

Surface Enhanced Raman Spectroscopy

NIL Technology

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Technology Summary

Raman spectroscopy is the use of inelastic scattering of light to probe various properties of molecules and materials. Incoming photons interact with the electron cloud of the molecular bonds and inelastically scatter. During this scattering the energy of the incoming photon is shifted to red or blue depending on the particular process. This phenomenon is called Raman scattering and was discovered by C.V. Raman in 1928. By examining the photons energy shift in Raman spectroscopy one thereby probes the molecular bond properties of the material.



Figure 1: C. V. Raman the Indian physicist who discovered the Raman effect. For his work he received the Nobel Price in Physics in 1930.

From a practical point of view the main issue with Raman spectroscopy is that Raman scattering usually is very weak compared to other scattering mechanisms. In order to get detectable Raman scattering it is necessary to use an array of filtering techniques or to enhance the Raman scattering process. The latter of the two can be achieved using Surface

Enhanced Raman Spectroscopy (SERS). SERS is a surface effect and is obtained by patterning the substrate which enhances the Raman scattering, with the material that should be analyzed on it, significantly with up to 15 orders of magnitude.

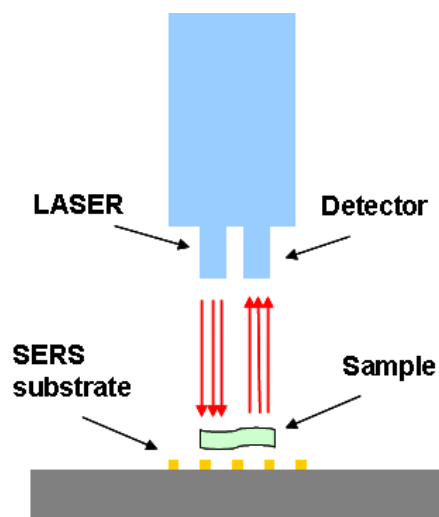


Figure 2: Schematic drawing of a typical SERS setup.

The exact mechanism behind SERS is not completely understood and is therefore still a subject of investigation and discussion. However, SERS is believed to be caused by interaction with surface plasmons. Surface plasmons are located in metals so the typical choice of surface is either silver or gold. For the scattering to occur the plasmon oscillations must be perpendicular to the surface. This implies that the surface must have a certain roughness, which can either be a physical roughness or made up by the use of nano particles. Such a surface can be used to enhance the Raman scattering from e.g. a single molecule laying on the surface. SERS is believed to play an important role in the future of health care and is thus a topic widely studied by universities and companies around the world.

SERS using Nano Imprint Lithography

If a SERS substrate is to be fabricated one can use self assembling nano particles, of gold or silver, to create a surface with metal roughness. However, the self assembling method creates substrates with random particle distributions and therefore random SERS efficiency. In order to create substrates with ordered nano particles, lithography must be used. Since the roughness should be on the nano scale, the individual metal particles should be nano sized. If these particles are to be made by lithography one must use lithography methods capable of producing nano sized patterns, e.g. e-beam lithography or nano imprint lithography (NIL). E-beam lithography combines small feature size with precise line width and pitch, but since it is a serial process the process of creating large patterned areas is both costly and time consuming. This can be countered by the use of nano imprint lithography to define the nano patterns. In NIL the slow and costly process of writing the nano structures with e-beam is only done once in order to define a stamp. This stamp can then be used repeatedly to imprint the nanostructures into a polymer and in this way turning the fabrication of the SERS substrates into a parallel process capable of volume production. Using metal deposition and lift-off the metal nano patterns can be realized on the surface of the substrate, which can be seen, from the schematic process outline, in fig. 3.

The NIL process shown in fig. 3, describes a typical flow for fabricating SERS substrates. First a stamp is fabricated using e-beam and dry etching. This stamp is used repeatedly to imprint into substrates coated with imprint resist. The imprinted substrates are processed further by first removing the residual layer of resist in the bottom of the imprinted holes. This can be done by using oxygen plasma. The desired metal is then evaporated onto the substrates, which are finished by lift-off, where the resist and the metal on the resist are removed, leaving behind the desired metal pattern on the substrate. In this way NIL can be used to produce a large number of SERS substrates, significantly cheaper and faster than with e-beam lithography, but with the same quality and nano scale feature size.

