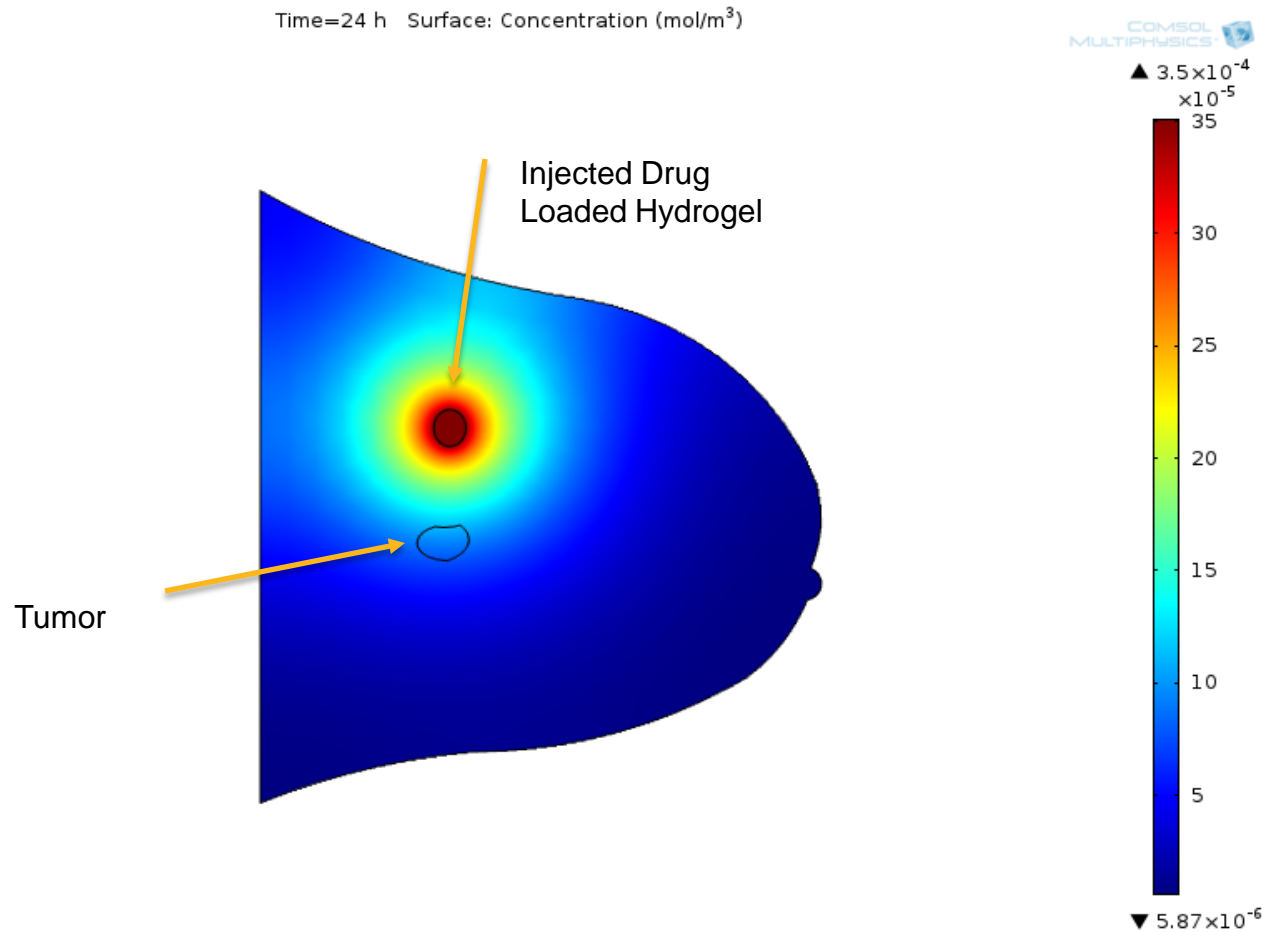
Mesh

Equation

- Governing Equation
 - Fick's Law of Diffusion

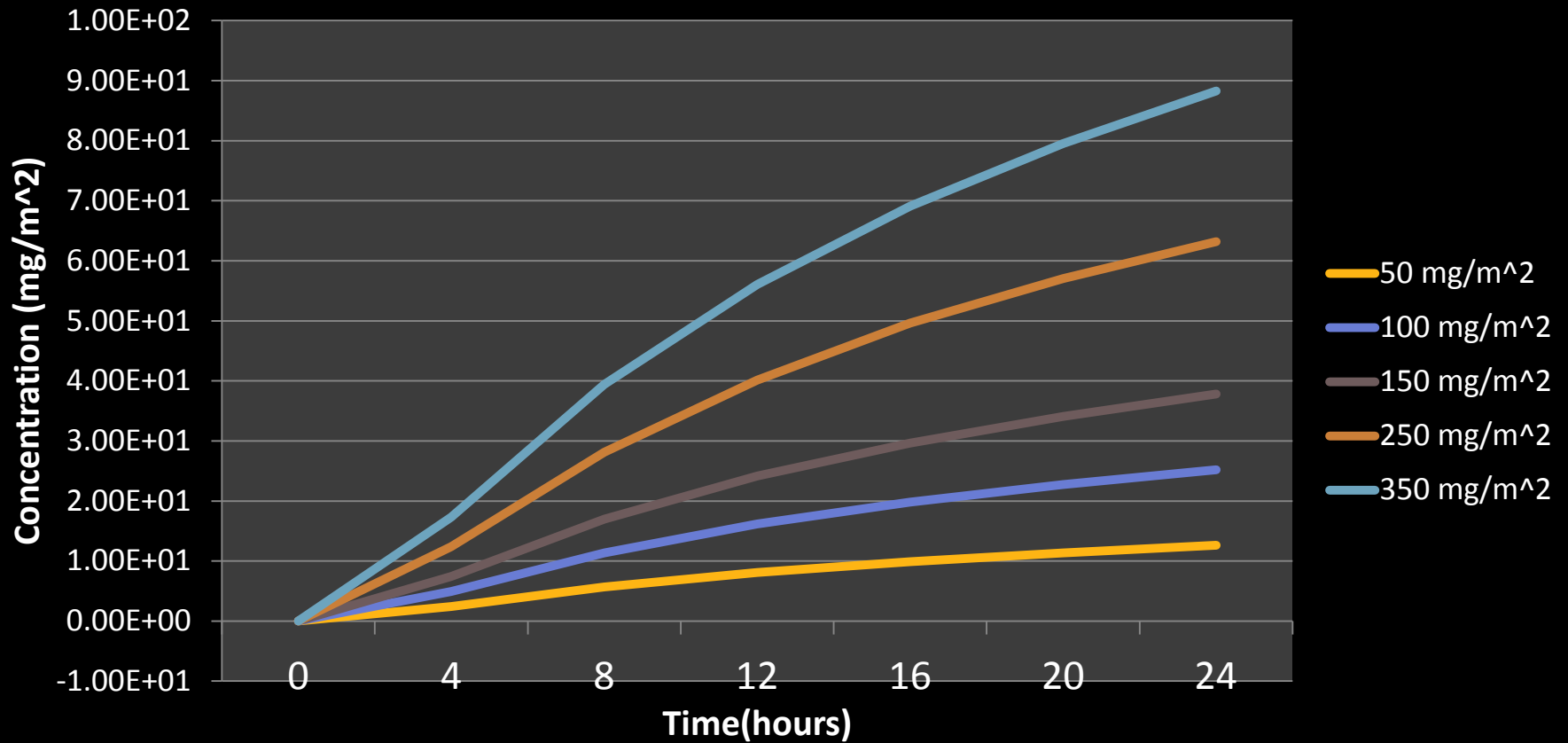
$$\nabla C = \hat{i} \frac{\partial C}{\partial x} + \hat{j} \frac{\partial C}{\partial y} + \hat{k} \frac{\partial C}{\partial z}$$

Results



Results

Drug Concentration in tumor when hydrogel injected above



Different Diffusion Coefficient based on polymer weight

Drug Diffusivity, D (cm ² /s)	Drug Concentration, c (mol/cm ²)
2.70E-05	5.22E-05
2.70E-06	3.44E-06
2.70E-07	1.82E-10
2.70E-08	1.48E-15
2.70E-09	8.56E-15

Conclusion

- CT-scan image of a patient with breast cancer tumor was converted to mesh using ScanIP, and the resulting mesh was converted to COMSOL multiphysics
- The drug release behavior from an injected drug loaded hydrogel into the tumor site was modeled using Chemical Reaction Module in COMSOL
- The results showed the best therapeutic initial concentration of drug in the hydrogel is 250 mg/m^2
- Different diffusion coefficient based on the polymer weight in the gel were modeled, the promising result was for **2.70E-05**

Q&A

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