Materials selection for high efficient DOE with strong curvature

M. Jagodzinski[1], S. Kühne[1], M. Malcher[1], D. Oberschmidt[1]

[1] Technische Universität Berlin, Germany, Institute for Machine Tools and Factory Management IWF, Department Micro- and Precision Devices

jagodzinski@mfg.tu-berlin.de

Abstract

Diffractive optical elements (DOE) are used in various production numbers and applications , e.g. single pieces in aerospace applications or large quantities in mass market applications as handheld spectrometers. The selection of a material depends on the designated application and production quantities. A detailed comparison of suitable materials is presented in this paper.

Primary, the achievable surface roughness and detail of microstrucure geometry are crucial criteria for DOE materials, wich is why finegrained or amorphous materials are preferred. The secondary criterion is a high coefficient of reflection.

DOE production can be conducted by lithographic or mechanical means. In terms of mechanical production, the demands in groove precision necessitate ultra precision machining. Electroless NiP enables the manufacture of surfaces with high hardness and therefore replication via hot-embossing or injection moulding. For IR applications Au offers high coefficient of reflection as well as corrosion resistance, whereas in VIS range Al is the material of choice. Fine grained RSA-aluminum types are widely used for production of continuous optics with curved tool geometries.

However, cutting with rectangular shaped tools causes surface damages in multiple RSA types that are designated for optical purposes. In order to achieve a quantitative comparison for various RSA-materials, cutting experiments have been conducted on a strongly modified 5-axis ultra-precision machining center LT Ultra MMC1100. In order to fine tune the process parameters and minimize the amount of surface defects, the produced diffractive geometries have been analysed via gray-scale-analysis of microscopic images. The diffraction efficiences were measured with a specially developed laser setup.

All proposed suitable materials have been processed to manufacture prototypes and replicates with curvatures of 20 mm, radii of 8 mm, and groove periodicities from 3 µm to 6.8 µm. Diffraction efficiencies of 94.5 % of the theoretical limit and roughness values R_q = 1.5 nm have been measured, which enables the production of highly reflective diffractive optical elements.

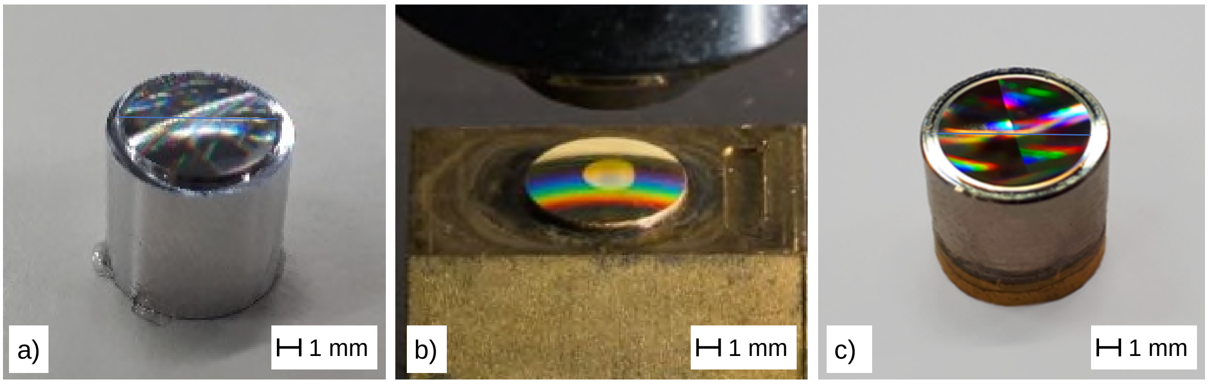

Figure 1: Spherical DOE, manufactured in various materials
a): RSA 501, b): Au, c): NiP