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REVIEW ARTICLE

Plasmonic components fabrication via nanoimprint

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Abstract

A review report on nanoimprinted plasmonic components is given. The fabrication of different metal–dielectric geometries and nanostructured surfaces that support either propagating or localized surface plasmon modes is discussed. The main characteristics and advantages of the nanoimprint technology for the fabrication of various plasmonic structures are outlined. The discussion of plasmonic waveguiding structures focuses on planar waveguides based on metal strips embedded into a dielectric and on profiled metal surfaces. Nanoimprint-based fabrication of two-dimensional nanostructured plasmonic surfaces for enhanced transmission studies and sensor applications is also discussed. Throughout the report, the main fabrication schemes are described, as well as the challenges facing future manufacturing of plasmonic components for device applications.

Keywords: plasmonics, surface plasmon-polaritons, nanofabrication, nanolithography, nanoimprint lithography, plasmonic waveguides

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Nowadays, the development of information technology demands miniaturization and increased functionality in integrated photonic circuits and the design of new materials with extraordinary optical properties. It has steadily evolved towards the use of nanophotonics that search for new approaches for manipulating light at the nanoscale. One of the avenues in nanophotonics research is plasmonics, or metal optics, based on the controlled excitation of surface plasmons (SPs) [1–4]. Metals that support SPs—collective oscillations of free electrons—can concentrate electromagnetic fields on the nanoscale, while enhancing local field strengths by several orders of magnitude. Plasmonic structures supporting different SP modes—propagating or localized—can serve both as nanophotonic components and as a link between the nano-and micro-worlds, coupling light into the nanoscale through plasmonic nanoantennae [5–7] and dramatically enhancing light–matter interaction on the nanoscale. Plasmonic structures exhibit a variety of novel effects, including extraordinary light transmission [8], collimation of light through a subwavelength aperture [9], giant field enhancement [2] and surface plasmon waveguiding [2–4, 10]. In addition to subwavelength confinement, plasmonics brings another attractive feature into the area of integrated optical waveguides—the unique possibility of using the same metal circuitry for guiding SPs and carrying electrical signals [11–14].

Light interaction with surface plasmons in specially designed metallic structures has also resulted in demonstrations of effects unattainable with naturally occurring materials including, for example, negative permeability (optical magnetism), negative refractive index at visible wavelengths...
and nonlinear effects in magnetic metamaterials [21, 22]. These observations led to a new area of photonics called optical metamaterials that has been exponentially growing over the last few years [18, 19].

Plasmonics does not only aim at developing optical devices for information technology. Surface plasmons are of interest to a wide community of researchers working in the areas of chemical and biological sensing, microscopy, nanolithography, light sources, data storage and energy conversion. Tight field confinement to the metal surface (typically on the order of or smaller than the wavelength in the corresponding media) makes SPs very sensitive to surface irregularities, so that SPs have long been used for surface analysis, including bio-sensing [3, 23, 24]. Giant field enhancement achievable in metal nanostructures gives rise to massive signal enhancement in surface-enhanced Raman spectroscopy (SERS), enabling single molecule detection [25–27].

The recent boom in plasmonics comes from advances in nanofabrication that allow metals to be structured on the nanoscale. Designing and nanostructuring metal surfaces in a controllable way opens up the possibility of controlling the SP properties and tailoring them for specific applications.

Typically, to fabricate plasmonic structures one should deal with small (subwavelength) periodicities and feature sizes of the order of 100 nm. Such feature sizes are smaller than the resolution of state-of-the-art photolithography (due to the diffraction limit), thus requiring nanofabrication processes with 100 or sub-100 nm resolution. One of the widely used techniques for making nanostructures is electron-beam lithography (EBL). In addition to high resolution (below 100 nm), EBL offers almost complete pattern flexibility and can be used for creating a large variety of nanostructures. The majority of plasmonic structures ranging from subwavelength metal nanowires [28, 29] and chains of metal nanoparticles [30, 31] for SP guiding to two-dimensional plasmonic nanostructures for SP manipulation, focusing and guiding [32–34] are made using electron-beam lithography. However, plasmonic arrays consisting of subwavelength holes in a metal film or metal nanoparticles should often be patterned on a large-scale (multiple length scales) to be used as plasmonic metamaterials [35–39] or substrates for sensing applications [40, 41]. Due to the low throughput of the serial point-by-point electron-beam writing and its high fabrication costs only small areas (of the order of 100 μm × 100 μm) can normally be structured with EBL. Hence, fabrication of plasmonic nanostructured surfaces requires the development of high precision and high throughput manufacturing processes. Examples of such techniques are microcontact printing (soft lithography) [42, 43] and nanoimprint lithography (NIL) [44–48].

