A.9: Enhancement in the diffraction efficiency of gratings using LSPR

Diffraction grating is an important optical component which has wide application in the area of optical science. Gratings are classified based on their shape (plane, concave, and convex), mechanism of action (absorption, phase, and mixed) and the mode of use (transmission and reflection). If the period of a grating is very large compared to its thickness and the readout wavelength, then it is considered as a thin grating. The diffraction efficiency (DE) is lower (~4.8% and ~6.25% for thin sinusoidal absorption and transmittance gratings respectively), which can be enhanced by using a suitable methodology. The localized surface plasmon resonance (LSPR) excitation in metal nanoparticles, which is the collective oscillations of conduction band electrons in the metal, enhances light absorption and scattering. LSPR has been found useful in the enhancement of DE. The modulation in the absorption coefficient in the grating is incorporated either by the periodic arrangement of plasmonic nanoparticles or by the periodic variation of the contact medium refractive index over the uniformly distributed plasmonic nanoparticles. The DE and its bandwidth in thin plasmonic nanoparticle transmission gratings (PNG) depend mainly on the extent of spatial modulation of the refractive index (n) and the absorption coefficient (α). This report is on the large area silver nanoparticle surface relief gratings (SRG) of ~10 µm period fabricated at ISUD, RRCAT using electron beam lithography (EBL) on a silver halide based film substrate, using SEM.

About 4 mm diameter area on the substrate was exposed to the electron beam 20X magnification. The total exposure time to expose 4 mm diameter was ~116 s. Morphological characterization shows that the period, shape and the relief depth in the grating are mainly dependent on the electron beam energy used for the fabrication for the grating. Fig. A.9.1 shows the AFM image of a fabricated grating with 15 keV electron beam. The periodicity of the gratings is ~10 µm. The depth of the gratings fabricated with electron beam of energy 10 keV, 15 keV and 30 keV was measured to be ~400, ~350 and ~300 nm, and the full width at half maxima (FWHM) was measured to be ~6.12, ~3.42 and ~3.7 µm, respectively.

Figure A.9.2 shows the experimentally measured first order DE profiles of the silver nanoparticle grating prepared by 10 keV electron beam. This grating shows a broad DE profile in the wavelength ranges from 450 nm to 800 nm with a peak DE ~4.6%. However, the grating fabricated with 30 keV electron beam gave much less DE (~2.8%) at 800 nm than those fabricated at lower electron beam energy of 10 keV (~4.6%) and 15 keV (~7.2%). The DE profiles of the gratings also got red shifted (see Fig.A.9.2) as observed in the absorption spectra of the gratings. This indicates the important role of LSPR in the enhancement of DE as well as in deciding the location of the DE profile. In conclusion, grating fabricated using 15 keV electron beam shows LSPR enhanced maximum DE of the grating.

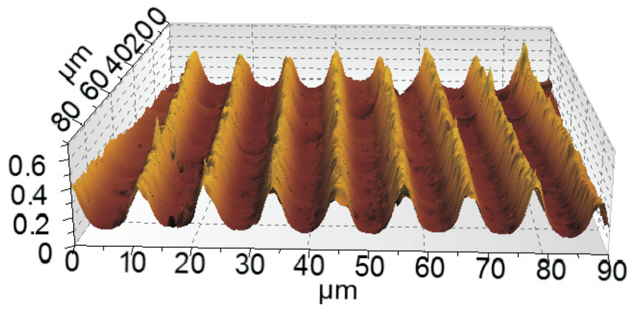

Fig. A.9.1: AFM image of a fabricated grating with 15 keV electron beam.

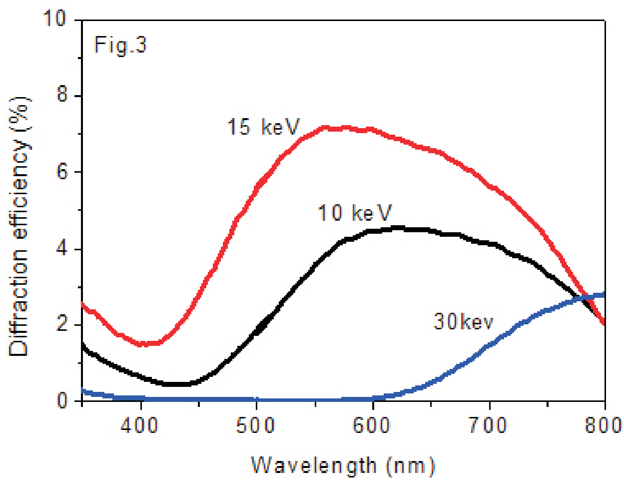

Fig. A.9.2: Diffraction efficiencies of gratings fabricated with 10, 15 and 30 keV electron beam

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