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Examination Micro- and Nano-Technology

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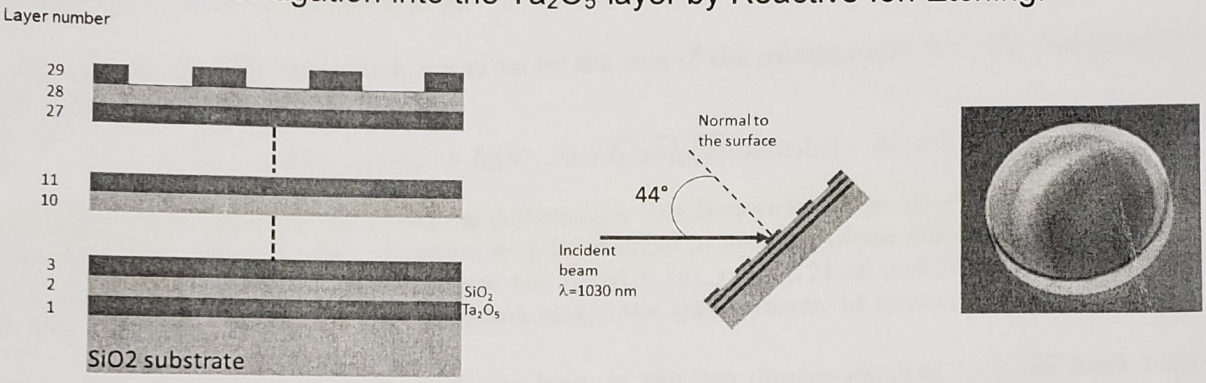
Diffraction gratings are optical components which have various applications. Here we will study a specific case: the fabrication of a multilayer grating for ultra-short pulse compression.

The grating to be fabricated should be made on a 25 mm diameter SiO_2 substrate on a multi-layer stack (29 layers of alternating Ta_2O_5 [h=126nm, n=2.15] and SiO_2 [h=192nm, n=1.51]), the corrugation is in the final Ta_2O_5-layer on top of the last SiO_2 layer [see figure]. The method used to write the grating is: transfers the periodic pattern into a 1µm thick positive photoresist layer by two beam interference lithography (by means of a He-Cd laser emitting at the wavelength of λ=442nm) and then transfer the corrugation into the Ta_2O_5-layer by Reactive Ion Etching.



Left: Schematic sketch of the multilayer grating. Middle: Operation mode of the final component. Right: Picture of the final component. (Ref.: Rumpel et al. "Broadband pulse compression gratings with measured 99.7% diffraction efficiency," Opt. Lett. 39 (2014)).

Questions:

1) The grating has a line density of 1250 lines/mm, what is its period in nm?
2) At a wavelength of 1030nm, and an incidence angle of 44°, what is the angle of diffraction of the -1st order in reflection in air?
3) Describe in few sentences and a sketch the principle of the two-beam interference lithography.
4) According to the wavelength of the laser and the period of the grating to write, what is the value of the angle between the beams for the lithographic step?
5) Starting from a SiO_2 substrate, make a flow chart describing all the steps to fabricate the final component (coating, lithography, development, and etching). Describe only the coating of the 2 first layers and of the last 2 of the stack.
6) Cite some coating techniques for the deposition of Ta_2O_5 and SiO_2 (coating of dielectric materials in general).
7) Which technique should be used for the coating of the photoresist? Justify your choice with a few words!
8) The duty cycle of the grating is 25%, what is the width in nm of the Ta_2O_5 lines? How can the duty cycle be controlled during the two-beam interference lithography step (which parameters can be adjusted)?
9) Which characterization techniques can be used to measure the profile (thickness and duty cycle) of the fabricated grating? Justify your choice with a few words.
10) Assume that a series of 100 gratings has to be fabricated. Explain with a few sentences an alternative lithographic method to produce the resist mask of the grating!
11) Bonus: What is the purpose of the multi-layer stack under the grating?