Being a next generation lithography candidate, NIL accomplishes pattern transfer by the mechanical deformation of the resist via a stamp rather than a photo- or electro-induced reaction in the resist, as in most lithographic methods. Thus the resolution of the technique is not limited by the wavelength of the light source, and the smallest attainable features are given solely by stamp fabrication. Moreover, NIL provides parallel processing with high throughput, being therefore suitable for large-scale patterning of plasmonic structures. Nowadays NIL provides high resolution wafer-scale processing using standard cleanroom procedures offering simplicity and low cost.

In addition to the ability of creating high resolution, large scale patterns in a resist, in a similar way to other standard lithography techniques, NIL can imprint complex, non-planar profiles in various polymers. This feature is crucial for the imprinting of functional devices for a wide range of applications in electronics, photonics, data storage, and biotechnology [46]. In plasmonics, imprinting complex surfaces in polymers are used to make profiled metal surfaces, such as metal V-grooves for SP guiding.

In this review an overview of plasmonic structures fabricated with the use of nanoimprint technology is given. The focus is on recent advances in the manufacturing of nanostructured metal surfaces and different metal–dielectric structures using either nanoimprint lithography or a combination of NIL and other lithography types. The review is organized as follows. Section 2 describes the main features of NIL. Section 3 is devoted to plasmonic waveguides. Two types of geometries for plasmonic waveguides are considered: nanometer-thin metal strips embedded into a dielectric environment (planar plasmonic waveguides) and profiled metal surfaces. Section 4 focuses on two-dimensional plasmonic structures that can be used for different applications, ranging from extraordinary transmission studies to biosensing. Finally, some concluding remarks are offered in section 5.

2. Nanoimprint lithography

The ability to fabricate nanoscale plasmonic structures with high precision is of crucial importance to real-life applications. Even though expensive tools such as electron-beam lithography, focused ion beam (FIB) milling techniques or deep-UV projection lithography can be successfully employed for making plasmonic structures, they do not offer a low cost, large-scale fabrication method that can be used for plasmonic-based device manufacturing. Several methods that could offer high precision and high throughput have been exploited in the past 15 years including microcontact printing (or soft lithography) [42, 43], dip-pen lithography [49] and nanoimprint lithography [44–48]. Below, the basic features of the nanoimprint technique are outlined, together with the possibilities it brings to plasmonic structures fabrication.

Unlike traditional lithographic approaches, where pattern definition relies on the modification of the chemical and physical properties of the resist caused by photons or electrons, NIL is based on the direct mechanical deformation of the resist material. Thus the resolution achievable with NIL is beyond the limitations set by light diffraction or beam scattering in other techniques.

In the originally proposed NIL process [44] (figure 1(a)) a hard stamp (mold) that contains nanostructure is pressed into a polymer (NIL resist). Pressing the stamp at a controlled temperature and pressure creates a thickness contrast in the polymer. A thin residual layer of resist is intentionally left
underneath the stamp protrusions so that this layer acts as a cushioning layer that prevents direct impact of the hard stamp on the substrate and protects the delicate nanoscale features on the stamp surface. After the separation process the residual layer can be removed by etching (for example, an anisotropic O2 plasma etch) to complete the pattern definition.

The key process in NIL is replication—a surface pattern of a stamp is replicated into a molded material by mechanical contact and three-dimensional material displacement. This can be done, for example, by shaping a liquid followed by a curing process for hardening, by variation of the thermomechanical properties of a film by heating and cooling, or by any other kind of shaping process using the difference in hardness of a mold and a moldable material. Various processes that can be used for replication in NIL allow one to choose from a wide variety of materials for stamps and molded materials, ranging from transparent glass stamps for UV-curable polymers [50] to hard molds for direct imprinting (embossing) of metals [51].

The local thickness contrast of the resulting imprinted thin film can be used in two different ways. As in the originally proposed scheme, this layer can be used for patterning an underlying substrate by standard pattern transfer methods (for example, etching) (figure 1(a)). This approach is similar to fabrication methods where standard lithography schemes are used. The difference is only in the method of obtaining the patterned resist layer—either by lithographic exposure and development or by nanoimprint and residual layer etch. In such an approach, the stamp is usually fabricated via an EBL or FIB approach, and NIL in this case can be considered a large scale version of these techniques (for example, in optical metamaterial fabrication [52]).

