Micromachining of sinusoidal microstructure surface in monocrystalline InSb

M. H. M. Dib, M.A.P. da Silva, R.G. Jasinevicius
1.Departamento de Eng. Mecânica, EESC, USP, São Paulo, Brazil.
2. Inst. de Física de São Carlos, USP, São Carlos, SP, Brazil
renatogj@sc.usp.br

Abstract.

In the present paper, a half radius negative rake (-25°) single point diamond tool was used to cut sinusoidal microstructured surface in single crystal indium antimonide. The sinusoidal microstructure generated presented constant amplitudes of 30 micrometer and different spatial wavelengths ranging from 1 mm up to 4 mm. The cutting tests were performed on a 2-axis ultraprecision lathe. Machining took place in a ductile mode an the surface roughness of the machined sample was in the range of 39 nm Ra.

1 Introduction

The application of elements with microstructured surfaces may find a wide range of applications in different fields of industry such as optical, electronic and mechanical [1]. The machining of microstructures was always thought as a challenge to be applied to normally brittle materials to generate diffractive optical elements. The machining of brittle materials presents two major challenges: cutting the material in the ductile mode and mitigate the rapid and deleterious wear caused to the diamond tool. Regarding the first point, it has been shown that the application of single point diamond turning to cut soft semiconductors crystals has been well succeeded once critical conditions are respected [2]. Moreover, with respect to tool wear when machining II-VI semiconductors crystals recent results reported the absence of wear based upon machining tests [3].

2 Experimental Procedure

Single crystal Indium Antimonide (100) was single point diamond turned in a face operation (Fig. 1) to produce an array sinusoidal microstructure with constant amplitude and different wavelengths. The tests were performed with ALKALISOL

900 (~100ml/h) on a high stiffness machine (ASG 2500 from Rank Pneumo®). The cutting conditions used to cut each of the sinusoidal path were in the range that ductile mode is achieved (f = 1 µm/rev ap = 5 µm). The diamond tool used to machine the crystal sample has a special geometry with "half radius" made by Contour Fine Tooling (UK) and Radius= 0.025 mm, Rake = -25°, Clearance = 10° degrees primary, Included Angle = 30°, Waviness <0.25um over 55° excluding elliptical form. The array of sinusoidal structures was characterized with optical profiler and Scanning Electron Microscopy (SEM). The form and the surface roughness were assessed by means of an optical profiler.

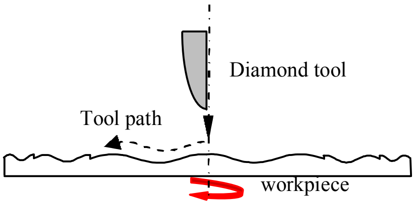


Fig.1. Schematic diagram of the machining strategy used to cut the sinusoidal structures.

3 Results

Figure 2 shows the Veeco NT1100 measurements results of the surfaces machined with different wavelengths. Figure 3 presents a 3D image of the machined surface finish. The surface roughness values of the different machined sinusoidal wavelengths varied according to the tool path orientation and were in the range of 23 up to 38 nm Ra. These values may be considered high for an optical surface. It has to be regarded that the tool used to cut this features is a half radius tool which leaves a characteristic mark on the surface finish. This can be better understood by the AFM image shown in Fig. 4. Fig. 4 also shows a tool path model where no compensation of tool geometry is applied during machining of the sinusoidal profile. When the tool is downward there is a slight difference in surface roughness when compared to the upward path. When the tool cut with the round part (upward), the surface finish was always smoother. The difference between the upward and downward surface generation is more evident for the 1 mm wavelength which presents steeper slope. The half radius may not be appropriated to machine such surface. A radius tool with very small radius and appropriated included angle should generate a better surface finish. This will be considered for sinusoidal profiles with amplitude and wavelengths in the micrometer range which will be subject of future work.

