GLASS NANOPILLAR ARRAY BASED NANOPLASMONIC LAB-ON-A-CHIP FOR HIGHLY SENSITIVE SURFACE ENHANCED RAMAN SPECTROSCOPY

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ABSTRACT

This work presents the novel glass nanopillar array based nanoplasmonic lab-on-a-chip for highly sensitive surface-enhanced Raman Spectroscopy (SERS). In this work, large-area glass nanopillar arrays are fabricated on both sides of the wafers by combination of metal dewetting and reactive-ion-etching (RIE) process. Metal layer is deposited onto one side to construct nanoplasmonic biosensing sensor, and remaining one side works as nanostructured antireflective (AR) layer to increase the SERS intensity. The simple, cost-effective fabrication method is very desirable for large-area nanoplasmonic biosensors, and fluidic channel can be integrated for advanced bio-applications with SERS.

KEYWORDS

Surface-enhanced Raman Spectroscopy (SERS), Glass nanopillar arrays, Plasmonic biosensor, Antireflective nanostructure

INTRODUCTION

Surface-enhanced Raman Spectroscopy (SERS) has been widely used to acquire vibrational spectra from adsorbents on metal surfaces. It has provided great opportunities to detect biomolecules with label-free, nondestructive, and highly sensitive methods. The design and fabrication of the nanostructures for advanced SERS bio-applications has been an emerging issue.

This work presents the glass nanopillar array based nanoplasmonic lab-on-a-chip for highly sensitive SERS. Recently, nanoplasmonic substrates have been widely studied and applied to biosensing applications [1]. The strong local electric field can be provided by nanoplasmonic substrate, which provides strong SERS. Furthermore, combining the plasmonic structures with mico/nanofluidic devices have become an emerging issue for advanced SERS bio-applications [2].

In this work, glass nanopillar arrays are served as both the nanoplasmonic and antireflective (AR) nanostructures. The glass nanopillar array demonstrated here can provide strong and patternable SERS-active nanostructures for nanoplasmonic lab-on-a-chip (Figure 1).

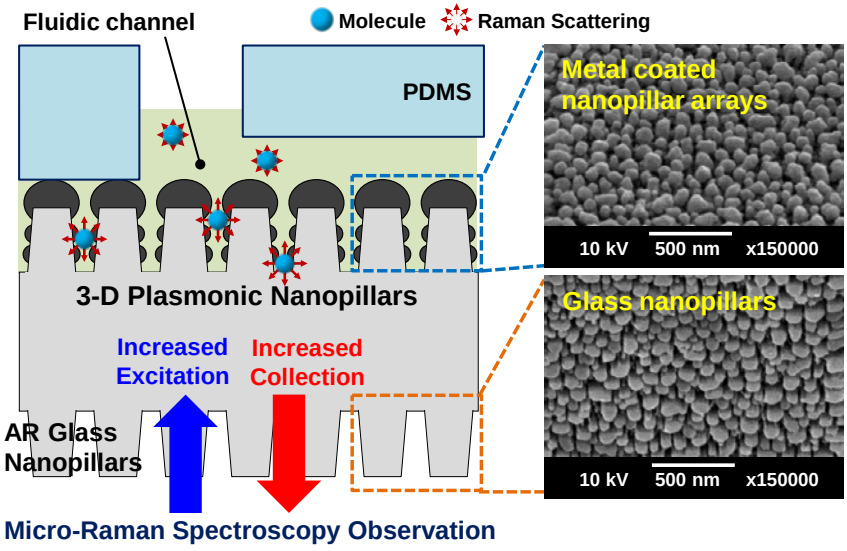

Figure 1. A schematic diagram of glass nanopillar array based nanoplasmonic lab-on-a-chip. The AR nanopillars increase the excitation power and SERS signal collecting efficiency for highly intense SERS. The PDMS layer can be easily incorporated to construct the fluidic channel.

EXPERIMENTAL

The glass nanopillar arrays are constructed by combining the thin metal film annealing and reactive ion etching (RIE) of the glass wafers (figure 2). The silver nanoisland arrays as the etch mask are formed by thermal evaporation onto glass wafer, followed by annealing at high temperature. Subsequent RIE step of the wafer manufactures the large-scale glass nanopillar arrays. By using the simple fabrication procedures, the glass nanopillars can be defined onto both sides of the substrate.