Another possibility is to use the NIL-patterned layer directly, for example, in applications where a bulk modified functional layer is needed. This unique feature offered by NIL is different from any planar fabrication methods, since it gives a possibility of replicating a profiled surface (figure 1(b)). This is really crucial for plasmonic applications where the materials to be structured—metals—are very difficult to pattern using standard processes. Below, such a replication method is considered for making plasmonic waveguides based on metal grooves. Direct and indirect ways of using nanoimprinted layers are further discussed in section 4, focusing on two-dimensional plasmonic structures.

3. Plasmonic waveguides and waveguide components

Various geometries of plasmonic waveguides have been proposed as candidates for ultracompact nanophotonic components. To demonstrate subwavelength confinement and efficient guiding of the SP modes, waveguide configurations based on metal strips with nanometer-scale thickness [53–55], subwavelength nanowires [28, 29], metal gaps [56, 57] and wedges [58, 59] were studied experimentally.

One of the approaches in plasmonic-based optical circuits focuses on long-range surface plasmons (LR-SPs) [60] propagating on nanometer-thin metal strips embedded in a dielectric material [53, 60]. Efficient LR-SP excitation via the end-fire technique and guiding (at telecom wavelengths) along thin gold stripes embedded in a dielectric was demonstrated by several groups [54, 61]. The low propagation and coupling loss attainable with LR-SPs stimulated experimental studies of LR-SP-based integrated optics components [62, 63], including...
Bragg gratings [64, 65] and dynamic devices where the same metal stripe circuitry is used for both guiding optical radiation and transmitting electrical signals that control its guidance [11–13].

Another SP-supporting configuration that has recently attracted a lot of attention is a triangular (V) groove made in a metal substrate. This configuration is similar to SP gap waveguides based on the SP propagation between metal surfaces with varying separation [56]. A V-shaped metal groove supports a strongly localized plasmon-polariton mode called the channel plasmon-polariton (CPP). CPPs were shown to exhibit relatively low propagation and bending losses and can be integrated into planar optical circuits [66–71]. The inverse geometry, namely, a triangular metal wedge, also supports a strongly localized plasmon-polariton mode—wedge plasmon-polariton, WPP [58, 59, 72–74].

3.1. Planar plasmonic waveguides based on thin metal strips

Thin metal strips that serve as long-range plasmonic waveguides can be easily fabricated using standard UV-lithography [62, 63]. However, adding functionality to such waveguides (for example, wavelength selectivity via metal gratings) requires nanostructuring of metal strips. Electron-beam lithography-based fabrication of the metallic LR-SP gratings reported earlier is quite complicated and time-consuming, which makes it unsuitable for real device applications [65, 75]. In contrast, using nanoimprint in combination with photolithography, first reported in [76], offers a simple and robust method for making nanostructured metal gratings.

In the fabrication process, a silicon stamp is first made using EBL (figure 2(b)). A substrate prepared by spin-coating a silicon wafer with 23 µm nanoimprint resist mr-I T85 (micro resist technology GmbH) is then used in a thermal nanoimprint lithography process to transfer the grating pattern from the silicon stamp onto the resist. Plasmonic strip waveguides are then made using standard UV-lithography, gold deposition and lift-off (figure 2(c)). To form the top polymer cladding, a borofloat glass wafer was spin coated with a resist layer identical to the substrate, and the two wafers are thermally bonded together (figure 2).

Typical values of the propagation and coupling loss obtained for 8 µm-wide and 14 nm-thick gold strips are presented in figure 3, together with an example of the output mode from such plasmonic waveguides. Propagation loss decreasing toward longer wavelengths is accompanied by the increase in coupling loss, and values of losses are comparable with previously reported results [62, 76, 77]. Detailed studies of strip waveguides with varying dimensions (width and thickness) can be found in [62, 77]. Typical transmission spectra for nanostructured gratings (normalized to the transmission through an unstructured strip waveguide)
are shown in figure 3. The spectra indicate standard Bragg-grating behavior, with the dip in transmission increasing with increasing grating length. Even though thickness modulated gold strips provide higher effective refractive index modulation [65] than corrugated strips of constant thickness [76] the described large-scale fabrication method offers an undeniable advantage for possible real device applications of metallic gratings.

