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Review Article

A Review on Microneedles Based Drug Delivery Strategy

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ABSTRACT

Microneedles (MNs) offer a minimally invasive and effective strategy for drug delivery, particularly for vaccines and other therapeutics. They create microchannels in the skin, allowing drugs to bypass the stratum corneum (the skin's outer layer), which is a major barrier to drug absorption. This approach provides several advantages over traditional methods like injections, including reduced pain, improved patient compliance, and enhanced bioavailability. Pain is a personalized event or body alarm system that can limit a patient's activities and lead to negative repercussions. The commercially available conventional treatment strategies like oral, parenteral, and topical drug delivery systems for pain management are associated with side effects and poor patient compliance. The transdermal route is eminent for its painless distribution. Among transdermal drug delivery system, microneedles (MNs) are gaining attention for their application with delivery at the deeper dermal layer because it bypasses the major barrier of the skin, easily accesses the skin dermal microcirculation, prevents damage to dermal blood vessels, and can be simply inserted into the skin without utilizing any additional applicator devices.

INTRODUCTION

Skin is the largest organ in the human body. For several decades, it was only perceived as an “envelope” for the human body, aimed at separating the exterior from the interior. However, research has shown that the skin has multiple functions. Protection is one of them, but it is also involved in the immune system, thermal regulation, and even molecular synthesis. Skin can be used as a gateway for medical applications, for example, transdermal drug delivery, where the molecules released can be systemically absorbed into the bloodstream While the skin can act as a gateway for the absorption of therapeutic molecules, its effectiveness is hindered by the numerous layers it possesses. In a sense, this process goes against the very purpose of skin. Therefore, several strategies have been developed over the years to overcome this resistance. Micro-

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needles have attracted increasing interest in recent years in biomedical areas, such as drug delivery, biosensing, and fluid extraction. The tips of the micro-needles can penetrate the epidermis layer of skin to arrive at the top layer of the dermis that is above the blood capillaries. Thus, the micro-needles would not touch the nerve endings to further avoid bleeding and pain. Micro-needles are small, minimally invasive devices used in a variety of medical, cosmetic, and drug delivery applications. These needles are typically between 25 and 1000 micrometers in length—far smaller than conventional needles, making them virtually painless. They are designed to pierce the outermost layer of skin (the stratum corneum) without reaching deeper tissues, allowing for a more comfortable experience compared to traditional injections. Micro-needles work by creating micro-channels in the skin, enabling the delivery of therapeutic agents such as vaccines, insulin, or cosmetic products like serums and anti-aging treatments directly into the dermal layers. This technique can be more efficient and less painful than traditional methods, and it also improves the absorption of drugs that otherwise would not penetrate the skin effectively. Since the 2000s, there has been discoveries on new fabrication materials of MN(Micro- needles), like silicon, metal and polymer. Alongside with materials, a variety of MN types (solid, hollow, coated, hydrogel) has also been developed to possess different functions. The research on MN has led to improvements in different aspects, including instruments and techniques, yet adverse events are possible in MN users.

History of Micro needles: During 1905, Dr. Ernst Kromayer, a German dermatologist (skin doctor), preserved damaging, hyper active pigmentation, then other skin disorders by means of changed dimensions of power-driven dental burst (Dentist). The main part of poetry those discussions micro-needle usage be located in 1921 by Compartments anywhere she injected her needle hooked on the egg cell placing. In the 1960s, transporting medicines by inoculation inside the stratum corneum activated in the direction of is a magnet for concentration. After, the micro needle thought be located introduced in the 1970s though, this thought was non-established experimentally up to the 1990s. In 1979, the primary transdermic organization remained accepted used to distribute scopolamine (sedative, hypnotic drug) through put on a three days patch to remedy sign disorder. In 1994, a sequence surgical procedure remained performed through Orient Reich anywhere he injected a try-bevelled hypo dermal needle hooked on the skin to discharge rubbery components. This surgery targeted the coetaneous deficiencies placed below the skin which remained to blame designed for miserable scars and wrinkles. The primary micro needle for transdermic distribution remained suggested in 1998 then be located made-up since silicon crackers finished particle engraving then photo lithography. The study defined the usage of micro made-up micro needles designed for the reason of improve drug delivery crossways the membrane. These papers directed to wide-ranging investigate directed in the micro needle field. Different ingredients such as glass, ceramic, metallic, and polymer remained presented to manufacture micro needles. In 2004, a micro needle arrangement was used to penetrate holes interested in the skin for transdermic drug transfer, which led to some manufacture technique too material individual explore designed for the reason of TDD. Solid, coated, hollow, dissoluble, and hydro gel-creating MNs remain all dissimilar categories of MNs. additionally, a variety of manufacturing technique such as laser abstraction, photo lithography, micro-inoculation moulding etc. This discovery led in the direction of the primary information of a dissoluble micro needle actuality used for TDD in 2005. According in the

direction of clinical Trials Gov. Website towards 43 clinical trials contain be finished by means of micro needles, through the primary micro needle clinical testing finished in 2007 (accessed on 30 June 2021, 5 p.m.). Freshly, additive manufactured approaches to production MN moulds be located established to supply inferior price solution for micro mould manufacturing. Information viewing the usage of commercially presented 3D printer to manufacture the MN leading mould accessible a novel phase in piece of equipment manufactures and potential for tradition constructed large volume manufacturing of MNs.

Types of Micro-needles: There are 5 types of micro needles

1. Solid Micro needles
2. Hollow Micro needles
3. Coated Micro needles
4. Dissolving Micro needles
5. Hydrogel-Forming micro needles

Solid Micro needles:

Design: Solid MN are the first type of MN fabricated and are the most commonly used. Hard solid MN shave sharp tips that pierce through and form pores on the stratum corneum. A drug patch will then be applied to the skin for drug to be absorbed slowly and passively through numerous micropores. Solid micro-needles are made from materials like silicon, metal, or polymers. They simply puncture the skin to create micro- channels through which drugs, vaccines, or cosmetic agents can be administered.

