MIGHTEX

PHOTO-PATTERNING: DMD-BASED MICRO-PATTERNING & PHOTO-POLYMERIZATION

eBook

Contents

1 Introduction

Spatially patterned microenvironments play a huge role in cell growth, differentiation, and behaviour, providing a 3D biomimetic culture condition for studying biological functions in vitro. This can be achieved by providing geometric, topographical, and mechanical cues onto scaffolds or surfaces along with incorporation of essential proteins, extracellular matrix (ECM) components, and growth factors. These parameters are particularly important for the proliferation of stem cells and other progenitor cell lines or for developing co-cultures and tissue-on-chip models with hierarchical organization of cells, blood vessels, etc. In addition, these approaches can be leveraged to produce biological scaffolds for tissue engineering and regenerative medicine applications.

Surface coatings and 3D scaffolds can both be produced via bulk synthesis techniques using chemical (covalent) or physical (ionic, dipole, etc.) crosslinking with or without photochemical reactions. In this scenario, the entire surface or material is crosslinked indiscriminately, lacking spatial control. While these methods provide a uniform material distribution with no spatial distinctions, they can be tailored to some extent by stoichiometric control of material components and implementing multi-step processes. In addition, porogens can be used to introduce gaps and pores in the system to generate diverse patterns. However, they fundamentally lack the resolution and precision needed to produce fine features or complex and precise patterns.

In the following sections, we will explore the principles of micropatterning and 3D photopolymerization techniques to provide a brief background. We will then discuss the most common techniques used to achieve such material architectures along with their advantages and disadvantages. In particular, we will focus on projection-based micropatterning using DMD-based technologies as a revolutionary, high-resolution, easy to use approach for contactless and maskless patterning applications in research and prototyping.

2 Overview of Surface Coating and Micropatterning

Precise and selective deposition of macromolecules onto surfaces to tune their interactions at micro/nano scale is critical in many biological applications from routine cell culture and molecular assays to developing advanced biosensors and bioelectronics. It also allows for multiplexing different targets on the same substrates for high-throughput applications and creating surface gradients to provide directionality for cell migration, adhesion, differentiation, and more [1]. Bulk surface coating techniques achieve this by incubating the substrate with a solution of the target molecule via dipping, immersion, spin-coating, or similar methods. This provides a conformal coating with uniform distribution and thickness, generated by passive adsorption of macromolecules (ionic, dipole, Van der Walls forces, etc.). This can also apply to chemically reactive coatings, which create a covalent bond modifying the substrate albeit with no spatial control of the deposition.

High resolution surface micropatterning can be achieved using direct printing techniques such as laser writing or dip-pen nanolithography, which provide high resolution patterning via targeted photochemical reactions on the substrate. These methods typically operate at a slower rate due to the point-by-point nature of the light exposure they provide, resulting in curing times up to 1 min per layer, which can limit scaling and parallelization. On the other hand, mask-based lithography methods are faster due to simultaneous exposure of entire layers with curing times up to 10s or less per layer. However, this requires expensive and time-consuming production of photomasks for each unique structure. Incorporation of cells or sensitive biomacromolecules during the printing process is also difficult with these techniques. Therefore, DMD-based maskless projection such as those using Mightex's Polygon DMD module are an attractive approach providing optimal speed, resolution, and compatibility to overcome the drawbacks of other techniques.

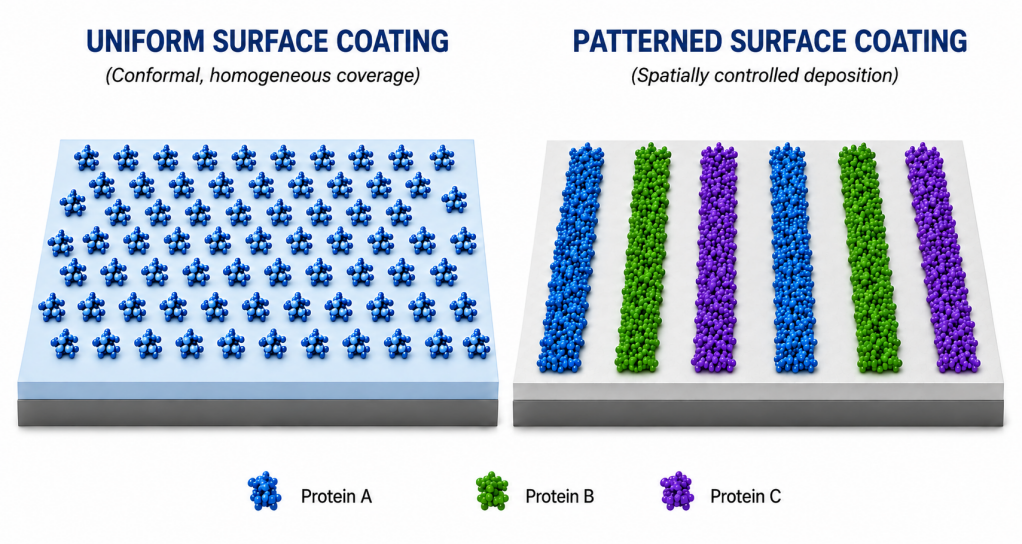

Figure 1: *Schematic representation of uniform (left) and patterned (right) surface coatings. Conventional bulk coating methods produce a homogeneous distribution of biomolecules across the substrate surface, while photopatterning enables spatially controlled deposition of multiple biomolecules for selective and multiplexed biological applications.*

