Precision Engineering

COPEN 2003-04

Proceedings of the
Third National Conference on
Precision Engineering
December 19-20, 2003

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Central Manufacturing Technology Institute
Bangalore, India

Narosa

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P.V. Shashi Kumar
T. Gurumurthy

Central Manufacturing Technology Institute
Tumkur Road, Bangalore, India

22 Daryaganj, Delhi Medical Association Road, New Delhi 110 002
35-36 Greams Road, Thousand Lights, Chennai 600 006
306 Shiv Centre, D.B.C. Sector 17, K.U. Bazar P.O., Navi Mumbai 400 705
2F-2G Shivam Chambers, 53 Syed Amir Ali Avenue, Kolkata 700 019

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FOREWORD

In the last decade, a new grouping of engineering, scientific skills and techniques known as "Precision Engineering" has come into prominence. The trend is towards high precision and miniaturisation to micro and nano levels of technology.

Precision Engineering finds application in a host of fields ranging from computers, computer peripherals, bio medical devices, digital electronics and metrology instrumentation. Advancements in measurements and transducer/sensor technology, digital signal processing, information processor packaging and features-compaction endeavors have led to miniaturisation in products and systems in various applications. Integration of functionalities into ever reducing physical dimensional domains is pushing the goals of precision engineering into realms of nanometry.

Product design, manufacture and measurement aspects are increasingly being influenced by enhanced precision requirements since light weight constructions, high speeds and better exploitation of material properties are pushing technological achievability of products to higher levels. Precision Engineering has to percolate to the shop practices in a big way across the country to improve the product quality.

The third National Conference on Precision Engineering is deliberating on various facets of precision engineering. Topics covered have a wide range. The themes include, design for achieving enhanced precision levels and functionality, engineering of manufacturing processes for achieving higher precision, measurement techniques for assessing precision, micro machining processes, simulation studies for precision manufacturing and assembly - there is a common thread of endeavor to enhance precision' running through the diversity of multidisciplinary fare presented in this conference.

It is a pleasure to present the proceedings of the Conference in this concise volume, which has been brought out with due diligence by the editorial team.

Professor C Gajendran
Director–CMTI
Convenor–COPEN 2003–04

PREFACE

Advanced technology products ranging from computers and their peripherals, bio medical devices, digital electronics and entertainment electronics to metrology instruments are the application of precision engineering in their design, manufacture and measurement. Precision Engineering has contributed to a great extent in the development of digital electronics, space and biotechnology through miniaturisation leading to weight reduction, reduction in cost and enhanced reliability. This new technology has not yet been introduced to the required extent in our country. As a result, the skill and knowledge available in the industry mainly limited to low precision applications. Introduction of precision engineering and manufacture will also bring in a new culture of product quality and wide spread improvements in the accuracy of engineering products.

Precision Engineering is playing a vital role in this century and it has got great relevance to our industry. In the coming years, with the fast changing environment, the need for research and development in this field is essential. Further, understanding of Precision Engineering concept needs a closer look at the design manufacture measurement and control aspects. The topics of 3rd national conference on Precision Engineering COPEN 2003-04 has addressed these areas to enable Scientists, academia, Researchers and practicing Engineers to come together for a closer interaction on various aspects of Precision Engineering. This conference will also provide an opportunity to have a glimpse on these future technologies and their applications.

Call for papers received enthusiastic response from leading Scientists & Researchers from Indian and abroad. About 43 papers have been accepted for presentation and publication covering all fields of Precision Engineering. We thank the authors for their valuable contributions to this conference.

We have great pleasure in compiling and editing the technical papers presented at the 3rd National Conference on Precision Engineering. Papers in the proceedings have been grouped topicwise. We hope that the readers would find the papers useful and stimulating.

We gratefully acknowledge the support extended by the donors, sponsoring & co-sponsoring organisations, organising committee members for their valuable co-operation & contributions to the conference.

We sincerely thank M/s Narosa Publishing House for bringing out the proceedings of the conference in an attractive form.