In addition, the nanoimprint process planarizes the surface of the polymer, which could lead to reduced losses in thin-strip plasmonic waveguides when compared to a simpler fabrication process [62]. Together with the required grating nanopatterning, nanoimprint provides metal strips with reduced surface roughness, resulting in improved optical performance of the plasmonic device.

3.2. Profiled metal surfaces for surface plasmon guiding

Large-scale fabrication of profiled metal surfaces remains a challenging task. While sharp grooves and wedges can easily be made in silicon using standard lithographic and etching techniques, profiling metal surfaces often requires complex fabrication such as focused ion beam milling [58, 69]. Thus, the first experiments to investigate metal wedge-and channel configurations were based on using the FIB technique [58, 69, 70]. In addition to the limitations, such as high cost and complexity, FIB-fabricated components are hard to interface with optical fibers to achieve efficient end-fire excitation. Recently developed NIL-based fabrication of metal grooves [71, 78] allows replicating a profiled silicon surface in metal, offering a large scale, robust manufacturing method for plasmonic components that can be easily interfaced with the outside world.

The fabrication method for making V-groove plasmonic waveguides is schematically presented in figure 4. The main idea of the method is to make a metal replica of a profiled silicon structure, where any desired geometry can be obtained via standard patterning and etching techniques. This approach is used to transfer structures from a silicon stamp to a PMMA (polymethyl methacrylate polymer) layer. After the imprint process, gold is deposited on the PMMA, followed by deposition and selective UV exposure of a hybrid polymer (Ormocomp®, Micro Resist Technology). Once the Ormocomp layer has been post-exposure baked, the PMMA layer can be dissolved, leaving a gold-on-polymer replica of the initial silicon stamp (figure 4).

The developed process where grooves are first made in a silicon substrate and then replicated in metal using a nanoimprint process allows the reduction of the roughness of the metal film on the sidewalls of the groove when compared to standard deposition techniques [71, 78]. This is achieved by using the backside of the deposited film, similar to the process of template-stripping [79]. The fabricated components show good replication of stamp features, with shrinkage due to cooling and cross-linking of the polymer measured at 4% and an rms roughness of the gold film of around 2 nm [71]. However, the gold edge is ragged due to breaks from ultrasound agitation, which has a significant effect in increasing the coupling loss (figure 4). To reduce this effect, further optimization of gold thickness and adhesion is needed.

Initial profiling of silicon stamps can be achieved by using a variety of established techniques, including reactive ion etching (RIE) (both isotropic and anisotropic) and wet etching using KOH. For example, samples fabricated via wet etching of silicon have limitations of an apex angle fixed to 70° and easy patterning of only straight waveguides [78]. In this case, thermal oxidization of silicon structures can be used to alter the groove geometry, providing different apex angles, for example decreasing the angle from 70° to 50° [78]. In order to make waveguides of different geometries (bends, couplers) wet etching of silicon can be replaced by RIE, where nearly any desired channel geometry is achievable (figure 5). Since RIE is a complex process, better reproducibility and homogeneity across the wafer can be achieved via a combination of RIE with an oxidization process that helps to change the geometry and smoothen out the surface. CPP transmission,
Figure 4. (a) Schematic of the fabrication method for making metal V-grooves: a silicon stamp containing etched V-grooves is imprinted into a PMMA (shown as NIL polymer on the figure) layer on a silicon carrier wafer, resulting in a negative copy of the stamp. After nanoimprinting, 200 nm of gold is deposited on the molded PMMA layer, followed by deposition and curing of the second polymer (Ormocomp) on top of the gold film. Finally, the PMMA layer is dissolved, releasing the plasmonic components. Scanning electron microscope (SEM) images of (b) the V-groove in the silicon stamp (as in [78]) and (c) the fabricated V-groove, 200 nm gold layer on top of a transparent polymer.

with subwavelength confinement and propagation lengths exceeding 100 µm, achieved in oxidized grooves is reported in [71].

