Nanolithography for metallic quasi crystals for nanobio applications

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There is currently an urgent need to develop micro and nanotechnique for the fabrications of quasi periodic crystals in a plane for the study and applications of novel optical properties when light propagating in or through such a photonic structures with fold symmetries (10 fold symmetry in this work). It has been clear that quasi periodical crystals in dielectrics with various fold symmetries also exhibits complete photonic band gap (PBG) property as periodical photonic crystals do. However, the novel physical properties related to the interactions of electromagnetic waves with metallic holes arrays in quasi periodical order (metallic quasi crystals) is being discovered both theoretically and experimentally, which demands technical development for the construction of theoretically designed structures. [1] In this work, we report a nanofabrication technique recently developed for the replication of quasi crystal in 100 nm Al on a slab (quartz wafer in this work) by electron beam lithography using chemically amplified resist, UVN-30. A wealth of novel photonic behaviours of lights vertically incident through the q-crystal were observed.

The metallic quasi crystal features aperiodical array of nanosize holes with 10-fold symmetry in metals such as Al and gold (figure 1). This work involves high resolution electron beam lithography on the negative tone CAR resist, UVN-30. The effects of developing condition including both a hot developing process and ultrasonic agitation were studied to improve the profile of the patterned UVN-30 resist (figure 1(c)). The lithography property of UVN-30 was compared to non CAR negative tone resist such as HSQ by Dow Corning Ltd. UVN-30 pattern with high aspect ratio was achieved with high resolution. By successful metalisation and lift-off processes, metallic quasi crystals on quartz with transmission mode were fabricated. The high precision positioning capability of the beam writer used, VB6HR from Vistech Lithography Ltd successfully ensured the high quality lattice, which is essential for the observation of novel nanophotonic behaviours. Extraordinary discoveries (figure 2 and figure 3) have been made out of such kind of metallic quasi crystals such as the first observation of Montgomery Effect (self imagining of quasi crystal array of holes), sub-wavelength focusing by the nano-hole array [2] and invisible metal due to 100% transmission of light without phase change[3], etc.

By summary, we have developed a nanolithography process which is promising for the fabrication of nanophotonic quasi crystal in metals such Al and Au, etc. The hole size from 200 nm down to 50 nm has been achieved, which reached the resolution limit of the UVN-30 resist used. The fabricated optical devices have enabled scientists to make extraordinary discoveries, which will surely lead to broad applications in multidisciplinary areas such as nanobio sensors, photo detectors with high quantum efficiency and light transmission enhancers and filters.

References

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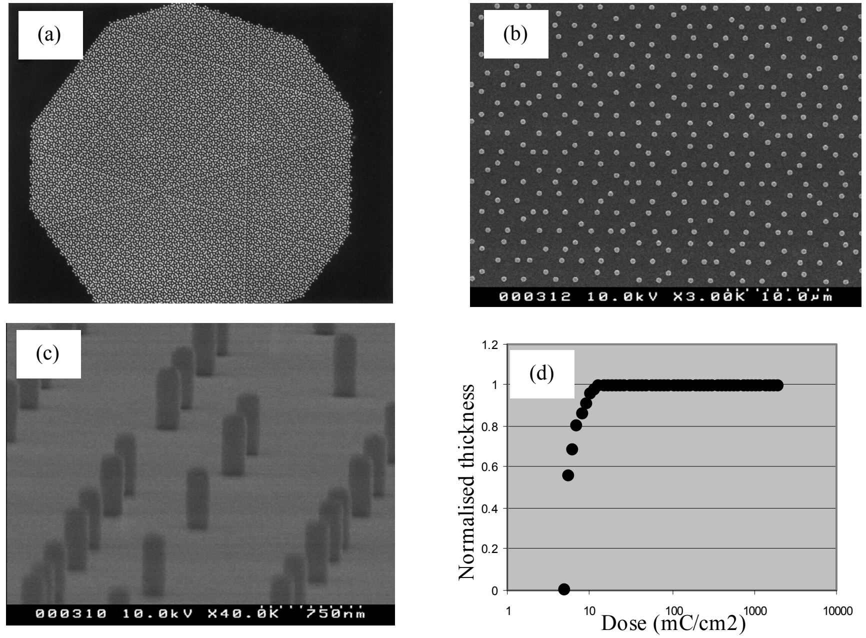

Figure 1. The 10-fold symmetric quasi periodical crystals in 100 nm Al. (a-b) The fabricated crystal with holes of 200 nm. (c) The resist pillars of UVN-30 resist on quartz. (d) The contrast curve of UVN-30.

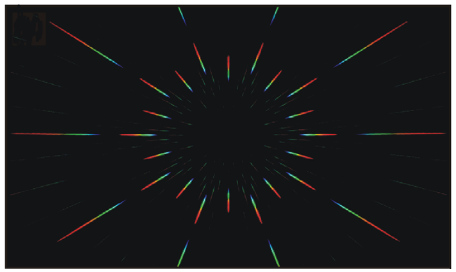

Figure 2. The diffraction pattern of light (600 nm) through the quasi crystal.

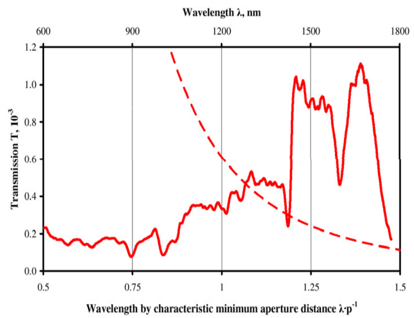

Figure 3. Optical transmission (solid line) considerably exceeds the Bethe-Bouwkamp theoretical value (dashed line) for non-interacting subwavelength holes.