AN EXPERIMENTAL INVESTIGATION ON PARTIAL-DUCTILE MODE GRINDING OF SILICON

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IN THE NAME OF ALLAH, THE GRCIOUS, THE MERCIFUL

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ABSTRAK

Tumpuan utama penyelidikan ini adalah untuk mencanai mod mulur secara persis (menggerek) ke atas permukaan rata silicon, terutamanya ke atas cip silikon tersepadu (I.C.), yang mana ketebalannya kira-kira 700 µm dan permukaan atasnya diselaputi dengan satu lapisan silikon nitrida. Penghasilan jumlah yang besar jalur separa mulur di atas permukaan silikon setelah pemesinan dapat mengurangkan masa penggilapan secara mendadak. Ini sangat penting terutama sekali dalam pembuatan cip dan industri optik bagi analisis kegagalan. Analisis kegagalan adalah satu teknik yang biasanya dilakukan untuk mencari sebarang kegagalan dalam produk siap I.C. Dalam industri pembuatan cip, analisis di lakukan ke atas I.C. dan silicon yang telah siap tanpa kecacatan dan permukaannya adalah seperti cermin. Pencanaian, pempelasan dan/atau operasi penggilapan diperlukan untuk mendapatkan permukaan yang licin. Pencanaian persis dalam keadaan mod mulur menjadi kritikal dan merupakan operasi pemesinan terpenting kerana kerosakan pada atas dan di bawah permukaan akan dikurangkan. Ini menghasilkan kualiti permukaan yang baik dari segi kemasan permukaan dan kerataan dan pada masa yang sama dapat menjana jumlah jalur mulur yang maksimum ke atas permukaan yang dimesin. Disebabkan bilangan cip I.C. yang terhad, bahan silikon selain daripada silikon I.C. telah juga di uji bagi tujuan perbandingan. Silikon seperti bahan keras dan rapuh yang lain sangat dikenali mempunyai kebolehmesinan yang rendah melainkan ia dimesin dalam keadaan mod mulur. Pemesinan mod mulur adalah proses yang membuatkan bahan rapuh berkelakuan seperti bahan mulur. Teknik pemesinan kos rendah telah dihasilkan untuk membantu pencanaian kawasan kecil secara mod mulur separa ke atas silikon nipis seperti wafer. Mesin penggerek menegak CNC MAHO telah diubahsuai secara khusus dengan dilengkapi alat tambahan peningkat kelajuan berkuasa rendah. Pusingan spindal bagi alat tambalan ini digerakkan dengan angin mampat untuk melakukan proses pencanian intan. Lekapan khusus telah direkabentuk dan dipasang untuk memegang benda kerja serta mencegah mereka dari berlakunya keretakan semasa pemesinan.Kedua-dua teknik tradisional dan statistikal telah digunakan dalam merekabentuk ujikaji dan seterusnya menganalisis keputusan dalam penyelidikan ini. Alat dinamometer *Kistler* (Compacdyn) yang mampu mengukur daya pemesinan yang rendah telah digunakan untuk mengukur daya semasa pemesinan. Form Talysurf, Surfcom, mikroskop berdaya atom telah digunakan untuk mengukur parameter tekstur permukaan. Teknik mikroscop optik dan imbasan elektron digunakan bersama dengan alat penganalisa permukaan Surfcom dan mikroskop berdaya atom untuk menganalisa morfologi permukaan silikon yang di mesin. Hasil kajian mendapati bahawa jumlah jalur mulur tidak sahaja bergantung kepada uluran dan kedalaman potongan tetapi ia juga bergantung kepada saiz grit intan dan kepadatannya. Teknik pemesinan pencanaian telah menghasilkan kemasan permukaan canaian serendah 50nm dan daya pemesinan sekitar 0.8 Newton. Kerataan permukaan yang dimesin adalah sangat baik. Satu model kekasaran permukaan (R_a) bagi pencanaian persis silikon nipis telah dihasilkan.

ABSTRACT

This research work was primarily concentrated on precise ductile-mode grinding (milling) of flat surfaces of silicon, mainly Integrated Circuit (IC) silicon chips (dies), which were about 700 μm thick and the top of their surfaces covered with a silicon nitride layer. Substantial amount of partial-ductile streaks on a machined silicon surface shortens polishing time dramatically. This is of vital importance particularly in chip-making and optical industries for failure analysis. Failure analysis is a technique usually practised for locating a fault in a finished IC product. In chip-making industries, the analysis is done on the damage-free mirror-like finished silicon die of the IC. Grinding, lapping and/or polishing operations are required to get such a smooth surface. Precision grinding in a ductile mode therefore remains the critical and most important machining operation as the surface and sub-surface damages will be minimized. This results in good quality surface in terms of surface finish and flatness and at the same time generating the maximum amount of ductile streaks on the machined surface. Silicon material other than the IC silicon was also tried out for purpose of comparison and because of limited number of IC chips. Silicon like any hard and brittle material is well known for its low machinability unless it is machined under ductile mode condition. Ductile mode machining is a process that makes brittle materials to behave like ductile materials. A low cost machining technique, which facilitates partial-ductile mode grinding of small areas on thin wafer-like silicon, was developed. A specially modified conventional MAHO CNC Vertical Milling Centre that has an air driven low powered high-speed attachment (precision jig grinder) facilitated the diamond grinding. Special fixtures were designed and fabricated that held the workpieces in position and prevented them from damage during machining. Both traditional and statistical techniques for designing of experiments and subsequent analysis of results were employed in this study. A low cutting force dynamometer (Compacdyn) was used to measure cutting forces. Form Talysurf and Surfcom Surface Analysers and Atomic Force Microscope were used to measure surface texture parameters. Optical, Scanning Electron microscopy techniques, together with the Surfcom Surface Analyser and Atomic Force Microscope, were used to examine the surface morphology of the machined silicon surfaces. It was found that the amount of ductile streaks generated on a work-piece surface was not only dependent on feed and depth of cut but also on the grit size of diamond abrasive. The machining technique of grinding yielded ground surfaces with R_a as low as 50 nm, and forces around 0.8 Newton. Flatness of the machined surfaces is very good. A model of surface roughness (R_a) for precision grinding of thin silicon has been established.

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ABREVIATIONS AND DEFINITION OF TERMS

SEM - Scanning Electron Microscope

AFM - Atomic Force Microscope

DOC - Depth of cut

nm - nanometer

µm - micrometer

R_a - The arithmetical average value of all absolute deviations of the roughness profile R from the centre line within the evaluation length generally 5 times the sampling length.

R_{max} - The maximum individual peak to valley dimension of any sampling length occurring with the evaluation length.

R_t - The maximum peak to valley height within the evaluation length or traversed length.

IC - Integrated Circuit

Ge - Germanium

Si = Silicon

H-P silicon - IC silicon

L-P silicon - Silicon (from Group II-VI optical industry)

Ge - Germanium

f - feed rate

d - depth of cut

l - litre

N - Newton

Ch1, 2, 3 - Channels 1, 2, 3

RSM - Response Surface Methodology

ANOVA - analysis of variance

F_x - feed force component

F_z - tangential force component

F_y	- thrust force component
FA	- Failure analysis
W_a	- Waviness height
S_m	- Waviness spacing

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