Function: These micro needles are primarily used to enhance skin permeability. Once inserted, they allow for the passive diffusion of drugs or act as carriers for the active substances.

Applications: Solid micro needles are used in drug delivery (e.g., insulin delivery for diabetes) or cosmetic treatments (e.g., enhancing the penetration of anti-aging serum.

I. Hollow Micro needles:

Design: Hollow MN are designed with a hole at the tip and a hollow capacity that store drugs.Upon MN insertion, stored drug is directly injected into the dermis and this effectively facilitates the absorption of either large-molecular or large-dosage drug. Yet, a portion of the drug can be leaked or clogged and it may hinders the overall drug administration. These micron needles have a hollow core, similar to traditional hypodermic needles, allowing them to inject liquid substances into the skin.

Function: The hollow micro needles act as channels through which drugs, vaccines, or other treatments can be injected directly into the skin layers. They are used for vaccination, insulin delivery, or local anesthetic injections.

Applications: Hollow micro needles are especially useful in medical treatments, such as vaccine delivery and other parenteral drug delivery applications.

Coated Micro-needles:

Design: Coated MN are fabricated by coating drug solution over solid MN and the thickness of the drug layer can be adjusted depending on the amount of drug to be administered. A benefit of coated MN is that less amount of drug is needed as compared to other drug administration route. This is because the layer of drug will quickly dissolve and delivered into the systemic circulation directly across the skin. Coated micro needles are often covered in other surfactants or thickening agents to assure that the drug is delivered properly. These

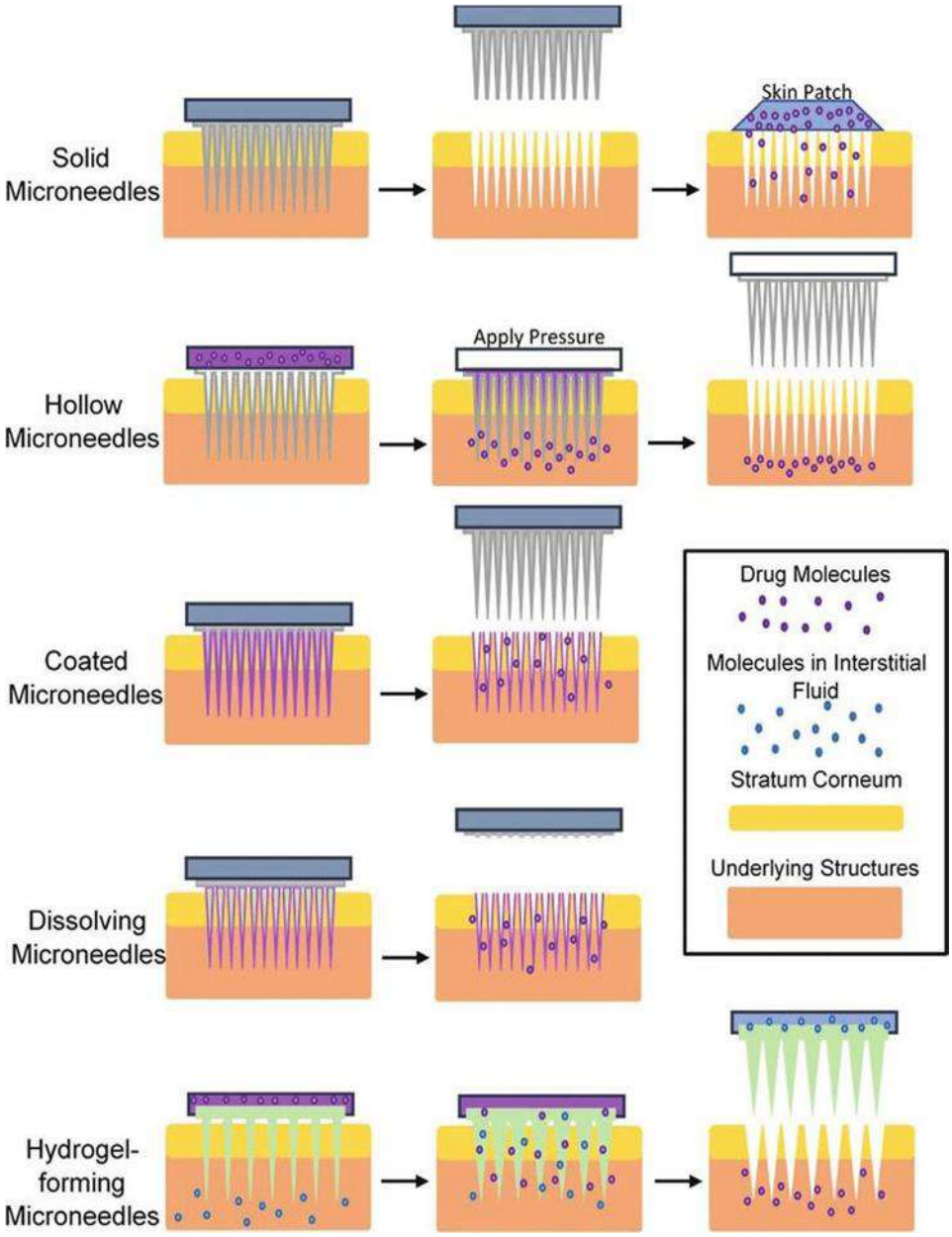
micro needles are coated with a thin layer of the active drug or vaccine. The coating is designed to dissolve once the micro needles are inserted into the skin, releasing the therapeutic substance.

Function: Coated micro needles allow for the delivery of solid formulations in a more controlled and localized manner. The micro needle tip dissolves, releasing the coating into the skin, where it can be absorbed.

Applications: This type is often used in cosmetic treatments, such as anti-aging therapies, and in vaccinations.