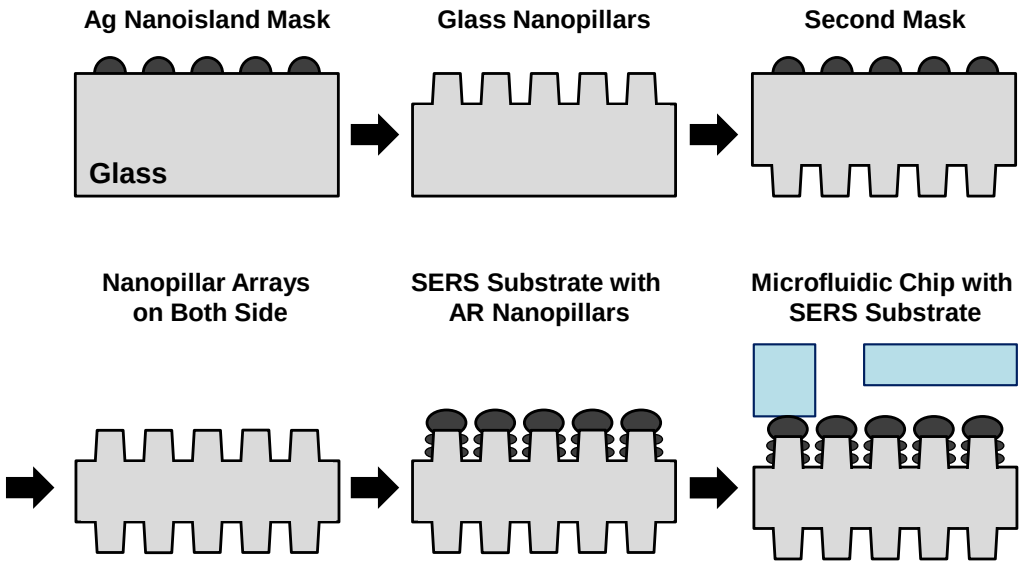

Figure 2. Nanofabrication procedures of the glass nanopillar array based nanoplasmonic lab-on-a-chip. The combination of metal dewetting and RIE process enables the fabrication of glass nanopillar arrays on both sides of the substrate. The glass nanopillar arrays on one side are covered with metal film by evaporation, and PDMS layer is covered to construct the microfluidic channel onto nanoplasmonic substrate.

The deposition of second metal layer onto glass nanopillar arrays defines the nanoplasmonic nanopillar arrays. The remaining one side works as the AR nanostructures for improving the SERS intensity, therefore provide more intense SERS. PDMS layer is covered onto the nanoplasmonic nanopillar arrays to construct the fluidic channel.

The laser excitation and collection of the SERS spectra from the nanoplasmonic lab-on-a-chip was done by an inverted micro spectroscope. The excitation laser wavelength was 632.8 nm, and the excitation power was 0.5 mW for benzenethiol monolayer, and 1.6 mW for crystal violet solution. The excitation laser power was controlled by neutral density filters. The signal integration time was 1 sec for benzenethiol, and 0.5 sec for crystal violet.

RESULTS AND DISCUSSION

The three-dimensional metal nanoislands are constructed onto the glass nanopillar arrays that provide multiple nanogaps for electromagnetic hot spots. The small nanogaps can provide highly enhanced local electric field, which serves as hot spots for SERS. The nanogaps can be controlled by metal deposition thickness to maximize the SERS intensity. The reduced nanogaps between silver nanoislands onto glass nanopillars provide SERS enhancement factor (EF) over 10^7 [3]. The high density hot spots and high EF over the plasmonic substrate is very promising for biosensing applications.

The AR nanostructures can increase the light-matter interactions [4], which can also enhance the SERS intensity from nanoplasmonic structures. Figure 3a shows the significantly enhanced SERS signal from the nanoplasmonic substrate with AR structure comprised of glass nanopillar arrays. The benzenethiol monolayers were used as reference target molecules.

The whole and patterned nanoplasmonic nanopillar arrays can be integrated with fluidic chip for constructing the nanoplasmonic lab-on-a-chip. Figure 3b shows the SERS measurement from microfluidic channel constructed onto the glass nanopillar based nanoplasmonic substrate. Target sample was the crystal violet 1 μM solution.

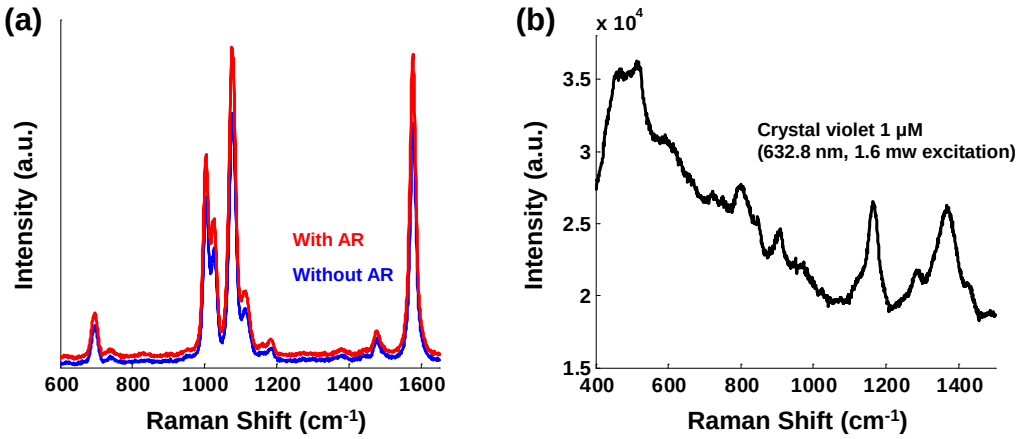

Figure 3. (a) The enhancement of SERS intensity from the nanoplasmonic nanopillar arrays with AR glass nanopillars. Target sample was the monolayer of benzenethiol. (b) SERS measurement of crystal violet (1 μM) from nanoplasmonic nanopillar arrays integrated with the microfluidic channel.

CONCLUSIONS

This work demonstrates the glass nanopillar array based nanoplasmonic lab-on-a-chip for highly sensitive SERS. The simple method demonstrated here can provide easy fabrication of glass nanopillar arrays at wafer level. The nanopillar arrays serves as the nanoplasmonic and AR nanostructures. Furthermore, the patternablity and tunability are also very useful for the plasmonic sensing of the biomolecules with integrated lab-on-a-chip. The nanoplasmonic lab-on-a-chip with highly sensitive nanoprobes and AR nanopillars will provide the advanced applications in biosensing, analytical and biomedical field in the future.

ACKNOWLEDGEMENTS

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