Supplemental Materials

Dynamic Colorimetric Sensing with All-Dielectric Metasurfaces Governed by Bound States in the Continuum

Yanli Xu,*[a] Yinye Yang,*[a] Hongxu Li,[b] and Lirong Ren[a]

[a]School of Physics and Mechanical and Electronic Engineering, Guizhou Minzu University, Guiyang 550025, China

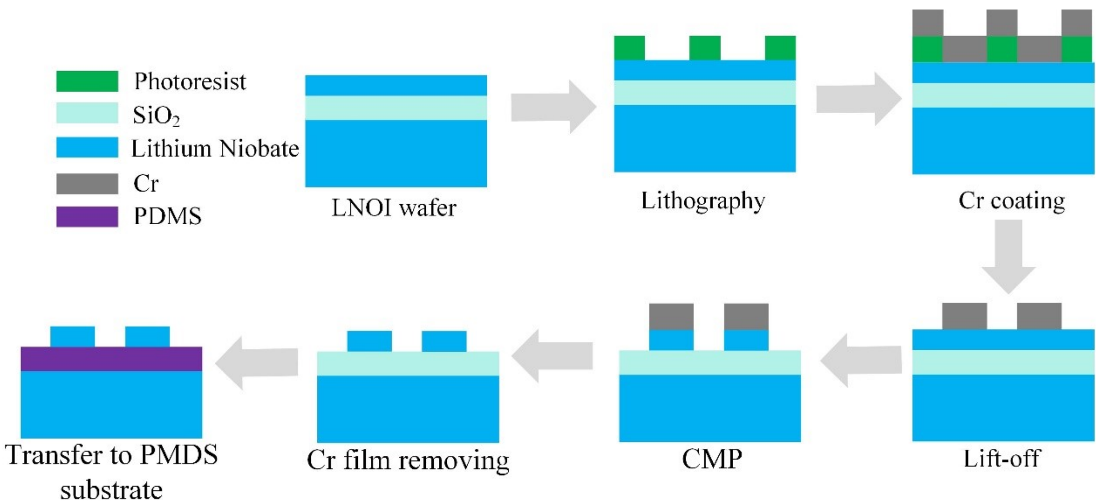
[b]Guizhou Light Industry Technical College, Guiyang 550025, PR China

*Corresponding author: yanlixu@gzmu.edu.cn

To facilitate the execution of the relevant experiments by researchers, this section outlines the device fabrication process. The recommended manufacturing process for the device is based on references R1-R4.

As a matter of fact, in recent years, the manufacturing process of on-chip ultrathin surface structures based on lithium niobate on insulator (LNOI) is similar to other on-chip micro/nanophotonic structures (such as waveguides, microcavities, etc.) based on LNOI [R1]. The typical manufacturing process is shown in supplementary Fig. 1. First, lithography technology is used to pattern the photoresist, where the photoresist can directly serve as a mask, or a layer of metal can be deposited after lithography as a mask, and then the patterning process is completed by combining the lift-off process; after the mask is prepared, the excess lithium niobate is removed by combining dry etching or chemical mechanical polishing (CMP) technology to complete the pattern transfer; subsequently, a post-processing process is carried out to remove the residual mask by wet etching to achieve the initial manufacturing of the micro/nano structure.

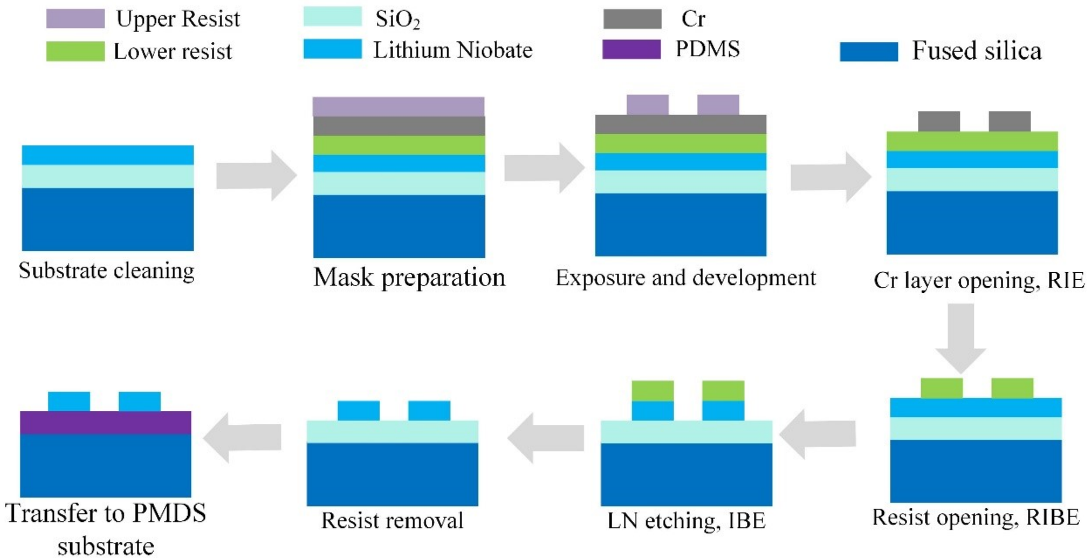
Among them, the manufacturing of on-chip optical structures using CMP technology usually includes four steps: 1) depositing a layer of Cr on the LN thin film as an etching mask; 2) patterning the Cr mask by lithography technology or femtosecond laser ablation; 3) removing the unmasked LN by CMP technology; 4) removing the surface Cr mask by wet etching.