Dissolving Micro needles: Dissolving MN are mostly composed of water-soluble drugs that enable the dissolution of MN tips when inserted into skin. This is a one-step approach which does not require the removal of MN and is convenient for long-term therapy. However, incomplete insertion and delay dissolution is observed with the use of dissolving MN. This polymer would allow the drug to be delivered into the skin and could be broken down once inside the body. Pharmaceutical companies and researchers have begun to study and implement polymers such as Fibroin, a silk-based protein that can be molded into structures like micro-needles and dissolved once in the body.

Hydrogel-forming Micro needles: The primary material for the fabrication of hydrogel- forming micro needles (HFMs) is hydrophilic polymer that encloses drugs. This material draws water from interstitial fluid in the stratum corneum and results in polymer swelling and release of drug. Besides, the hydrophilic features of HFMs allow readily uptake of interstitial fluid that could be used for disease diagnosis.



Material Used in micro needles:

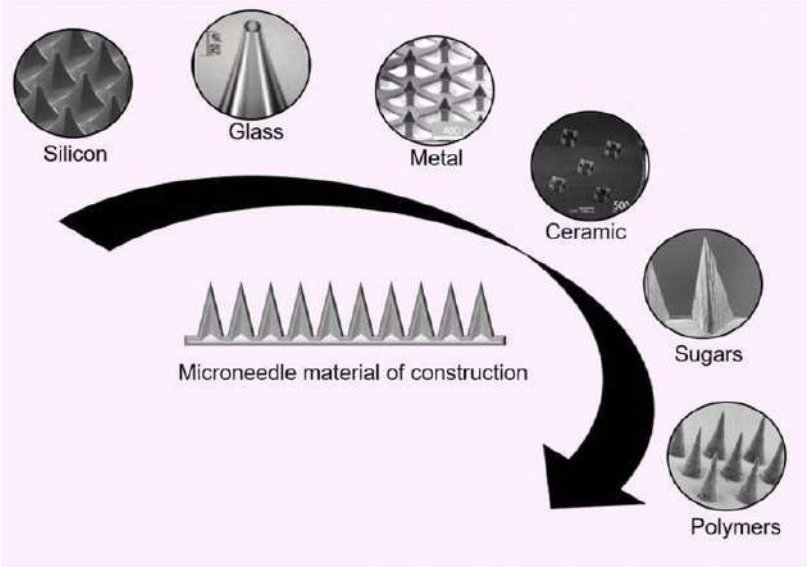
Silicon: Silicon micro-needles are popular due to their sharpness and precision in penetrating the skin. They are often used in solid micro-needles. MNs made of metals like stainless steel, titanium, and aluminum, are non-toxic and possess strong mechanical properties to penetrate the skin without breakage.

Polymers: Polymer is also regarded as a promising material for MN due to its good biocompatibility and low toxicity. Biodegradable polymers, such as poly(lactic-co-glycolic acid) (PLGA) and polyvinyl alcohol (PVA), are frequently used for dissolving micro-needles, allowing them to degrade after drug release.

Metals: Stainless steel and titanium are commonly used for hollow micro-needles due to their strength and durability.

Ceramic: Due to their superior chemical properties and compression resistance, ceramic

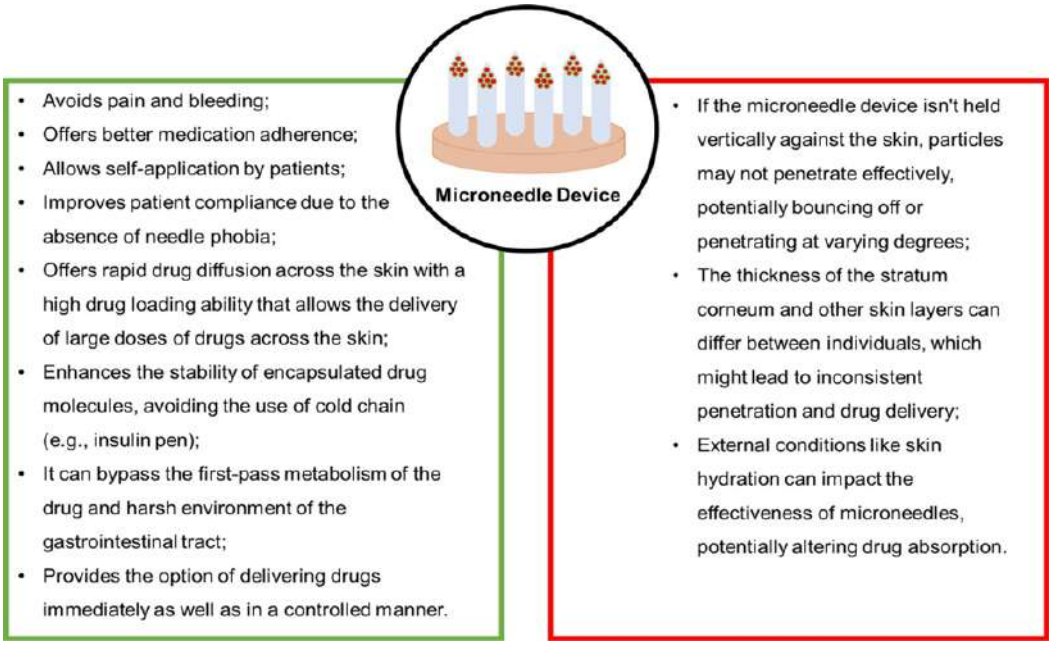
materials such as alumina have been used to fabricate a MN. However, alumina possesses a lower tensile strength compared to other materials. Calcium sulphate dehydrate and calcium phosphate dehydrate are additional types of ceramics utilized in the fabrication of MNs. A study conducted by Bystrova et al. showed that MNs fabricated from alumina fractured upon manual application to the skin.