3 Overview of Projection-Based 3D Patterning

Fabrication of hydrogels, scaffolds, and other 3D biomaterials can be achieved using one of several methods depending on the required architecture and throughput. Laser stereolithography is commonly used for rapid prototyping of 3D scaffolds generated by using motorized platform to move the sample which is selectively crosslinked by focused UV laser. This can be performed layer-by-layer to build up intricate surfaces and structures using ECM proteins and other biological macromolecules. Although the use of galvo mirrors for laser scanning in favor of a motorized stage is faster, this method is inherently slow due to the point by point scanning. [2] Two-photon (2P) methods also provide a similar result with highly localized exposure of light at the focal point of the laser and exceptional resolution (100nm) compared to laser stereolithography (50μm). However, this comes with a trade-off between resolution and speed, where the 2P technique is the slowest in its class [3].

3D printers provide a fully integrated system for creating detailed 3D structures including biological scaffolds. There are several ways to achieve this, which can be broadly classified into two categories: precise deposition of resin ejected through a nozzle or precise crosslinking of bulk resin using light modulators (Fig. 2). In the first approach, precise structures are pre-formed by expelling resin through a nozzle following a pre-determined pattern and then photocrosslinked at once using UV or other light sources. A common technique in this category is inkjet printing, a contactless method using piezoelectric, thermal, or electromagnetic actuators for precise volume control during deposition. While this allows for high resolution and fast printing speeds, it also constrains its use to low viscosity solutions to avoid clogging of the print nozzle, introducing significant limitations for bioprinting applications.

Extrusion bioprinters address this concern by using mechanical or pneumatic dispensing systems accommodating more viscous bioinks while maintaining cell viability, making them the most common choice for bioprinting [4]. Despite these capabilities, there is a trade-off between high resolution and fast printing speeds vs. the shear stress experienced by cells during extrusion for biological applications. Bioprinting applications often use high viscosity inks due to the physicochemical properties of compatible materials required for scaffold preparation and cell growth. As a result, extrusion-based methods need to consider nozzle pressure for cell compatibility as high pressure can be detrimental for viability and reducing viscosity may compromise the mechanical integrity of the final structure.

An alternative approach to extrusion-based methods involves light projection into a vat of resin for precise crosslinking using lasers or light modulators. Stereolithography (SLA) 3D printers use a laser to photocure the material point-by-point during the printing process while an internal stage moves the cured sample in the z-plane incrementally once a layer is complete. Although this can yield intricate microstructures with a wide array of materials, photocuring of samples point-by-point is a limiting step for print speed. As a result,

digital light processing (DLP)-based 3D printing aims to overcome the drawbacks of SLA by projecting a digital mask to crosslink the entire focus plane at once, substantially reducing the build time compared to point-by-point scanning. DLP printing can proceed in a layer-by-layer or continuous fashion, the latter improving printing times up to 10x by not requiring separation of each cured layer. Instead, continuous projection methods can inhibit polymerization at the printing plane to eliminate adhesion between finished layers and the working solution [3, 5, 6]

The most common light modulators implemented in DLP-based printing are liquid crystal displays (LCD) and digital micromirrors (DMD). Compared to LCDs, DMDs can provide better spatial resolution, higher contrast, and the ability to accommodate various 2D or 3D patterning applications by easily changing optics or light sources (high power lasers, LEDs, etc.) [2, 7]. Mightex's Polygon is a market-leading DMD module providing these benefits along with high temporal resolution (up to 6.6kHz) and optimized optics for easy implementation in any research application in any lab.

