Dissolving Microneedle Arrays for Transdermal Delivery Using Aerosol Jet Printing

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INTRODUCTION

Microneedles have been extensively studied for the transdermal delivery of drugs over the last number of decades. They are an attractive means for drug delivery as they are painless and can facilitate the delivery of drugs which would not ordinarily penetrate the skin. In recent times, additive manufacturing techniques such as stereolithography have been used to fabricate microneedles. However, research to date is limited to solid, hollow and coated microneedles[1, 2]. Stereolithography methods do not lend themselves well to dissolving microneedle fabrication due to the limited materials available for this technique. The traditional method of fabricating dissolving microneedles by micro-moulding has its drawbacks such as variability in the administered dose, needle breakage upon removing from moulds and long curing times. Aerosol Jet Printing is an additive manufacturing technique which may overcome these issues due to its high reproducibility and precision. Structures are formed as the instrument creates an aerosol mist and deposits the ink dropwise in a controlled manner onto a substrate, thus building up layers to form a microneedle array. The instrument gives freedom of design in terms of needle shape and spacing and can print formulations with a wide range of viscosities.

OBJECTIVES

- Prepare a formulation which can be aerosolised and deposited onto a substrate with good adhesion.
- Fabricate microneedles which have suitable mechanical strength, sharpness and aspect ratio to penetrate the skin.

METHODOLOGY

- A formulation of 3:1 PVP:trehalose with 2% glycerol in water was prepared[3].
- A microneedle array was designed using CAD (Fig: 3b).
- Si wafer substrate was cleaned using acetone.
- Microneedle array was fabricated using the Aerosol Jet Printer.
- Compressed air was used to remove overspray and other excess material from the surface.

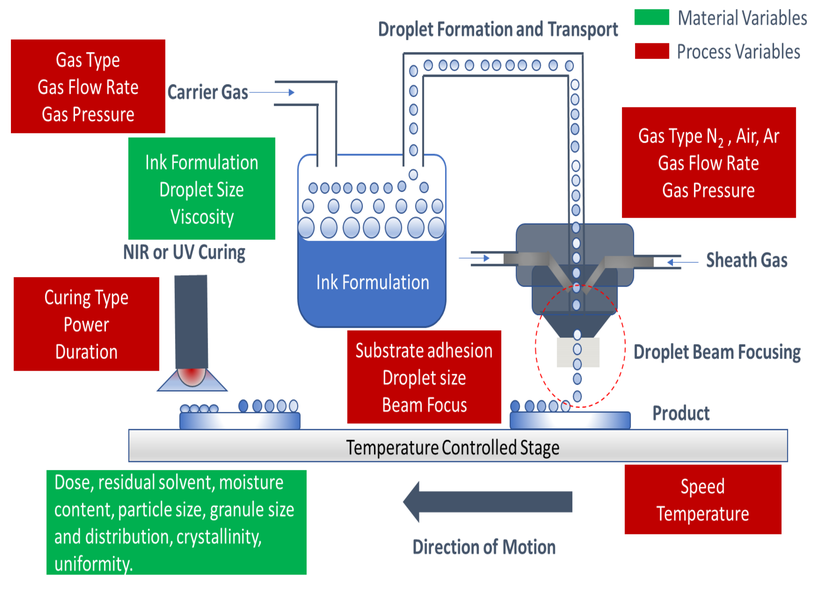

Figure 1: Schematic of Aerosol Jet Printer.

RESULTS & DISCUSSION

Parameter	Value
Formulation viscosity n = 3	3.82 ± 0.22 cP
Formulation density n = 6	1.0023 ± g/cm^{-3}
Surface tension n = 6	63.76 ± 0.25 mN.m^{-1}
Contact angle n = 3	29.72 ± 0.63 °

Table 1: Characteristics of formulation and substrate.