MN Type	Advantages	Disadvantages	Manufacturing	MN Type fit
Silicon	Flexible enough to	Time-consuming	Etching	Soli Hollow
Metal	Good	High startup cost.	Laser ablation	Solid Hollow
Ceramic	Possesses	Low tension	Micromolding	Solid Hollow
Polymer	Excellent	Low strength	Lithography	Solid Hollow

Overview of micro needle materials

ADVANTAGES AND DISADVANTAGES



Application of Micro-needles:

a. **Drug Delivery:** The first application of MN for drug delivery was by using a solid silicon MN in 1998. A dissolvable MN patch was used to deliver human growth hormone for transdermal delivery to hairless rat skin. A dissolvable caffeine loaded MN patch was able to control the weight of obese mice and work as an anti-obesity treatment plan. A coated MN patch was used to deliver salmon calcitonin. Furthermore, MNs have been used for transdermal permeation for several drugs such as ibuprofen, ketoprofen, and paracetamol. Other drugs administrated via microneedles include L- Ascorbic acid, riboflavin, aspirin, docetaxel, pilocarpine, lidocaine, hydrochloride, ketoprofen, and glycerol.

Vaccine Delivery: A dissolvable MN is a common type of MN used for vaccine delivery purposes. The dissolvable MNs were used to replace hypodermic injection needles that were typically used to administer vaccines. Unlike other types of MN, the dissolvable MNs are biocompatible, robust, scalable, and do not generate biohazardous waste. Dissolvable MNs were used to deliver vaccines for malaria, diphtheria, influenza, Hepatitis B, HIV, and polio . Even though dissolvable MNs are most frequently used for vaccine delivery, coated MNs arrays have also been successfully used for vaccination purposes

b. **Diseases Diagnosis:** Disease diagnosis and therapeutic efficacy can be monitored via several established bioassays that sample body fluids to assess and monitor health conditions. The current methods induce pain, require specialised techniques, tailored equipment, and professional medical personnel However, microneedle technology offers bioassays solution with painless experience and simple implementation. A hollow MN has the ability to diagnose several diseases such as cancer diabetes and Alzheimer's disease. Patient health monitoring is another application of the MNs. For example, a hollow glass MN may be used to investigate the glucose level.

c. **Cosmetic Application:** MNs have widely been used in cosmetic applications such as skin treatment and hair growth Kim et al. developed a hyaluronic acid-based dissolvable MN patch for the intradermal delivery of ascorbic acid and retinyl retinoate. Kumar et al. showed an enhancement of local delivery of eflornithine (used to reduce facial hirsutism) in vitro and in vivo using a solid MN. Further, MN technology was able to treat two patients suffering from alopecia areata disease. These patients experienced hair growth after treatment. Effective clinical trials have been conducted in atrophic facial scarring atrophic acne scars and hypertrophic burn scars using a MN. Microneedles are considered as an effective treatment for cosmetic applications related to aging, skin lesions, vulgaris, and wrinkles With an increasing demand of cosmetic products, microneedles (patches and rollers) have a high potential in the future

Micro-needle Fabrication method

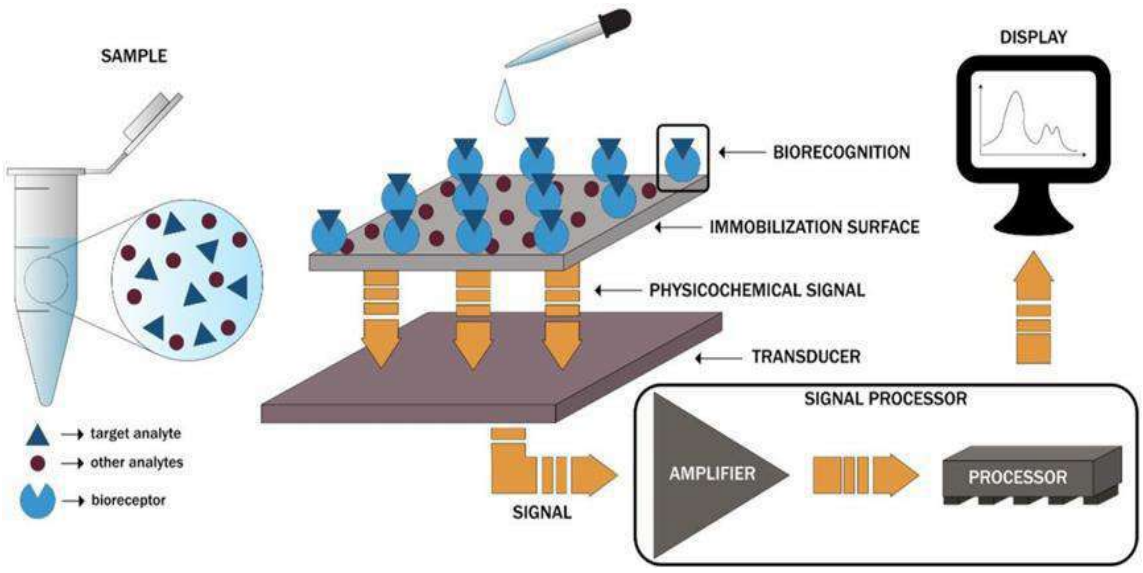
There exist numerous techniques for fabricating micro needles. This section outlines the predominant methods employed not just for crafting micro needles themselves, but also for producing molds tailored to micro needle fabrication. Indeed, micro needles can be manufactured either directly or via a mold, particularly when aiming for cost-effective large-scale production.