This method is a general NIL-based scheme for replicating silicon structures in gold on a polymer, and can be readily changed to different geometries. For example, a previously demonstrated large-scale method of fabricating wedge waveguides [59] based on parallel UV lithography-based technique can be extended to the use of NIL. In the case of making structures for WPP guiding, sharp wedges can be first made in silicon and then replicated in metal. It was shown that by successive reactive ion etching and oxidation processing steps, different shape silicon wedges can be fabricated [80, 81]. Figure 6 shows an example of a silicon wedge made via RIE, oxidation and the oxide etch processes. In conclusion, controlled profiling of silicon substrates converts complex plasmonic waveguide fabrication into a wafer-scale manufacturing process that uses standard cleanroom procedures and can be adapted to various designs.

4. 2D plasmonic surfaces

Two-dimensional plasmonic surfaces (also called plasmonic metamaterials [35] or plasmonic crystals [38, 41]) have become increasingly important in many applications ranging from compact in-plane optical components to sensor substrates. For 2D optics, tight field confinement to the metal surface allows one to manipulate the SP in the surface plane by using different types of surface metal nanostructures [32, 82]. With the recent progress in the fabrication of different nanostructured metal surfaces, efficient control of the SP propagation was achieved in different scattering and guiding surface configurations [2–4, 28–34]. Since for these structures relatively small areas (of the order of 50 µm x 50 µm) are normally patterned, EBL is still a method of choice for fabricating plasmonic optical elements [32–34]. For creating plasmonic metamaterials where ordered arrays of nanoparticles or holes are created on much larger scales (up to cm²) high throughput nanofabrication techniques are required, such as soft interference lithography [35] or nanoimprint [36, 39–41].

The use of the nanoimprint technique for making large-area plasmonic structures can be divided into two main categories—NIL with post-processing and direct imprinting/embossing. In the first category, various fabrication schemes utilize NIL for pattern transfer (in analogy with conventional lithographic approaches) followed by metal deposition and related processing that creates metal nanostructures [36, 37, 40, 41]. In direct embossing a hard mold is pressed into a thick metal film that is deformed under specific temperature and pressure conditions. Removal of the mold releases the structured metal surface and no further processing is required [51].

The usage of NIL as a large-scale analog of conventional patterning techniques (like EBL) was successfully demonstrated for the fabrication of various types of optical metamaterials [52]. For example, NIL can be used for the fabrication of chiral metallic metamaterials, with feature sizes down to sub-100 nm, for the study and application of novel polarization ef-
Figure 5. Simulation of thermal oxidization on (a) a reactive ion etched channel with sloped sidewalls and a flat bottom: an oxidization step can transform this geometry into (b) smooth high angle V-grooves (2D process simulator from Silvaco, SSuprem4).

Figure 6. Simulation of thermal oxidization on (a) a reactive ion etched (RIE) silicon wedge where (b) oxide (darker shade) can be removed subsequently in a highly selective etch (buffer hydrofluoric), leaving a sharp wedge, together with SEM images of the fabricated silicon wedge (c) after RIE and (d) after thermal oxidation and subsequent oxide removal.

fects [37]. In these fabrication schemes, prior to imprinting, a bilayer structure is normally spun onto a substrate. The NIL resist is then imprinted with the mold and the resulting pattern is transferred into the transfer layer after residue layer and transfer layer RIE etchings. The resulting structures are then obtained by a thermal deposition and lift-off process [52]. In these examples, NIL is used in its originally proposed scheme and requires additional processing steps for pattern transfer such as etching, deposition and lift-off.

The idea of reducing the amount of post-processing steps led to the development of various fabrication methods, for example, combining nanoimprint with shadow evaporation of metals to create metallic nanoprisms arrays [40] or large-area aperture arrays [36]. In the latter case, 2D arrays of subwavelength holes in Ag and Al films were successfully made by thermal NIL and metal evaporation, without the need for further etching or lift-off (figure 7). This technique only requires the fabrication of a mold, NIL resist spin-coating of a substrate followed by the imprint process and metal deposition. In this case, no process or material optimization is needed, unlike the originally proposed scheme where a successful lift-off procedure often requires careful material choice and bilayered resist structures.

The subwavelength aperture arrays in [36] were fabricated by thermally imprinting an Si template into a 350 nm-thick layer of PMMA spin coated on a 100 mm diameter Si wafer. Then shadow (angled) evaporation of Ag or Al was used for metallization of the imprinted substrates, which were continuously rotated during the evaporation (figure 7). The rotation ensured the presence of the metal on the periphery of the holes creating the aperture arrays.