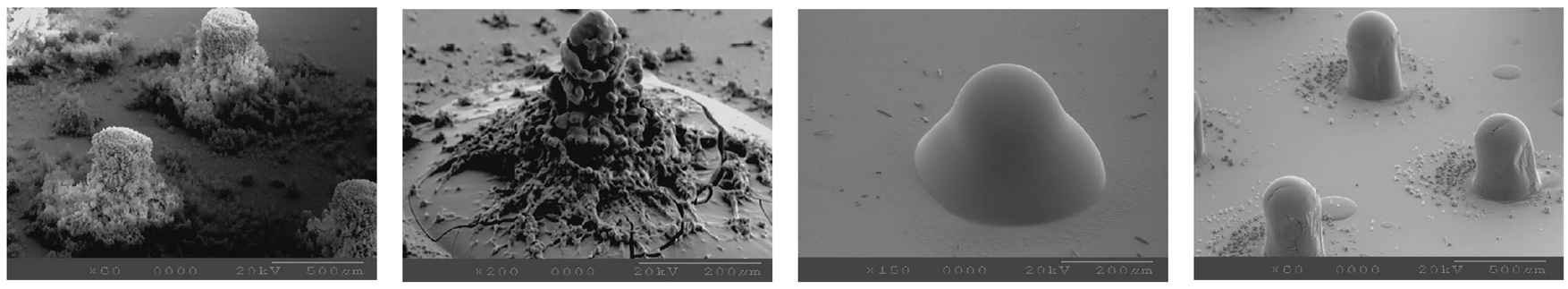

Figure 2: SEM images showing the evolution of printed microneedles during development using Aerosol Jet Printing.

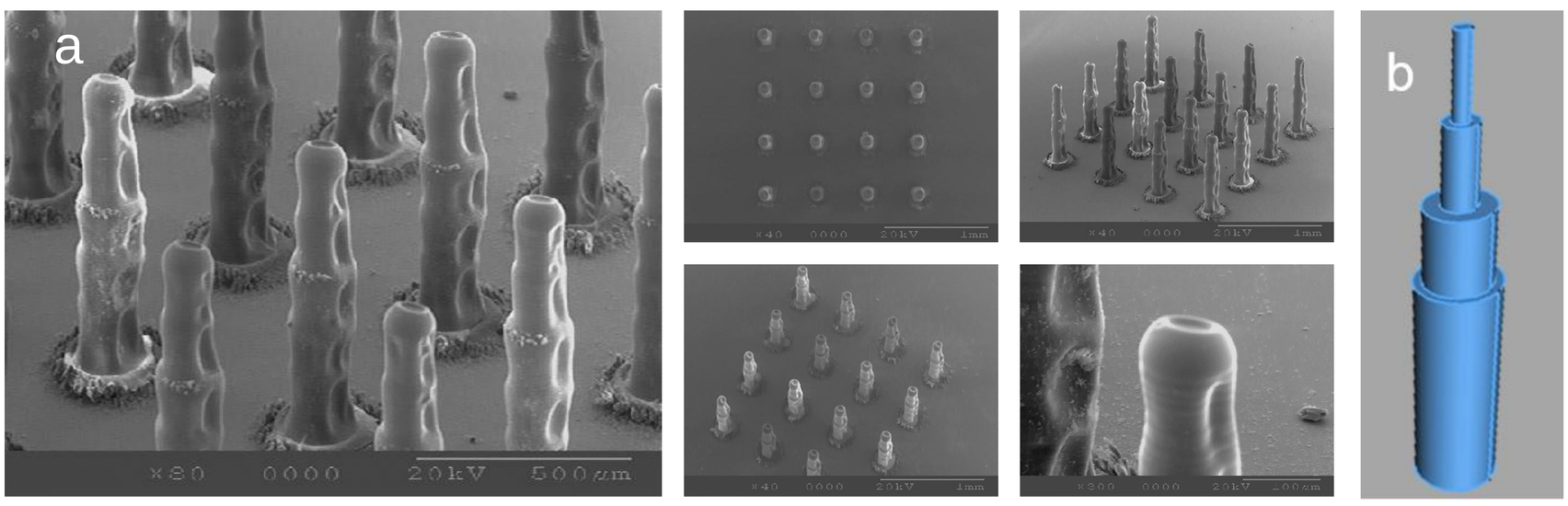

Figure 3a: SEM images showing a 4 x 4 microneedle array printed at 40°C on a double - sided polished silicon wafer. **3b**: CAD drawing of microneedle design showing progressive decrease in layer radius with increasing height.

Table 2: Characteristics of printed microneedles

Characteristic	Value
Height	713 ± 3.8 µm
Needle base diameter	142 ± 2.3 µm
Needle tip diameter	111 ± 1.4 µm
Print time for 16 needles	24 min
Needle spacing as per CAD	600 µm
Fracture force per needle n = 3	0.048 ± 0.02 N

- Indentation at tip centre and minor cavities/folds along the needle structure.
- Overspray at the base and along the needle structure.

CONCLUSIONS

- Good adhesion properties between the prepared microneedle formulation and substrate.
- High aspect ratio microneedle arrays can be fabricated using Aerosol Jet Printing Technology
- Benign processing conditions should facilitate biomolecule printing

CHALLENGES FACED

- Deposition of airborne particulate material to unintended locations (overspray)
- Nozzle clogging
- Unwanted material being deposited onto the substrate (fouling)

FUTURE WORK

- Skin penetration studies.
- Incorporation of drug molecule in formulation for microneedle fabrication.
- Evaluation of drug release through porcine skin using Franz Diffusion cells.

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