Methods of fabrication are as follows:

1. MEMS (Micro-electromechanical systems)
2. Micro molding
3. Laser ablation
4. Injection moulding
5. Lithography

1. **Micro-electromechanical systems :** MEMS methods can be used to manufacture hollow and solid micro needles, as well as molds for dissolving micro needles, directly from an appropriate material substrate .The fabrication process for micro needles, along with molds using this technique, involves a meticulously controlled three-step process—deposition, patterning, and etching of materials In this way, complex three-dimensional structures emerge as a result of variations in etchant selectivity among different materials. The first step consists of forming a film with a thickness ranging from a few nanometers to 100 µm on a substrate through chemical or physical vapour deposition

In this way, the film can be formed through the chemical reaction on the substrate surface (chemical vapour deposition process) or by atoms transferred directly from the source to the substrate through the gas phase (physical vapor deposition process). Subsequently, during the second stage of the process, named patterning, a two dimensional master pattern of the desired material is transferred from the initial photomask to the substrate coated with photosensitive material. Typically, a silicon wafer serves as the substrate, and the transfer process is conducted using a radiation source in one of the lithography techniques (photolithography, ion beam lithography, or X-ray lithography. The most common type of lithography used is photolithography, which is activated by ultraviolet light and an X-ray onto diverse photosensitive polymers, including SU-8 [, poly (methyl methacrylate) (PMMA), polyethylene glycol diacrylate (PEGDA) and chitosan lactate.



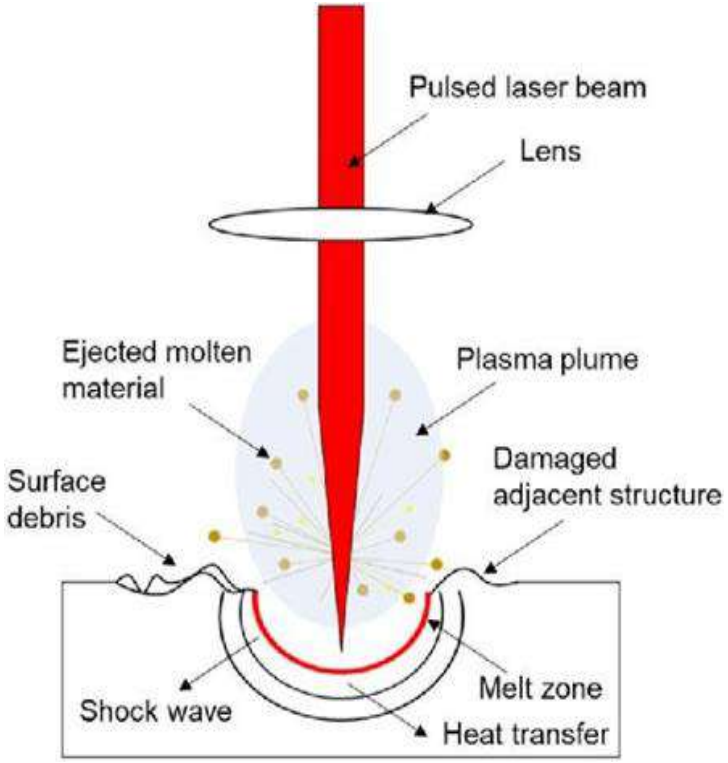
2. Micro-Molding:

The micro-molding process consists of making replicates of the master mold. The mold is casted with a solution containing a polymer and active pharmaceutical substances. Micro-molding is considered a cost-effective method and is used for mass production Micro-molding is commonly used with polymer material for MN fabrication [. The PDMS has several advantages in micro-molding techniques such as low cost, ease of use,

low surface energy, and thermal stability. The limitations associated with this technique are difficulties associated with controlling the depth of penetration, drug load capacity, and mechanical behavior of the polymer.

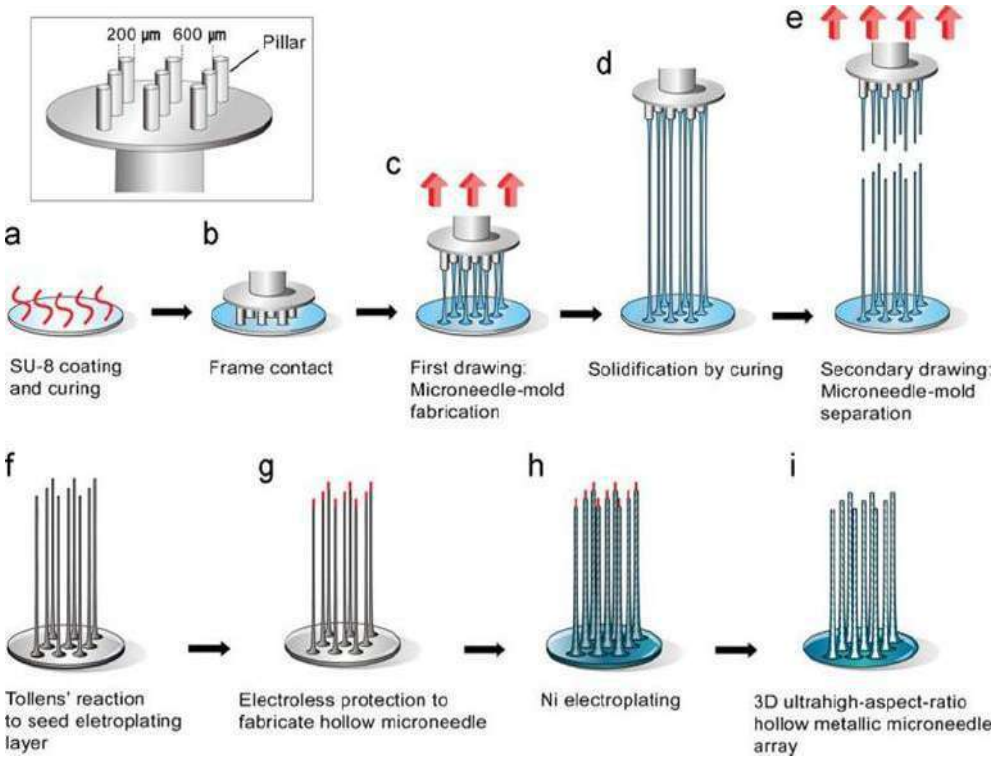
3. **Laser ablation:** Laser ablation incorporates the use of a focused optical light beam in eliminating material from a substrate to create MN arrays. Lasers have been used to process different materials ranging from micro- and nano-scale for several applications Various laser types have been studied for the manufacture of MN arrays. These include CO2, UV excimer and femtosecond laser machine. The laser ablation method is considered an effective and fast method for MNs fabrication. The laser beam takes 10 to 100 nanoseconds to approach the burn point in the material sheet. Laser could also be used to shape any metal. This method is associated with thermal effects at the cutting surface that result in the alteration of MN structure and mechanical properties. This might lead to undesirable effects in MNs such as cracking, or fatigue resistance. The laser ablation method is a non-contact process and subjects low heat loads to the substrate. However, the cost of the laser is higher compared to other types of equipment. The laser ablation method is not suited for large scale manufacturing.

