Theoretical and Practical Approach For Transdermal Drug Delivery Using Microneedle For Successful Skin Penetration

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Introduction: The tissue damage and infection during a needle insertion and needle breakage are the major issues related to hypodermic needles. The microneedles mechanically create the pathway through the upper skin layer and pierce the upper epidermis so as to increase skin permeability and, therefore, improve drug delivery efficiency. a drug delivery device featuring miniaturized projections (i.e., microneedles) and a drug reservoir is claimed. The needles are small enough to penetrate only the stratum corneum and can be either solid or hollow.

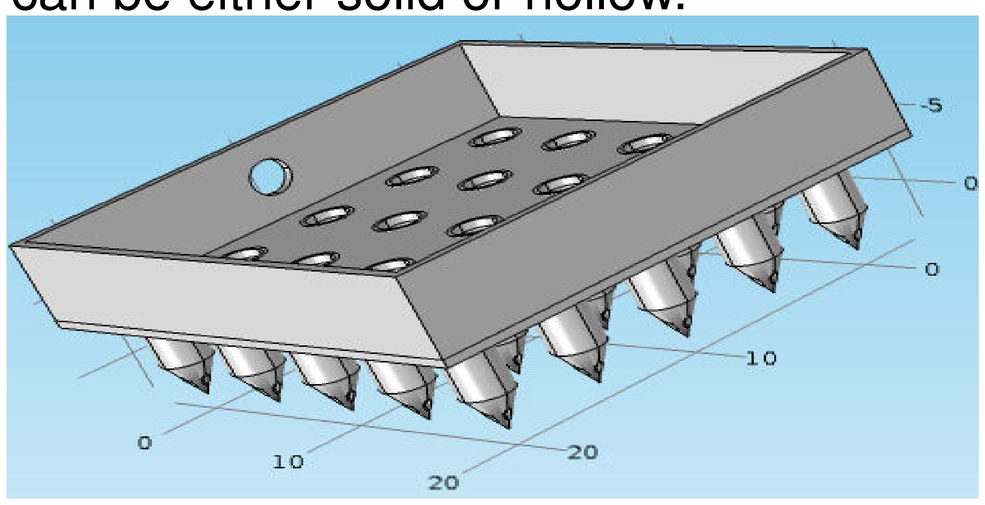

Figure 1. Model diagram of Microneedle with reservoir

Computational Methods: The pressure drop required to flow fluid through a microneedle depends on needle geometry and fluid viscosity and density.

Navier-Stokes theorem for one dimensional equation is the governing equation for fluid flow inside needle.

$$\rho \partial u/\partial t + \rho u \partial u/\partial x = \mu \partial^2 u/\partial x^2 - dp/dx + F_x$$

Net acceleration + convective force = Viscous force + pressure force + external force

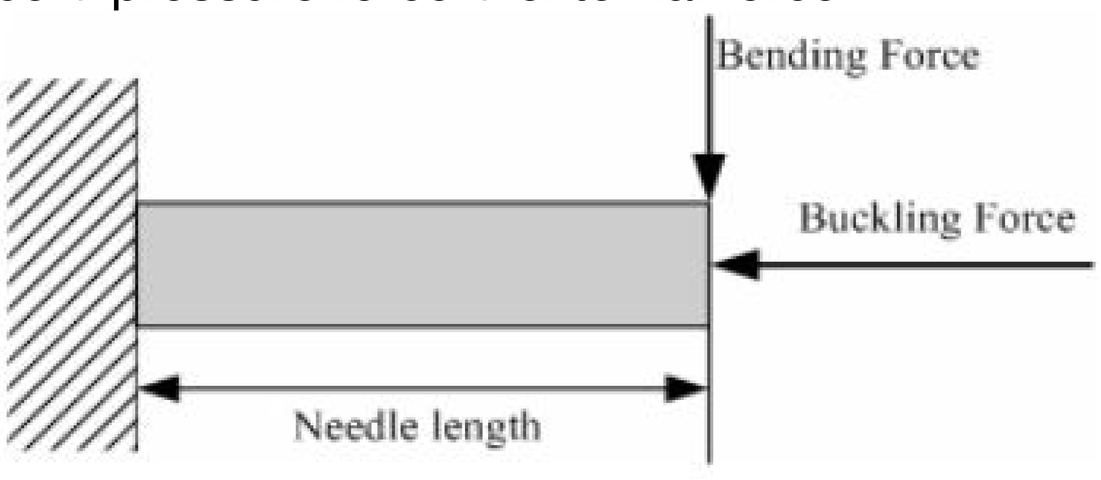

Figure 2. Schematic model for forces acting on a microneedle.

Results: The cylindrical section of the microneedle is having a height of 400μm, 50μm at their bases and conical section with a height of 100μm. The needles are positioned in a 5x5 array with center-to center spacing of 100μm between needles.

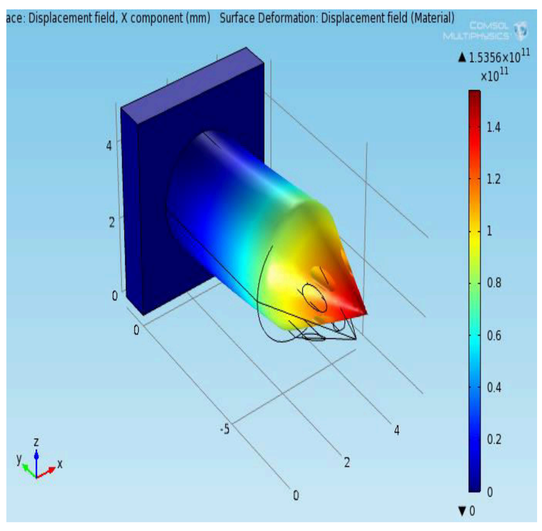

Figure 3. Stress-displacement simulation for a single microneedle

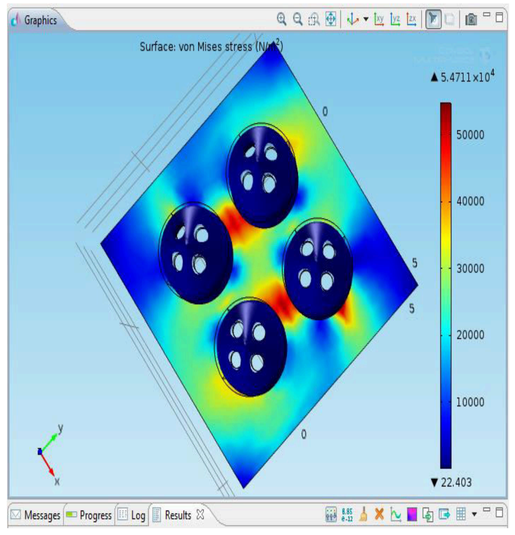

Figure 4. Stress analysis of uniform distribution of microneedle on wafer area

Conclusions: Stress analysis and computational fluid dynamics has been studied and simulated using COMSOL Multiphysics for a single microneedle as well as array of microneedles.

It has been found that the proposed structure overcomes the issues like tissue damage and needle breakage. And opens the door for fabrication and implementation of the proposed structure for future biomedical applications.

References:

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