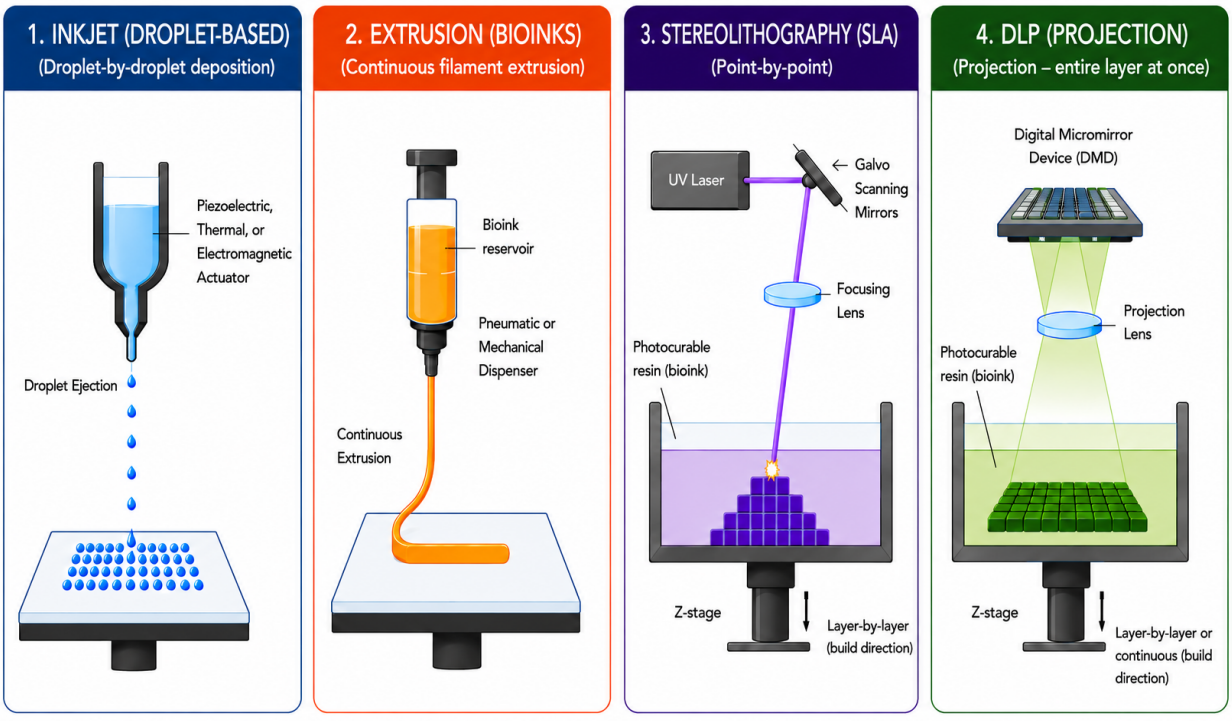

Figure 2: *Overview of major 3D bioprinting modalities used for fabrication of hydrogels, scaffolds, and engineered biological structures. Inkjet printing (1) deposits discrete droplets, whereas extrusion bioprinting (2) continuously dispenses bioinks to support higher viscosity materials and cell-laden constructs. Stereolithography (SLA) (3) uses point-by-point laser photopolymerization for high-resolution fabrication, while DLP-based printing (4) projects patterned light to crosslink entire layers simultaneously for high throughput.*

Overall, a DMD provides superior accuracy and versatility, and faster pattern modulation with a longer lifetime than LCD systems. By projecting an entire pattern simultaneously, DMD-based methods can fabricate complex, multifunctional architectures while achieving a more favorable balance between throughput and resolution than point-scanning techniques such as SLA. In addition, it has a high transmission efficiency due to reduced loss of light from DMD reflection unlike LCDs, which suffer from reduced transmission efficiency due light absorption of the display itself. DMDs can also accommodate a wider range of wavelengths and higher power light sources compared to LCDs, making them an ideal choice particularly for UV-based applications [8, 9].

4 Spatial Micropatterning

Micron-scale spatial patterning of light is a powerful technique with broad applications in cell biology, chemistry, material science, biomedical engineering, and more. Light-sensitive compounds can be used as templates and building blocks to engineer unique cellular microenvironments, surface topologies, and complex material architecture with spatially targeted photochemical reactions. Achieving such patterning with projection-based techniques without physical contact with the sample is an ideal technique for rapid R&D prototyping and high iteration testing. It is also advantageous for biological applications, where sterility of the sample may be a critical factor.

Several factors must be considered when planning to implement spatial patterning techniques, such as:

1. Sample type and properties – biological (cell/tissue), organic molecules (DNA, proteins, natural polymers), or inorganic molecules (ceramics, micro/nanoparticles).
2. Processing equipment – dependant on the patterning technique and size of material – microscope, 3D printer, other custom optical apparatus, etc.
3. Light-sensitive compounds – the photochemical properties of the light-sensitive compound such as stability, the wavelength and power required for reaction, and cytotoxicity (for biological applications).
4. Resolution and speed – dependant on the dimensions, features, and architecture of the final sample.

Depending on the proposed application, there might be trade-offs when it comes to achieving the desired resolution, speed, compatibility, and cost. However, an ideal system will have good resolution, speed, and compatibility at a reasonable cost for rapid R&D prototyping and widespread implementation to advance research and knowledge. DMD-based solutions for light modulation such as the Mightex Polygon provide sub-micron lateral resolution and pattern switching speeds up to 6.6kHz, making it compatible with a wide range of applications for both 2D and 3D micropatterning. The Polygon is used by scientists all over the world, with citations in more than 175+ peer-reviewed, scientific publications. The system also provides simple implementation into existing imaging infrastructure in most labs along with versatility and precision to accommodate intricate features on both small and large-scale materials.

5 Basics of DMD-Based Patterning

DMD-based photopatterning enables crosslinking and photopolymerization of multiple points or areas in partial or entire layers of a scaffold or coating, providing a faster approach over point-by-point scanning systems. Since patterns can be designed and uploaded to the DMD module electronically, this provides an efficient way to produce complex patterns with precision. The ability to change patterns with ease also reduces the cost and time needed to perform iterative and high-throughput experiments.

DMD arrays are composed of millions of reconfigurable micromirrors that can be actuated with high-speed to provide spatial light modulation within microseconds. This allows for continuous generation of digital patterns using one or more light sources, effectively replacing static photomasks (Fig. 3). Once projected onto the substrate, the patterned light delivers site-specific exposure and serves as a reprogrammable photomask for high-throughput fabrication. This method of light projection was first adopted commercially for maskless lithography, providing sub-micron resolution using binary bitmap patterns through integration with optics for magnification. Since its inception, there have been several advancements including pulse-width modulation for grayscale illumination of the substrate and closed-loop control of the DMD for full-automation, leading to more advanced patterning experiments expanding from 2D planar substrates towards 3D architecture.