Injection moulding: Injection molding is another MN fabrication method. The process of fabricating MNs using injection molding and the hot embossing technique Lhernould et al. used poly carbonate (PC) material to fabricate a 4 × 4 hollow polymer MN array. The MNs were shown to withstand high force and were used for multiple insertions without blunting the needle. Another study used a micro-injection molding process to fabricate a solid MN. These needles could deliver hydrophilic-high molecular weight molecules. Sammoura et al. fabricated a polymeric MN by molding plastic material.



The needles were used to successfully penetrate a fresh chicken leg and beef liver and ~0.04 µL of liquid was drawn from these tissues. The proposed method allows the mass production of MNs at low cost. Micro-injection molding also offers high repeatability, accurate dosing, and high injection flow rates when separating the plasticization and polymer melt injection. The limitation of applying injection molding technique is controlling the small shot size due to the common size of screw which is approximately 15–150 mm and higher initial cost of the equipment.

Lithography: The lithography technique is used to transfer the master pattern of the geometric shapes onto a surface of a substrate. Photolithography is primarily used for pattern transfer due to its wide applicability in the field of microelectronics. Other techniques such as microelectronic and micro machining use lithography as the first step in fabricating a MN. Lithography requires precise processing of the photoresist. This technique contributes to approximately 30–35% of costs for manufacturing integrated circuits. Lithography possesses the ability to create products from a variety of materials such as glass, metal, ceramics, and plastics It also produces precise geometries and smooth vertical sidewalls. However, this technique requires an advanced facility (cleanroom) and extended production time.



Fabrication Method	Advantages	Limitation
MEMS	Very precise geometries;	Time consuming; Expensive;
Micro molding	High precision; Cost effective;	Difficult to fabricate complex
Laser ablation	Less time consuming	Might cause a crack or fatigue
Injection Moulding	Mass production; Cost	High initial cost (machine

Micro-needles Uses in Cosmetics:

Micro needles are tiny, needle-like structures that are used in various cosmetic treatments and

products. These micro needles are typically smaller than 1mm in length and are designed to create micro channels or tiny punctures in the skin, which can enhance the delivery of active ingredients into the deeper layers of the skin.

Different forms of micro needles used in cosmetics:

1. Micro-needles Rollers
2. Micro-needles Patches
3. Electric Micro-needles pen

1. Micro-needles Rollers:

Micro-needle rollers, often known as derma-rollers, are skincare tools designed to improve the texture, appearance, and overall health of the skin by using tiny needles that create micro-injuries to the skin. These rollers typically have small needles, ranging from 0.2mm to 3mm in length, that are rolled across the skin to stimulate collagen production and enhance the absorption of skincare products. They are commonly used in at-home treatments for a variety of purposes, including:

a. Reducing the appearance of fine lines and wrinkles
b. Treating acne scars and stretch marks
c. Improving skin texture and tone
d. Enhancing the absorption of serums or skincare products

How micro needle roller work??

The micro-needles on the roller create small punctures or micro-injuries in the skin's outer layer. These micro-injuries trigger the skin's natural healing process, stimulating collagen and elastin production, which helps the skin look more youthful and smoother. Micro-needle rollers can also enhance the absorption of active ingredients from serums and creams, as the tiny channels they create allow for deeper penetration.

Different Needle Sizes:

0.2mm to 0.3mm: Ideal for boosting the absorption of skincare products and for general skin rejuvenation.

0.5mm: Often used for reducing fine lines, minor scars, and improving skin texture.

1.0mm: Used for deeper scars, wrinkles, and stretch marks.

1.5mm and above: Typically used for more advanced treatments, including deep scars and significant skin concerns, and usually requires professional guidance.

Examples of Ingredients in Micro-needles Roller: Hyaluronic Acid: Hydration and plumping

Vitamin C (Ascorbic Acid): Brightening and anti-aging

Retinol (Vitamin A): Skin renewal and anti-aging Tea Tree Oil: Acne treatment and anti-inflammatory

Niacinamide (Vitamin B3): Skin barrier repair and brightening

Precautions:

• **Patch Test:** Always patch test any new product to ensure your skin doesn't react negatively.

• Avoid using certain ingredients immediately after micro-needling: Active ingredients like retinol, salicylic acid, or vitamin C may cause irritation or discomfort immediately after micro-needling, so it's best to use these ingredients cautiously or at a later stage in your skincare routine (i.e., after your skin has recovered).

• **Sun protection:** After using a micro-needling roller, your skin will be more sensitive to the sun. Always apply sunscreen to protect your skin from UV damage.

Micro-needles Patches: Micro-needle patches are a newer form of skincare technology that delivers active ingredients into the skin using tiny, painless micro-needles. Unlike traditional micro- needle rollers, micro-needle patches are adhesive, patch-like products that are applied directly to the skin. These patches contain an array of microscopic needles that can painlessly penetrate the outer layer of the skin to deliver ingredients deeper into the dermis, bypassing the skin's natural barrier and allowing for more effective absorption.

How Micro-needles Patches Used:

The patches are covered with tiny needles, usually smaller than 1mm in length, which dissolve or break upon contact with the skin. These needles create micro-channels or micro-injuries in the outermost layer of the skin, allowing active ingredients to be absorbed more effectively. The micro-needles are often infused with ingredients like hyaluronic acid, peptides, retinol, or vitamin C, which are then delivered directly into the skin during use. The patch is applied to the skin (usually on areas with wrinkles, acne scars, or other specific concerns), left in place for a period (ranging from 30 minutes to a few hours), and then removed.