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is greatfully acknowledged.

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CONTENTS

PRECISION MEASUREMENTS

Precision Engineering
Editors: M.V. Suryaprakash et al.

HIGH PRECISION GRINDING OF IC CHIPS, INFRARED OPTICS AND OPTICAL GLASS

V.C.VENKATESH* **S.IZMAN#**

*PROFESSOR, UNIVERSITI TEKNOLOGI MALAYSIA, JOHOR, E-MAIL: VENKATES@FKM.UTM.MY
#Lecturer, Universiti Teknologi Malaysia, Johor. e-mail: izman@fkm.utm.my

PART 1

High precision grinding of IC chips for failure analysis

Abstract:

The objective of this research is to machine the silicon die of an IC chip and the surrounding chip packaging. The silicon die had to be reduced from a size of 85 μm to about 50 μm by a machining technique such that not a single transistor of the 40 million under the die is destroyed and at the same the die presents a mirror finish for examination on a back emission infra red microscope. The chip packaging had to be machined such that the six layers of power conduits in the form of copper traces and the dielectric (insulator) between them could be studied at low magnification for discontinuity. Initially electroplated diamond grinding pins were used for the die that was successful but it left undesirable tracks behind that remained even after polishing. These pins were not ideal for the soft but tough chip packaging. A new binderless diamond grinding wheel was developed that had a width equal to that of the IC chip die and also that of the width of the chip packaging with considerable success. This new wheel was also used to machine plano silicon and optical glass lenses successfully.

1. INTRODUCTION

The objective here is to go for low cost partial ductile grinding of the silicon die on Integrated Circuit chips (IC chips) and then mirror polishing them for purposes of failure analysis. Earlier success in partial ductile mode machining of optical glass and infra-red optics (Si and Ge) was encouraging (Venkatesh, 2003). Subsequent work in an optical industry revealed dramatic improvement in the grinding and polishing of optical moulds for making plastic lenses (Zhong & Venkatesh (1995)).

Integrated Circuit chips (IC chips) need to be tested for failure analysis. Normally testing can be done by desirable non-destructive and undesirable destructive techniques. Unfortunately with failure analysis of IC chips the testing has to be done by non-destructive techniques. However, only a few chips from a big lot need to be tested. The IC chip (die) is made from a silicon wafer of at least 120mm in diameter that is ground and mirror polished to a high degree of flatness. About 256 chips (dies) are made from each wafer. Each die has 40 million transistors under it and is then packaged for power connections. The whole packaged chip has solder balls under it for attaching them onto a printed circuit board PCB. Figure 1 shows the top view and a cross section of an IC chip.

Figure 1 shows IC Chip (i) Line diagram of the IC flip chip with the silicon die on the top connected by solder bumps to the packaging below it. (ii) before, (iii) after grinding of silicon die and chip packaging, (iv) Line diagram above shows details of the constituents within the chip packaging - copper traces, BT core, dielectric and solder mask with thickness indicated within brackets. It should be noted that there are solder balls also at the bottom of the packaging to connect it to a motherboard.