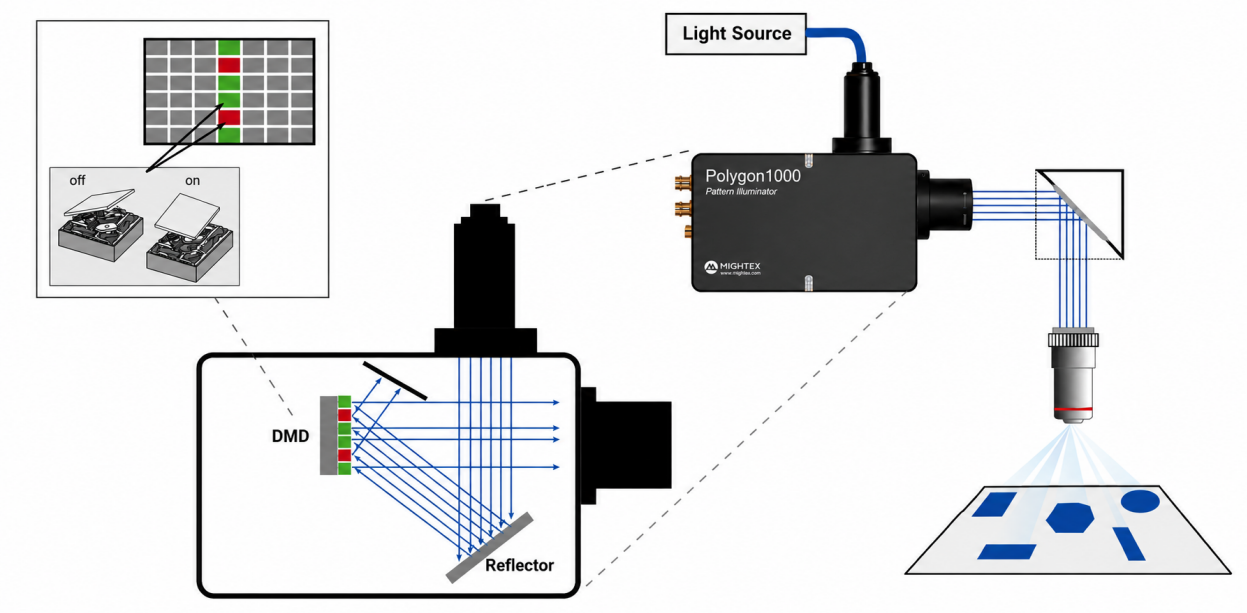

Figure 3: *Digital Micromirror Device (DMD) arrays consist of millions of high-speed, reconfigurable micromirrors that provide spatial light modulation within microseconds. By rapidly switching individual mirrors between ON and OFF states, the DMD selectively directs light toward or away from the optical path, enabling continuous generation of dynamic digital illumination patterns from one or more light sources.*

DMD-based photopatterning can be coupled with either UV or visible light depending on the target, which provides versatility in the choice of compatible substrates including cells, tissue, extracellular matrix, etc. By selectively exposing parts of the material to UV light, one can mitigate unwanted UV exposure that may occur with non-patterned crosslinking. The ability to easily incorporate multiple light sources also allows for studying photoconvertible materials.

a. DMD Patterning Speed and Resolution

High-resolution DMD modules provide an excellent balance between high fidelity and fast patterning speed, particularly with grayscale patterning. For example, Mightex's Polygon can switch between patterns at speeds up to 6.6kHz although actual patterning speeds are limited by the reaction kinetics of the chosen material chemistry and print geometry, leading to a range of curing times from 1-10s or more per layer. Regardless, most of these scenarios can be accommodated by DMD-based crosslinking, including commercially available photoresists for lithography applications. The ability to perform 8-bit grayscale patterning results in continuous variation of light intensity for more uniform printing results. With optimized optics and the development of new computational methods for optical correction, sub-cellular resolution can be achieved [10]. Also, multilevel microstructures and topographies can be generated with single-step grayscale exposure that results in higher resolution than SLA printers [3].

The resolution of DMD-based photopatterning depends on several factors related to the hardware including the micromirror pitch, binary nature of DMD operation, and other optical limits. The theoretical limit for resolution is governed by the diffraction limit of light. However, real world implementation requires both hardware and computational optimization to reach this theoretical limit and consider factors not related to hardware such as nonlinear response of photoresponsive materials. It is important to note that material properties including viscosity and opacity as well as print geometry, speed, and post-processing methods can all affect the printing resolution and time regardless of DMD hardware properties [10]. Overall, a DMD-system with optimized optical components such as the Mightex Polygon produces enhanced contrast and pattern fidelity for complex photopatterning architectures. Combined with motorized stages and TTL-based actuation, it also allows for large scale patterning by sequentially moving through pre-determined ROIs in a grid-like fashion.