Benefits of Micro-needle Patches:

1. Minimized Pain: Unlike micro-needle rollers, patches cause minimal discomfort since the micro-needles are smaller and designed for one-time use.

2. Targeted Treatment: You can place micro-needle patches on specific areas of concern, such as around the eyes, on acne spots, or on wrinkles.

3. Convenience: Micro-needle patches are often easy to apply and are typically designed for at-home use.

4. Enhanced Absorption: The tiny needles create tiny channels that allow for better penetration of active ingredients compared to standard topical application.

Examples of Ingredients in Micro-needle Patches:

Hyaluronic Acid: To boost hydration and plump the skin.

Retinol: To promote skin cell turnover and reduce signs of aging.

Vitamin C: For brightening the skin and reducing dark spots.

Peptides: To stimulate collagen production and improve skin elasticity.

Popular Uses:

Under-eye patches: Often used for dark circles and puffiness.

Wrinkle patches: Specifically placed on areas with fine lines and wrinkles, like around the mouth or eyes.

Acne Patches: To treat active acne by reducing inflammation and speeding up the healing process.

Precautions:

Do not use micro-needle patches on areas with active breakouts, sunburn, or wounds. Wait until your skin is fully healed and calm before applying them. Conduct a patch test by applying the micro needle patch to a small area of skin (like your inner arm) and wait 24 hours to see if any irritation occurs before using the patch on your face. If you have inflamed acne or any open wounds, it's best to avoid using micro-needle patches until the area has healed. After using a micro-needle patch, apply sunscreen to protect your skin from UV damage, and avoid direct sun exposure for at least 24 hours.

• Electric micro needles pen: An electric micro-needling pen, also known as a derma-roller pen or micro-needling pen, is a professional-grade tool designed for more precise and effective micro-needling treatments. Unlike manual micro-needling rollers, which require you to roll the device over your skin, an electric micro-needling pen uses a motorised mechanism that moves the micro-needles up and down in rapid motion. This allows for more consistent needle penetration, improved results, and less effort from the user.

How Electric Micro-needles Pen Used:

The pen has a set of tiny needles, typically ranging from 0.25mm to 3.0mm in length, that are attached to a disposable cartridge. The motorized mechanism moves the needles vertically in and out of the skin at a controlled speed, creating micro-injuries (tiny punctures) in the skin's surface. This triggers the skin's natural healing process, leading to increased collagen production and improved skin texture. The needle length can usually be adjusted to suit the treatment area, whether it's fine lines, acne scars, or more extensive skin rejuvenation.

Benefits of Electric Micro-needling Pen:

1. **Precision**: The pen allows for more precise and controlled micro-needling, especially in smaller, more delicate areas like around the eyes, mouth, or on the forehead.

2. **Faster Treatment**: Since the pen is motorized, it can cover larger areas in less time compared to manual rollers, making it an efficient option.

3. **Customizable Settings**: The depth of the needles can often be adjusted depending on the treatment area and skin concerns, providing versatility for different skin types and conditions.

4. **Less Pain and Discomfort**: With consistent needle penetration, electric pens may cause less pain and irritation compared to manual rollers, especially for deeper treatments.

5. **Improved Absorption**: The micro-channels created by the electric micro-needles improve the absorption of topical treatments or serums, helping to boost their effectiveness.

Common Uses of Electric Micro-needling Pens:

1. Anti-Aging: Stimulating collagen production can help reduce the appearance of fine lines and wrinkles.

2. Acne Scarring: Micro-needling helps to break down scar tissue and encourages new skin cell growth, improving the appearance of acne scars.

3. Stretch Marks: The treatment can improve skin texture and elasticity, reducing the appearance of stretch marks.

4. Uneven Skin Tone and Texture: Micro-needling can smooth out rough patches and even out skin tone.

5. Hair Restoration: Electric micro-needling pens are sometimes used in conjunction with hair growth serums to stimulate hair follicles and promote hair growth in thinning areas.

Precautions:

Use the micro-needling pen according to the recommended frequency. For at-home use, typically 1-2 times a month is ideal. Professional treatments can be done more frequently, depending on the skin's healing ability. After treatment, avoid harsh skincare products such as those containing retinol, AHAs/BHAs, or vitamin C for at least 24-48 hours. Stick to soothing, hydrating products, like hyaluronic acid, ceramides, and peptides. Always apply a broad-spectrum sunscreen of SPF 30 or higher after micro-needling to protect your skin from UV damage. For at-home use, choose an FDA-approved or certified micro-needling pen that is specifically designed for consumer safety. Avoid using professional-grade devices without proper training, as they can cause damage if misused.

Globally Future Growth of micro needles:

The global micro-needle market is experiencing significant growth, driven by advancements in drug delivery technologies and increasing demand for minimally invasive medical procedures. Micro- needles are tiny needles that painlessly penetrate the skin to deliver drugs, vaccines, or cosmetic treatments, offering advantages over traditional hypodermic needles. According to Data Bridge Market Research, the micro-needle drug delivery systems market was valued at approximately USD 5.99 billion in 2021 and is projected to reach USD 10.76 billion by 2029, reflecting a compound annual growth rate (CAGR) of 7.60% during the forecast period. BCC Research estimates that the global market for micro-needles will grow from USD 1.0 billion in 2023 to USD 1.3 billion by 2028, at a CAGR of 5.1%.Future Market Insights forecasts the micro-needle drug delivery systems market to expand from USD 768.9 million in 2023 to USD 1,459.1 million by 2033, with a CAGR of 6.6% over the next decade. A report by GlobeNewswire anticipates the market size to reach USD 9.46 billion by 2030, registering a CAGR of 7.4% from 2023 to 2030.In May 2025, Brisbane, Australia, will host the International Healthcare Conference on Micro-needles, bringing together over 400 experts to discuss advancements and applications in micro-needle technology.

