L.1: Development of a cost effective maskless photolithography system

Photolithography is an essential technique for the fabrication of all modern semiconductor devices. Photolithography transfers micro patterns on a substrate, and the particular step in fabrication process determines the functionality of the devices. Wide range of applications are associated with micro-patterning photolithography. Mask-based ultra-violet photolitho-graphy technique is capable of producing micro-patterns with very high throughput. In spite of the fact that mask-based photolithography systems are most suitable for industrial applications, cost associated in designing, fabricating, and maintaining a photo-mask and time delay in fabrication of a photo-mask are some of the serious disadvantages in mask-based systems. Thus, the difficulty, time and cost associated with designing and fabrication of a mask lead to conservative thinking, and stifles innovation. Therefore, a maskless optical lithography, offers a way out of these difficulties. In view of this, a simple low-cost (within ₹ 2 lakhs) maskless photolithography system is developed at Semiconductor Materials Laboratory (SML), RRCAT.

A simple way to avoid photo-mask is to project patterned light directly onto the substrate, which can be achieved by focusing the output light of a projector on the surface of a substrate. A projector with resolution 1920×1080, 3500 Lumens brightness and 1:13000 contrast ratio, is focused via an optical microscope over the area 8×6 mm^2. Therefore, a minimum pixel size in the exposure plane can be achieved upto 5.5 µm. Highly divergent light from the projector head is focused to the trinocular head of a stereo-microscope via suitable lens arrangements (Figure L.1.1(a), (b)). Objective lens of the microscope further focusses the incident light to a smaller dimension. Samples coated with photoresist are kept on x-y-z controlled stage, and the eye piece of the microscope is used to ensure focusing and alignment of incident light on the surface of the sample. After initial alignment via red patterned lights, same patterns with white light is used to expose photoresist. Magnification of the microscope was kept around 2.5X, which focuses the projector light over an exposure area of the sample. In order to achieve proper development of photoresist patterns, intensity of the projector and exposure time is optimized via several attempts. Shipley S1813 photoresist is coated on GaAs substrates using spin coater with 3500 rpm for 1 min. After the soft bake at 95 °C, substrates were exposed for 2 s and subsequently developed for 1 min in the developer MFCD26. So far, a minimum feature size obtained via the indigenously developed maskless photolithography system is 20 µm (Figure L.1.1(c)). It is to be noted that typical exposure area and the minimum feature size can be largely controlled by choosing a different magnification of the microscope with high resolution projector. The new experimental assembly is found to be beneficial for developing lasers, photo-detectors and also complex patterns for electronic transport measurements (e.g. Hall bar, Corbino disc geometry etc. Figure L.1.1(c-f) shows the photograph of laser diode, photodetector and Hall bar samples, which are patterned via maskless photolithography system (Figure L.1.1(d-f)). Using this system, geometrical size or shape dependent parameters of the devices are obtained. Also, classical and quantum Hall effect measurements are performed on the Hall bar patterned two-dimensional electron gas (2DEG) hetero-structure. Modulation behavior in the longitudinal and transverse resistivity (R_{xx} and R_{xy}) with magnetic field is clearly observed in the above patterned Hall bar 2DEG structures. Also Inverse spin Hall effect signal is measured in the patterned sample, which are fabricated by the above system. Now the maskless system is routinely used at SML. This low-cost, flexible, high quality maskless patterning system is very useful for a wide variety of applications in the field of micro-technology.

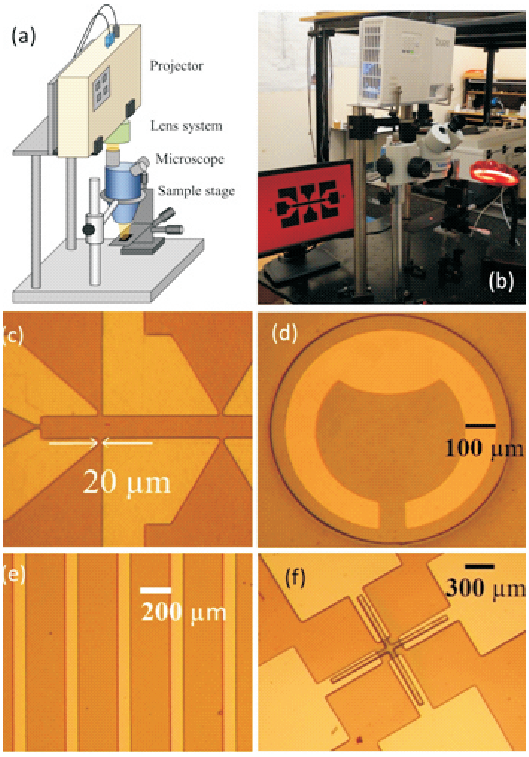

Fig. L.1.1: (a) Schematic and (b) photograph of experimental arrangement for maskless photolithography system. Photograph of (c) Hall bar of 2DEG sample, (d) detector structure, (e) laser diode arrays and (f) inverse spin Hall effect sample are shown, which are fabricated by the above system.

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