b. Grayscale Illumination and Patterning

Another key advantage of DMD-based patterning is the ability to generate digital grayscale masks, which creates spatial control of light intensity unlike traditional physical masks which are binary in nature. This enables smooth transitions and print quality for intricate architectures in 2D or 3D. A common way to achieve this is by using 8-bit patterns in which grays are encoded in bit planes that represent the ratio of light/dark

segmented for each pixel ranging from 0 to 255. Therefore, individual mirrors can be dithered ON or OFF for specific fractions of time to achieve gray values within this range using pulse width modulation (Fig. 4). Another approach to achieve this uses 1-bit binary grayscale masks generated using halftoning algorithms providing gray values that are spatially averaged from patterns that mimic a checkerboard configuration. This requires high-resolution DMD modules and enough pixels/individual mirrors per ROI to accurately project the required gray value (Fig. 4). Grayscale illumination is beneficial in 3D patterning, but additional optimization is required for setting the exposure and gray levels based on the desired final structure as its not a linear relationship to the rate at which crosslinking/polymerization may happen. However, optimization protocols have been described in the literature including computational tools for calibrating exposure depth and grayscale levels [10].

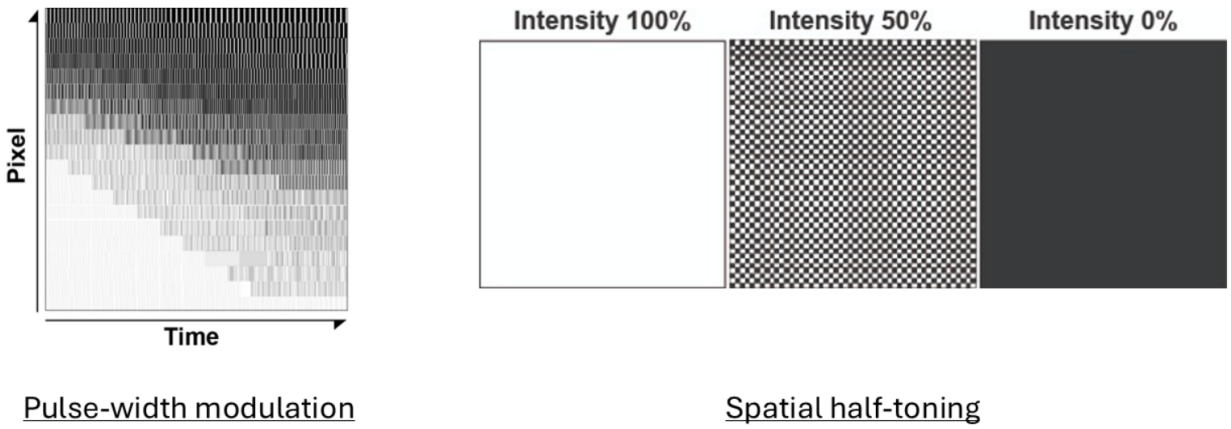

Figure 4: *DMD-based illumination systems can generate grayscale intensity patterns through both pulse-width modulation (PWM - left) and spatial half-toning (right).*

6 Sample and Substrate Considerations for Photopatterning

When planning your photopatterning workflow, there are some key factors to consider regarding the sample and substrate being used in your application, which may require some optimization to obtain the desired architecture. A versatile DMD system such as the Mightex Polygon, which accepts a wide range of illumination sources, allows for easy optimization of these parameters to accommodate most applications regardless of the type of sample being used. Examples of commonly used materials are as follows.

a. Live Substrates

Advances in microfabrication techniques and biomaterial research has led to the creation of complex and functional synthetic tissue for scientific investigations as well as clinical diagnostics and regenerative therapies. These approaches are particularly prevalent in tissue and organ engineering, where precise tissue architecture and heterogeneous cell organization is key to producing a biocompatible and functional model. The use of living substrates such as single cells or 3D organoids in bioinks and patterning experiments require special consideration within the methodology to maintain cell viability, function, and sterility. This includes precise modulation of light exposure, particularly at the UV range to reduce toxicity from photooxidation and other biochemical reactions.

In addition, contactless photopolymerization of scaffolds is favourable for sterile preparation of tissue constructs compliant with good manufacturing practices (GMP), especially for translational application in healthcare diagnostics or therapeutics. DMD-based solutions accommodate these requirements by enabling contactless micropatterning with easy integration into existing microscopes and other optical imaging infrastructure that is often found in most research labs.

While bioink viscosity is a key factor to determine the final structure's mechanical properties, cell viability can be significantly affected by shear stress during extrusion of high viscosity bioinks, particularly at high cell density. On the other hand, low cell density, often required for inkjet printing, may not achieve biomimetic cell populations and high concentrations can cause nozzle clogging and/or inhibit crosslinking. Therefore, DMD-based contactless vat polymerization is a favourable approach to provide a balance in maintaining mechanical properties and biological function of 3D printed tissue. This is particularly advantageous for bioprinting applications with vasculature and microstructures with features requiring fine resolution (less than 100μm).

b. Polymers

Polymers remain the backbone of most structures obtained through photopatterning. Biological macromolecules such as DNA, proteins, and extracellular matrix (ECM) components serve as excellent building blocks for the preparation of scaffolds and surface micropatterns in cell culture and tissue models. They provide binding motifs for cell adhesion, proliferation, and differentiation for several applications including assay development and imaging. Polymers derived from natural sources such as alginate, gelatin, chitosan, and hyaluronic acid also provide comparable benefits in addition to serving as a renewable source of materials that are biocompatible and scalable. These polymers are typically isolated from plant or animal tissue and undergo a series of mechanical and chemical processing to purify the final product in a top-down approach. As a result, variation in material properties arising from source material and method of processing is expected, which can lead to batch-to-batch variability, an important parameter to consider for experimental reproducibility and clinical translation.