Globally Future Challenges of micro needles:

On the other hand, high cost associated with the research and development proficiencies, limited infrastructural facilities, uneven distribution of medical services, rising interest in alternate routes of drug administration transdermal and intra dermal drug delivery systems and dearth of awareness in the backward economies are expected to obstruct market growth. Also, lack of favourable reimbursement scenario and technology penetration in the developing economies, poor absorption and changeability in absorption, limited insurance coverage and regulatory compliance, and lack of suitable infrastructure in low- and middle-income countries are projected to challenge the market in

the forecast period of 2022-2029. This micro needle drug delivery systems market report provides details of new recent developments, trade regulations, import-export analysis, production analysis, value chain optimization, market share, impact of domestic and localized market players, analyses opportunities in terms of emerging revenue pockets, changes in market regulations, strategic market growth analysis, market size, category market growths, application niches and dominance, product approvals, product launches, geographic expansions, technological innovations in the market. To gain more info on the microneedle drug delivery systems market contact Data Bridge Market Research for an Analyst Brief, our team will help you take an informed market decision to achieve market growth.

REFERENCES

1. Chuong, C.M.; Nickoloff, B.J.; Elias, P.M.; Goldsmith, L.A.; Macher, E.; Maderson, P.A.; Sundberg, J.P.; Tagami, H.; Plonka, P.M.; Thestrup-Pedersen, K.; et al. What is the “true”function of skin? Exp. Dermatol. 2002, 11, 159–160. [Google Scholar] [CrossRef]
2. Chien, Y.W.; Liu, J.-C. Transdermal Drug Delivery Systems. J. Biomater. Appl. 1986, 1, 183–206. [Google Scholar] [CrossRef]
3. Wong, W.F.; Ang, K.P.; Sethi, G.; Looi, C.Y. Recent Advancement of Medical Patch for Transdermal Drug Delivery. Medicina 2023, 59, 778. [Google Scholar] [CrossRef]
4. Al-Japairai, K.A.S.; Mahmood, S.; Almurisi, S.H.; Venugopal, J.R.; Hilles, A.R.; Azmana, M.; Raman, S. Current trends in polymer microneedle for transdermal drug delivery. Int. J. Pharm. 2020, 587, 119673. [Google Scholar] [CrossRef]
5. Zhang, R.; Miao, Q.; Deng, D.; Wu, J.; Miao, Y.; Li, Y. Research progress of advanced microneedle drug delivery system and its application in biomedicine. Colloids Surf. B Biointerfaces 2023, 226, 113302. [Google Scholar] [CrossRef]
6. Senel, M.; Dervisevic, M.; Voelcker, N.H. Gold microneedles fabricated by casting of gold ink used for urea sensing. Mater. Lett. 2019, 243, 50–53. [Google Scholar] [CrossRef]
7. Ranade V.V., Hollinger M.A., Cannon J.B. Drug Delivery Systems. CRC Press; Boca Raton, FL, USA: 2003. [Google Scholar]
8. eok J., Hong J.Y., Choi S.Y., Park K.Y., Kim B.J. A potential relationship between skin hydration and stamp-type microneedle intradermal hyaluronic acid injection in middle-aged male face. J. Cosmet. Dermatol. 2016;15:578–582. doi: 10.1111/jocd.12244. [DOI] [PubMed] [Google Scholar]
9. Seok J., Hong J.Y., Choi S.Y., Park K.Y., Kim B.J. A potential relationship between skin hydration and stamp-type microneedle intradermal hyaluronic acid injection in middle-aged male face. J. Cosmet. Dermatol. 2016;15:578–582. doi: 10.1111/jocd.12244. [DOI] [PubMed] [Google Scholar]
10. Naik A., Kalia Y., Guy R. Transdermal drug delivery: Overcoming the skin’s barrier function. Pharm. Sci. Technol. Today. 2000;3:318–326. doi: 10.1016/S1461-5347(00)00295-9.
11. Tröls A., Hintermüller M., Saeedipour M., Pirker S., Jakoby B. Drug dosage for microneedle- based transdermal drug delivery systems utilizing evaporation-induced droplet transport. Microfluid. Nanofluid. 2019;23:91. doi: 10.1007/s10404-019-2257-3.
12. Bariya S.H., Gohel M.C., Mehta T.A., Sharma O.P. Microneedles: An emerging transdermal drug delivery system. J. Pharm. Pharmacol. 2011;64:11 – 29. doi: 10.1111/j.2042-7158.2011.01369.x.
13. Yu, K.; Yu, X.; Cao, S.; Wang, Y.; Zhai, Y.; Yang, F.; Yang, X.; Lu, Y.; Wu, C.; Xu, Y.

Layered dissolving microneedles as a need-based delivery system to simultaneously alleviate skin and joint lesions in psoriatic arthritis. Acta Pharm. Sin. B 2021, 11, 505–519.

14. Chen, B.Z.; Ashfaq, M.; Zhang, X.P.; Zhang, J.N.; Guo, X.D. In vitro and in vivo assessment of polymer microneedles for controlled transdermal drug delivery. J. Drug Target. 2018, 26, 720– 729.
15. Chong, R.H.; Gonzalez-Gonzalez, E.; Lara, M.F.; Speaker, T.J.; Contag, C.H.; Kaspar, R.L.; Coulman, S.A.; Hargest, R.; Birchall, J.C. Gene silencing following siRNA delivery to skin via coated steel microneedles: In vitro and in vivo proof-of-concept. J. Control. Release 2013
16. Leanpolchareanchai, J.; Nuchtavorn, N. Response Surface Methodology for Optimization of Hydrogel-Forming Microneedles as Rapid and Efficient Transdermal Microsampling Tools. Gels 2023, 9, 306.
17. Wang, J.; Wang, H.; Lai, L.; Li, Y. Preparation of Microneedle Array Mold Based on MEMS Lithography Technology. Micromachines 2021, 12, 23.

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