Another example of simple, large-area fabrication of a plasmonic crystal is nanoimprint lithography using a soft, elastomeric mold [41]. The use of NIL with photocurable polymers was reported for manufacturing high resolution 2D plasmonic crystals for label-less sensing [41]. In this scheme, the stamp is prepared as a bilayer of hard polydimethylsiloxane (h-PDMS) to reproduce accurately the master’s features, and soft PDMS (s-PDMS) to provide a flexible support for the brittle h-PDMS. The PDMS mold is made by spin casting onto the master, followed by peeling of the composite PDMS replica. Many such molds can be produced from a single
master, and each mold can be used many times. After the UV imprint process photocurable polyurethane presents a relief structure in the geometry of the PDMS stamp. The imprinted polyurethane is then used as a dielectric template for the production of a plasmonic crystal by blanket evaporation of a thin layer of gold [41]. The resolution of this method is exceptionally high (features down to 1–2 nm can be produced).

In addition to high resolution and patterning on a wafer-scale, NIL-based fabrication allows easy integration of plasmonic structures into more complex device geometries, for example in micromechanical or microfluidic devices [83, 84]. This feature makes NIL a great candidate for future plasmonic device technology.

**5. Discussion and conclusions**

The performance of plasmonic structures, as well as possible applications, depends greatly on the fabrication method used. Thus, it is important to investigate different fabrication possibilities and find fast, robust, low cost and mass-production compatible methods of manufacturing plasmonic components with nanoscale features. The manufacturing procedure suitable for real device applications should offer simplicity of usage (only standard cleanroom processes, high reproducibility and throughput), combined with the possibility of adapting the procedure for various designs. Nanoimprint lithography is one such technique that offers high precision and mass-production, and considerably simplifies the large-scale integration and manufacturing of plasmonic structures. NIL is a powerful method for the fabrication of reproducible, large-scale plasmonic structures—from tunable SERS-active substrates and plasmonic metamaterials to non-planar geometry plasmonic waveguides.

For applications in integrated optics and sensing, nanoimprint-based fabrication of corrugated metal strips and profiled metal surfaces is the only (so far) method of making complex-geometry plasmonic waveguides on a wafer-scale. NIL-compatible processes offer simplicity (no complex techniques, such as FIB), high reproducibility, and can be adapted to different applications. In addition to high throughput, NIL-based fabrication offers new ways of improving waveguide structural quality, for example, metal surface roughness, through planarization or template-stripping methods using atomically flat molds.

NIL-involving fabrication of plasmonic waveguides requires a careful material choice that can be considered as a drawback or challenge of the method. For example, for corrugated metal strips, the NIL polymer (lower cladding of the metal strip) should allow further lithographic patterning.

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**Figure 7.** (a) Schematic of the nanoimprint and shadow evaporation processes together with scanning electron micrographs of (b) Ag and (c) Al gratings fabricated using thermal NIL and shadow evaporation [36]. The hole periodicity and diameter are 500 nm and 110 nm, respectively [34]. SEM images are from Sandia and used with permission from David Horsley.
using photolithography and hence should be compatible with associated wet chemistry. Thus, careful consideration of the various materials and processes involved is required for a successful fabrication outcome. However, rapid development of NIL resists makes it possible to choose between various polymer types tailored for specific processes—making the challenge become an advantage. Nowadays, the great choice of polymers allows the use of materials of various optical characteristics, making NIL-fabricated structures multifunctional [85, 86].

Nanoimprint technology can be extended into more geometries, for example, for making plasmonic waveguides based on subwavelength metal nanowires, which are compatible with current standards in optical communications, since they allow the elimination of the polarization dependence [87, 88]. Moreover, an NIL-based technology platform allows the integration of plasmonic components into more complex device geometries, e.g. including microfluidic channels for applications in chemical, bio-sensing and lab-on-a-chip devices.

NIL-based fabrication of large-scale 2D plasmonic structures can be used in different modifications and is easily extendable to a variety of inexpensive substrates (polymers, plastics). This makes nanoimprint one of the best candidates for the manufacture of disposable subwavelength devices, available for applications in medical diagnostics, bio-sensing and homeland security. In addition to NIL-based approaches that use various imprint techniques and mold types, metal direct nanoimprinting (embossing) can be applied for both the fabrication of metallic structures and the fabrication of metal-containing optical (and electronic) devices.

In conclusion, nanoimprint offers simple, high resolution, wafer-scale fabrication of plasmonic structures and opens up great opportunities for a wide variety of real-life plasmonic applications, ranging from subwavelength optical interconnects to bio-sensors.

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