On the other hand, synthetic polymers are manufactured from their monomeric building blocks in a bottom-up approach. As a result, their physical and chemical properties including purity, structural branching, and percentage of reactive side-groups can all be controlled to reduce variations unlike naturally-derived polymers. This allows for easier implementation and regulatory compliance, particularly in translational research and clinical application. These polymers are also typically more mechanically robust and can handle a variety of fabrication techniques without degradation or significant alteration of their physical and chemical properties. Examples include polyethylene glycol (PEG), polymethyl methacrylate (PMMA), polydimethylsiloxane (PDMS), etc.

Natural biomaterials are widely used in biomedical research, partly due to their biocompatibility but also their degradation properties, which makes them ideal for implant integration or tissue regeneration. Due to the nature of the chemical backbones found in most of these polymers, they are susceptible to degradation via enzymatic or photochemical reactions. This can also be useful for 2D surface patterning onto glass, plastic, or other substrates but consideration must be given regarding molecular conformation during surface adsorption to not hinder the material's bioactivity. Overall, the bioactivity and mechanical stability of the final structure can be controlled by strategic and targeted crosslinking and optimization, which a DMD such as the Mightex Polygon provides.

c. Micro and Nanoparticles

While most photopatterning applications target polymeric films or scaffolds, patterning with micro and nanoparticles have numerous application both in life sciences and material development. Quantum dots and other nanocrystals can be photopatterned for screen fabrications in industrial applications, providing an alternative to traditional lithography. While this can be effective in 2D surface patterning, extending the use of particles in 3D patterning may present some challenges. Particles with high refractive index such as ceramics or metals can reduce the transparency of resin baths leading to increased scattering, and ineffective light penetration and crosslinking. Nevertheless, the versatility provided by a DMD makes it an ideal solution for photopatterning experiments accommodating a wide range of materials, which are summarized in the figure below (Fig. 5).

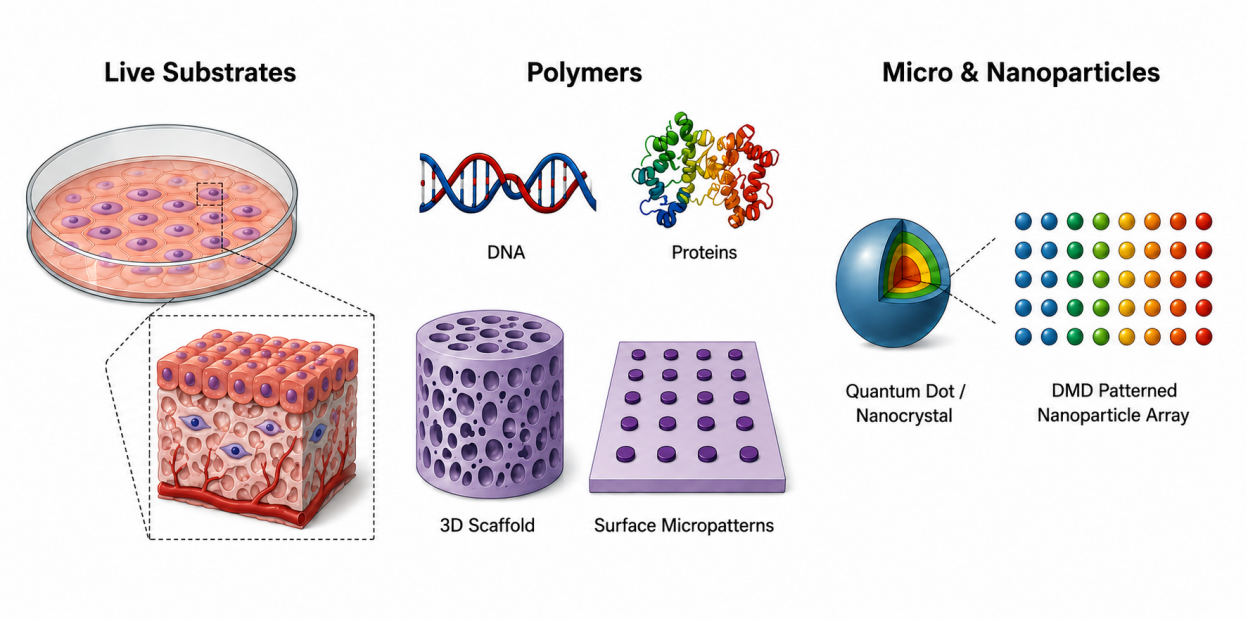

Figure 5: *Representative examples of commonly used materials in photopatterning applications in 2D and 3D including live substrates such as cells and tissue constructs, natural and synthetic polymers, as well as micro and nanoparticles such as quantum dots.*

7 Photochemical and Biological Considerations of Commonly Used Crosslinkers

a. Cross-Linking Chemistry

Early adoption of DMD-based photocrosslinking used industrial photoresists which were originally developed for 2D applications in masked lithography. [10]. Although the bulk properties of substrates mentioned above can influence the compatibility and stability of the final construct, the crosslinking mechanism is the primary determinant of its architecture and structural integrity. Examples of chemical functionalities and mechanisms used in crosslinking reactions include vinyl, acrylate, thiol, alkene/alkyne, light-mediated oxidation, and others [11, 12]. The choice of crosslinking chemistry depends on factors such as the substrate type, solubility, compatibility with cells or biological molecules, and the wavelength and photoinitiator required for photochemical crosslinking or photoconversion. Crosslinking also influences the mechanical properties and biocompatibility of polymers, enabling controlled degradation and tailored mechanical properties. The Polygon provides high contrast, multi-wavelength illumination with grayscale patterning capabilities, allowing precise spatial and temporal control of crosslinking to support a broad range of photochemical reactions.