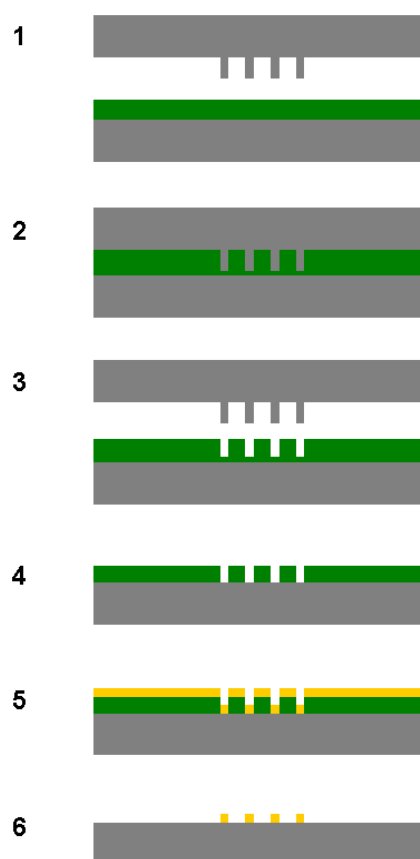


Figure 3: Fabrication of SERS substrates using NIL. 1) A stamp with the desired nano pattern is fabricated and an imprint polymer is spin coated onto a substrate. 2) The stamp is imprinted into the polymer. 3) The stamp is released from the polymer and a reverse pattern of the stamp is achieved in the polymer. 4) The residual layer of polymer, in the bottom of the imprinted holes, is removed by anisotropic oxygen plasma. 5) The SERS metal, e.g. gold, is evaporated onto the substrate. 6) Lift-off is finally used to remove the polymer thereby defining the metal nano pattern.

SERS substrates fabricated by NIL Technology

NIL Technology has fabricated SERS substrates for customers, with many different designs. Most of these have consisted of ordered arrays of metal dots, fabricated by the described lift-off process. When using lift-off to define the metal patterns, a wide selection of metals can be used. Gold, silver, platinum, copper, and aluminium are all widely used as metals for SERS experiments. These and many other metals can be evaporated at NIL

Technology's process facilities. Normally a thin layer of titanium or chromium is first evaporated onto the substrate as a barrier metal. The following figures show SEM images of different SERS metal patterns, which were fabricated by NIL Technology. Fig. 4 and 5 show a simple square array of gold metal dots. In order to test the influence of the metal dot distribution on the stamp, substrates with denser packed metal dots were also fabricated. These can be seen in fig. 6 and 7. In all cases the metal dots are 100 nm in diameter, but using NIL one can achieve even smaller sizes, only limited by the feature size on the stamp. In this way one could make metal dots that would only be a few nanometres in size.

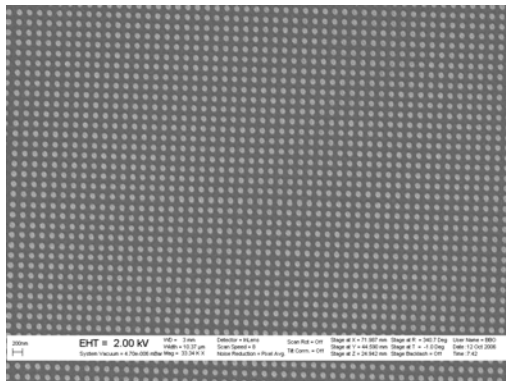


Figure 4: Square array of 100 nm round gold dots, with a pitch of 200 nm.

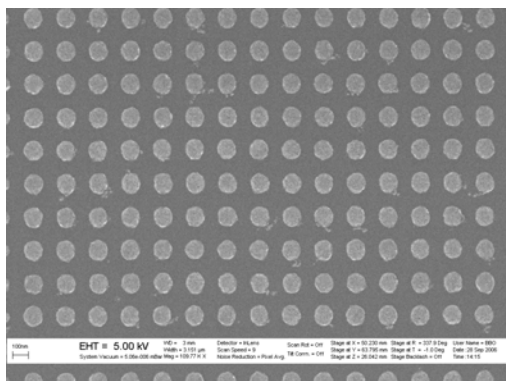


Figure 5: The square area dots at higher magnification.

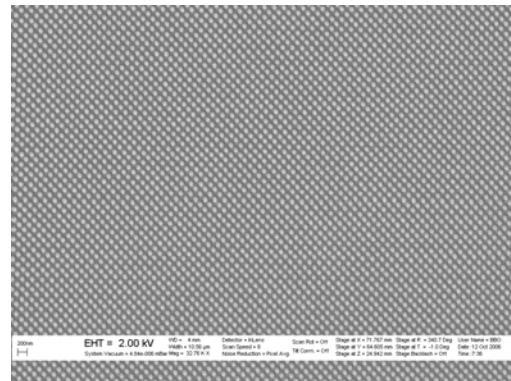


Figure 6: SEM image showing a different design where a metal dot has been placed at the centre of each of the squares in the square array (fig. 4 and 5), in order to increase the density of the dots.

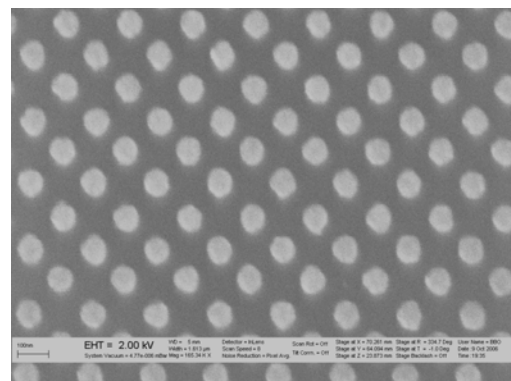


Figure 7: The denser metal dots at higher magnification.