MICROLINEAR OPTICAL ENCODERS MANUFACTURED BY IMPRINT LITHOGRAPHY

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Optical encoders have been used for decades as displacement measuring devices. In simple terms, an encoder consists of a scale and a scanning device that reads off the scale. Optical encoder scales are rigidly attached to a metrology frame and consist of grating or grid plates, and the read head which senses displacement relative to the grating scale (see Fig. 1a). Highest resolution (a small fraction of the grating period) is achieved with a variety of diffraction based schemes [1,2]. The main advantages of optical encoders are the short and constant beam path lengths between gratings and sensors, reducing the effects of the atmosphere by orders of magnitude compared to laser interferometers. However, the main problem with encoders today is that commercially available encoder plates are limited in accuracy to worse than 100 nm. Since the encoder can only be as accurate as the grating scale, advance in this area crucially depends on the availability of encoder plates with sub-nanometer accuracy over macroscopic distances.

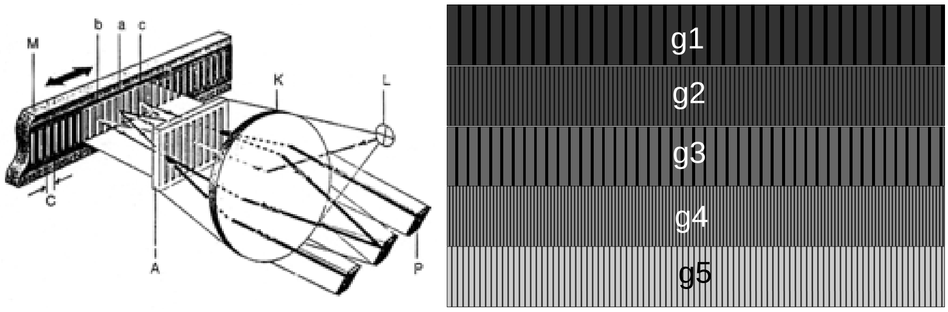
Grating scales are typically manufactured in two ways. They are either mechanically ruled with a diamond tip, which is a very low, expensive, and difficult to control process, especially for large gratings with fine periods, or the grating pattern is defined lithographically, typically by interference lithography or electron beam lithography. Interference lithography is fast, but prone to hyperbolic distortions [3], while electron beam lithography patterns suffer from stitching errors and take considerable time to write.

We propose to produce linear and angular encoders by Nanoimprint Lithography (NIL) looking for better resolution and/or accuracy. The possibility of producing linear encoders by NIL gives the technology needed to mass-produced encoders with very high resolution, and provided the process is accurate enough, high accuracy encoders may be manufactured in a low cost. This work is focused on the manufacturing of a linear optical microencoder by NIL (scale and read head) and it is understood as a former step to manufacture these components in the nanoscale range. We have designed five different linear encoders, as they are shown on figure 1b, each one of them with pitch among 3.3 and 11.3 micrometers. The length of each encoder is 20 millimetres and each line is 4 millimetres in length. The read head has been manufactured on pyrex as it works by transmission and the phase scale has been made on silicon on account of it works by reflection.

The stamps were manufactured by UV-Lithography and a RIE process in an atmosphere of SF_6/O_2 (see figure 2). An antiadhesive coating was given by evaporation of tridecafluoro-(1,1,2,2)-tetraydrroctyl-trichlorosilane (F13-TCS) under a weak vacuum. The imprinting process was optimized for both substracts –pyrex and silicon- coated with a monolayer of mr-I7030 thermoplastic or a bilayer of mr-IPMMA and mr-I7030. Pattern transfer was developed by a RIE process in oxygen and studied the etch rate for each substract by AFM measurements. A further step process was developed by making a *lift-off* with chromium on pyrex and a RIE process on silicon so as to define the transmission grating read head and the phase scale respectively (see figure 3). Finally, the phase scale was coated with a thin layer of aluminium by sputtering so that obtain higher reflectivity.

[1] Y. Jourlin, Y. Jay, O. Perriaux. Prec. Eng. **26**, 1 (2002)
[2] Original title: Digitale Langen –und Winkelmeβtechnik. Dr. Johannes Heidenhain GmbH, Traunreut. Printing and Binding: Ludwig Auer, Donauworth. Third Edition, 1998.
[3] J. Ferrera, M.L. Schattenburg, H. Smith. J. Vac. Sci. Technol. B. **14**, 4009 (1996).

Microlinear optical encoders manufactured by imprint lithography



a) **b)**

Figure 1. a)Classical_interferencial measuring principle. M=scale with phase grating, C=grating period, A=read head, L=semiconductor light source, K=condenser lens, P=photodiodes. a, b and c light beams that leave the scanning reticle in the 0, 1 and -1 orders of diffraction to strike the scale.
b) Different grating periods manufactured for the linear encoders studied. g1= 88 lines /mm, g2=100 lines/mm, g3=150 lines/mm, g4=191 lines/mm and g5=296 lines/mm.

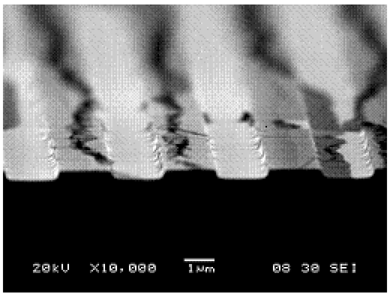


Figure 2. Silicon stamp manufactured on silicon by UV-Lithography and a RIE process with SF_6/O_2

a) **b)**

c) **d)**

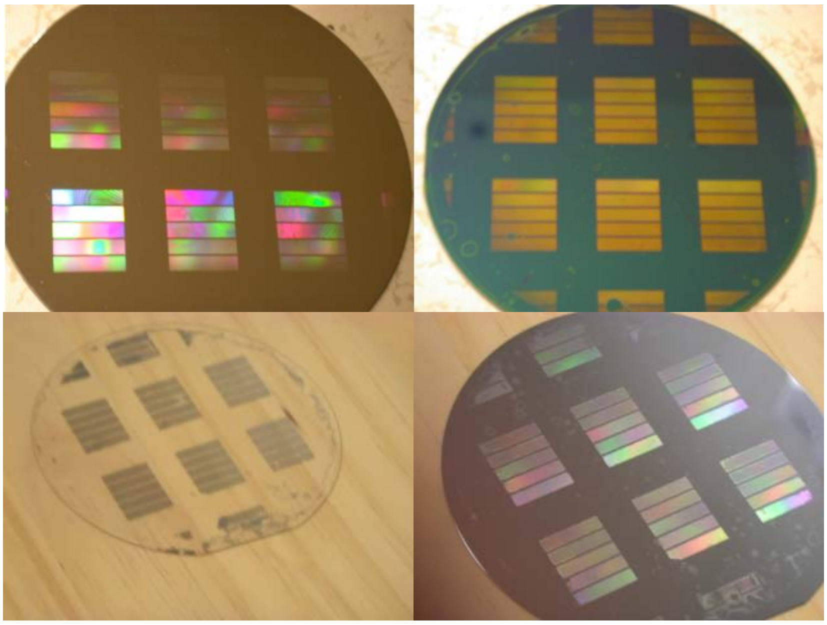


Figure 3. a) Silicon stamp with an antiadhesive treatment ready to imprint. b) silicon substract just after imprinting. c) Pyrex wafer after post-processing (residual layer etching and lift-off with chromium. The microencoder read head. d) Silicon wafer after post-processing (residual layer etching and silicon etching (depth=220 nm) using the thermoplastic as a mask. The microencoder phase scale.

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