Patterning speed is closely linked to the underlying crosslinking mechanism and can vary depending on the type of photoreactive chemistry involved. Common mechanisms include free-radical polymerization, cationic polymerization, ring opening reactions, and others. Among these, free-radical polymerization initiated by a photoinitiator is the most widely used mechanism in 3D printing and photopatterning methodologies. In this process, light activation of a photoinitiator generates free radicals that activate monomers or functional groups in solution, starting a chain reaction that propagates until termination. This can be triggered across a broad range of wavelengths, from deep UV to IR. However, there has been a growing shift towards the use of visible-light photoinitiators in biomedical applications for better biocompatibility. Commonly used photoinitiators are summarized below and include UV-responsive molecules such as Irgacure 2959 and lithium phenyl-2,4,6-trimethylbenzoylphosphinate (LAP), as well as visible-light photoinitiators such as Eosin Y and Ruthenium-based complexes (Fig. 6).

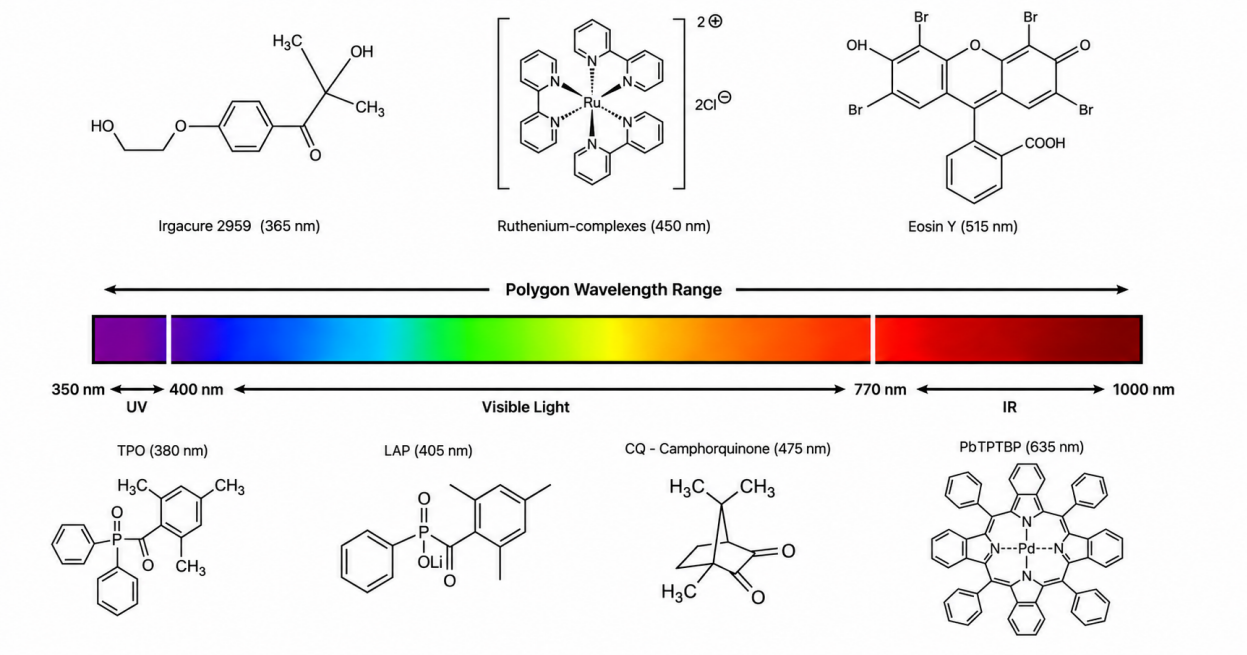

Figure 6: *Common examples of photoinitiators and their activation wavelengths along with the wavelength range of the Polygon1000 DMD module. Examples listed include: Irgacure 2959, diphenyl(2,4,6-trimethyl benzoyl) phosphine oxide (TPO), lithium phenyl-2,4,6-trimethylbenzoyl phosphinate (LAP), Tris(2,2'-bipyridyl)ruthenium(II) chloride, camphorquinone (CQ), Eosin Y, palladium(II)-meso-tetraphenyl-tetrabenzoporphyrin (PbTPTBP).*