Supplementary Figure 1. The main flow chart of the preparation of LNOI on-chip micro-nano photonic structures.

However, in contrast to most integrated photonics platforms, such as Si and SiNx, LN lacks an appropriate reactive ion etching recipe, which poses challenges in fabricating high-quality micro/nano structures. To address this issue, researchers have continuously optimized the etching parameters (e.g., gas ratio, power, etc.) [R2], and concurrently employed wet etching technology to eliminate excess reactants, thereby maximizing the smoothness of the sidewalls and minimizing scattering losses. In 2020, the research group of Professor Setzpfandt developed high-quality LN metasurfaces with smooth sidewalls using a multi-step reactive ion etching technique [R3]. This method can be integrated with various approaches, such as inductively coupled plasma (ICP), electron-cyclotron resonance (ECR), or ion-beam etching (IBE) systems, etc.

In summary, the manufacturing process of the LN metasurface in this work can be illustrated as shown in supplementary Fig. 2. Initially, a stack comprising a thick resist layer, a chromium layer, and a second resist layer was formed on a LN thin film with a thickness of several microns. The upper resist layer was exposed using a variable-shaped beam electron writer, which facilitated the quick exposure of circular shapes. After resist development, the chromium layer was etched using reactive ion etching (RIE). Subsequently, reactive ion beam etching (RIBE) was employed to locally open the thick resist layer. After the removal of chromium, ion beam etching (IBE) was carried out for the actual LN etching step. Finally, after resist removal, the cured PDMS was cut into the desired size, and the LN metasurface structure was separated from the SiO_2 substrate using the adhesiveness of PDMS, thereby achieving the transfer of the LN metasurface structure to a flexible PDMS substrate [R4].



Supplementary Figure 2. Schematic diagram of the fabrication process flow of LN metasurfaces

The light source of the laser can be incident on the metasurface by using an optical fiber collimator, and then collected by a spectral analyzer. Since the nanoplate dimer metasurface studied in this work is polarization-dependent, a linear polarizer can be added between the collimator and the metasurface to adjust the polarization of the light. Next, for refractive index sensing, a controllable refractive index (RI) material is introduced into the nanowire array, and images are captured using a bright-field microscope with a charge-coupled device (CCD) camera.

Reference

R1. Jia Y C, Wang L, Chen F. Ion-cut lithium niobate on insulator technology: recent advances and perspectives. Appl. Phys. Rev., 2021, 8(1): 011307.

R2. Honardoost A, Abdelsalam K, Fathpour S. Rejuvenating a versatile photonic material: thin-film lithium niobate. Laser Photon Rev., 2020, 14(9): 2000088.

R3. Anna Fedotova, Mohammadreza Younesi, Jürgen Sautter, Aleksandr Vaskin, Franz J.F. Löchner, Michael Steinert, Reinhard Geiss, Thomas Pertsch, Isabelle Staude, and Frank Setzpfandt, Second-Harmonic Generation in Resonant Nonlinear Metasurfaces Based on Lithium Niobate, Nano Lett. 2020 20 (12), 8608-8614.

R4. Shang Sun, Wenhong Yang, Chen Zhang, Jixiang Jing, Yisheng Gao, Xiaoyi Yu, Qinghai Song, and Shumin Xiao, Real-Time Tunable Colors from Microfluidic Reconfigurable All-Dielectric Metasurfaces, ACS Nano 2018 12 (3), 2151-2159.