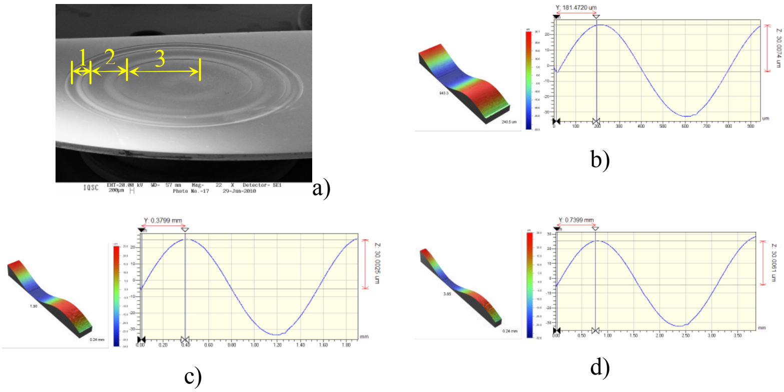
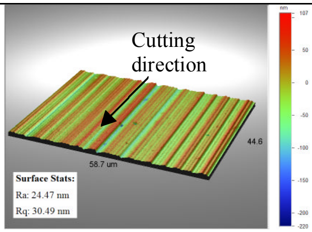


Fig. 2. Surface Form evaluation of the machined sinusoidal structures; a) SEM image of the machined sample showing 3 sinusoidal wavelengths; b) 3D image and cross section profile of the 1 mm sinusoidal wavelength; c) 3D image and cross section profile of the 2 mm sinusoidal wavelength; d) 3D image and cross section profile of the 4 mm sinusoidal wavelength.



Surface Roughness of each sinusoidal wavelength			
SIN	1	2	3
Ra (nm) Up	37,72	33,78	26,95
Ra (nm) Down	78,6	29,20	23,45

Figure 3. Three dimensional image of the surface finish of the sinusoidal structure.

SEM assessment of the machined sample showed that, under the cutting condition applied to cut the sinusoidal features, no significant damage due to brittle material removal was detected. The cutting tool was also examined by SEM and no sign of wear was detected after machining. No wear would be expected once InSb crystal does not contain unpaired d-electrons.

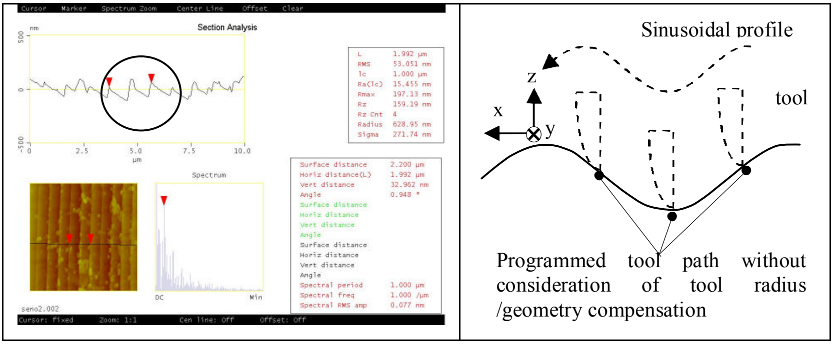


Figure 4. AFM image of the cross section of the machined sample showing cutting tool tip mark generated during machining. Tool path model without considering tool radius/geometry compensation. The half radius may not be appropriated to machine such surface.

4. Conclusions

Experiments of machining sinusoidal structures with 30 micrometers amplitude and different wavelengths on II-VI semiconductor crystal have been carried out. The surface form and surface finish has been measured using optical profiler in order to evaluate the material's ductile response to single point tool. The values of surface roughness were in the range of 30 nm Ra. The results showed that despite ductile mode was achieved with half radius tool, the roughness presented a slight difference when measure according to the tool path orientation, i.e., upward and downward.

Acknowledgements

This work was supported by the Brazilian research financing agencies FAPESP (08/53641-5) and CNPq.

References

[1] Zhang, H., Zhoun, M., Key Engg. Mat. Vols. 431-432, pp.94-97.
[2] Jasinevicius, R.G.. Proc. of the 6 th euspen, Glasgow, Scotland, 2004, p.171.
[3] Jasinevicius R.G. et al. Proc.of the 11th euspen, Como, Italy 2011, p.421.