Acrylates and thiol functional groups are among the most commonly used chemistries for free-radical photopolymerization. Radical polymerization can proceed through two mechanisms: Type I, which uses photocleavable initiators, and Type II, which relies on a bimolecular initiating system. Type I photoinitiators are more commonly used and are typically activated by UVA or UVB wavelengths, enabling rapid polymerization. In contrast, Type II can be activated by longer wavelengths, providing improved light penetration and biocompatibility, but often at the expense of slower reaction kinetics that can affect printing speed [3, 12]. Cationic polymerization is another common mechanism that uses onium salts or organometallic complexes. However, it can generate acidic byproducts that persist after photoinitiation, potentially altering the pH and reducing cell viability, particularly in tissue engineering applications [6]. Overall, Type I initiators are often favoured for their fast polymerization rates, although this must be balanced against potential effects on cell viability. Type II initiators are generally slower but may offer improved biocompatibility for certain applications. [12].

b. Reversible vs. Permanent Crosslinking

Photoconvertible chemistries are an emerging area with applications across numerous research and industrial fields. The ability to reversibly form and break crosslinked groups using light enables precise modulation of substrate properties, allowing researchers to study cellular responses to dynamic geometric and mechanical cues. These chemistries also have potential application in self-healing materials, recycling, and the

continuous modification of existing structures. Coumarin-based systems are among the most widely used photoconvertible chemistries for both 3D and 2D crosslinking, with a greater number of examples reported for 3D applications [13].

c. Light Source and Wavelengths

Free-radical polymerization can be initiated using photoinitiators activated across a broad wavelength range, from deep UV to IR. Most photocrosslinking applications in microfabrication and surface coating, particularly those involving acrylates, use UV light in the 250-400 nm range [3]. However, short wavelengths, especially UVB (290-320 nm), and prolonged exposure can cause cellular damage in bioprinting applications. For example, Irgacure 2959 is commonly used with 365 nm light sources despite having a maximum absorption wavelength near 275 nm. This mismatch reduces reaction efficiency and often requires compensation through increased photoinitiator concentration, exposure time, or light intensity. UV light also has limited penetration depth, which can result in incomplete crosslinking, particularly within the interior of thick 3D constructs. On the other hand, visible light (400-700 nm) generally offers improved biocompatibility and greater penetration depth [6]. Efficient crosslinking therefore requires a light source matching the maximum absorption wavelengths of the initiator.

In addition to the wavelength, light intensity and material photosensitivity can significantly influence crosslinking kinetics. Industrial photoresists are typically designed with high photosensitivity to enable precise photolithography. However, this parameter can vary depending on material thickness, density, opacity, and crosslinking chemistry, requiring optimization for each application. The Polygon supports a broad range of wavelengths and light sources, including LEDs coupled through a 3 mm core liquid light guide or fiber-coupled lasers for high-power applications. Mightex also provides a wide selection of wavelength-specific light sources that can be integrated with the Polygon for efficient patterning experiments. This modularity enables both simple and complex illumination schemes, including multi-wavelength patterning for photoswitchable chemistries or rapid prototyping across diverse material systems.

d. Cytotoxicity

When selecting a photopatterning or photocrosslinking strategy in biological applications, two broad approaches are commonly used: a multi-step process in which patterning or crosslinking is performed before introducing biological components, and a one-step process in which cells or other biological materials are incorporated during patterning. The choice depends on the specific application, as not all materials or chemistries are compatible with direct cell encapsulation. For example, 2D surface patterning experiments often employ a multi-step workflow, where proteins or cells are introduced only after the surface has been patterned and washed.

Cytotoxicity can arise from the presence of radicals during crosslinking, pH changes, or exposure to high doses of UV light, which may also generate heat in both 2D and 3D applications. Unreacted chemical groups and excessive UV exposure can reduce cell viability and induce genetic mutations or inflammatory responses. In extrusion-based bioprinting, shear stress is an additional factor that can affect cell viability. Beyond cytotoxicity, the reaction of oxygen with activated initiators can form peroxy radicals, which can reduce crosslinking efficiency. Despite these limitations, radical photoinitiators are generally more biocompatible than cationic initiators, as the latter can generate acidic byproducts and remain active after illumination has ceased [14]. DMD-based systems such as the Mightex Polygon help mitigate many of these challenges by providing a contactless patterning method that eliminates mechanical stress on cells while enabling efficient, high-contrast illumination that reduces overall sample exposure. Researchers can also easily exchange light sources to utilize and develop novel visible-light photoinitiators and crosslinking chemistries.

8 Conclusion

In summary, DMD-based photopolymerization and photopatterning support a wide range of applications with new techniques and approaches continuing to emerge in the literature. As a result, a versatile and adaptable platform capable of accommodating diverse experimental requirements is highly advantageous. The Mightex Polygon provides high spatial and temporal resolution, combined with optimized optics for straightforward implementation in both 2D and 3D applications. In addition, it can be synchronized with external equipment via TTL triggering, enabling high-throughput workflows and closed-loop automation using custom scripts. While individual applications may have unique requirements, the key parameters outlined in this document can serve as a practical guide. Across a broad range of photopatterning and photocrosslinking applications, the Mightex Polygon offers a flexible and powerful solution.

If you found this eBook enlightening, we encourage you to have a look at our other eBooks, Application Notes, and to stay tuned for future releases. The Mightex team is made of experienced researchers from behavioural neuroscience and other biomedical fields. We continually produce new content to bring these fascinating topics to a wider audience and empower our customers with the knowledge to conduct the highest-quality research possible.

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