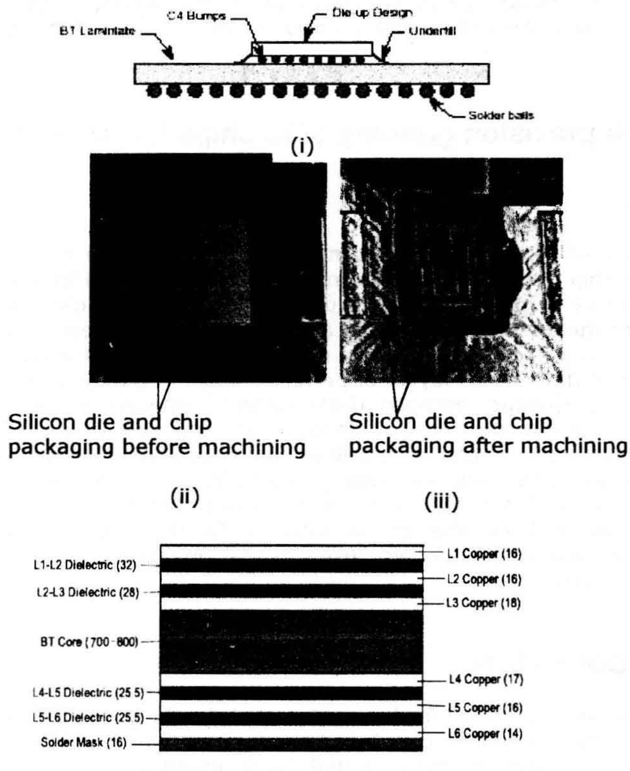


Figure 1. The IC chip and its cross section.

2. MACHINE TOOLS FOR DUCTILE MODE PRECISION MACHINING

The ideal non-dedicated machine tool for machining the die would be ultraprecision turning and grinding machines shown in figure 2. Figure 2A is a two-axis machine where the chip being rectangular or square constitutes a non rotational part and vertical grinding becomes impossible. Figure 2B has 3 axes and again it is not possible to use it as the third C axis is not helpful. In figure 2C also grinding is possible because of the 4^{th}. Y axis but the chip packaging has to be ground in two stages, the second one requiring indexing by 90 degrees. Figure 3 shows a 3 D view of this 4th. axis machine. A 5 axis machine not shown here, has a 5th B axis that can enable grinding of the die and the chip packaging but the prohibitive cost of $0.5 to 0.75 million makes it unattractive.

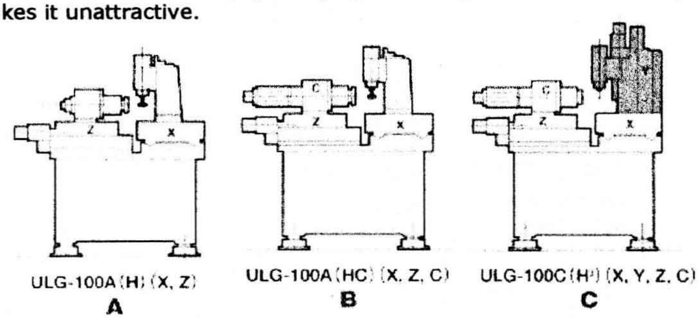


Figure 2. Ultraprecision turning and grinding machine with 2 -- 4 axes.

A CNC vertical high speed precision surface grinder which provides very fine in-feeds and fine cross feeds to do pocket machining would be ideal. A line diagram of such machine is shown in figure 4.

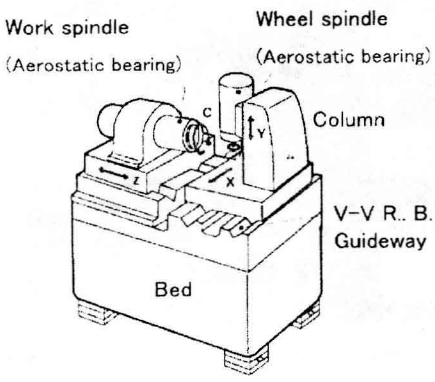


Figure 3. 3-D line diagram of a Toshiba 4-axes ultraprecision turning and grinding machine.

The concept of in-feed often mistaken as depth of cut similar to that in turning operations is clearly depicted by Boothroyd *et al* (1994) in figure 4. Since such a machine was not available in our labs, the final choice for this challenging problem was to use the precision CNC machining centre in our lab shown in figure 5. This machine was converted into a high speed machine with a capability for spindle rotation of 140,000 rpm. A special fixture was designed for the IC chip (Konneh 2003). The selected wheel was initially a commercial resinoid bonded diamond pin grinding wheel of 5mm in diameter (figure 6). These wheels have diamond surfaces at the bottom as well as at the sides, which make them suitable for use on vertical but not on horizontal surface grinders for this particular application.

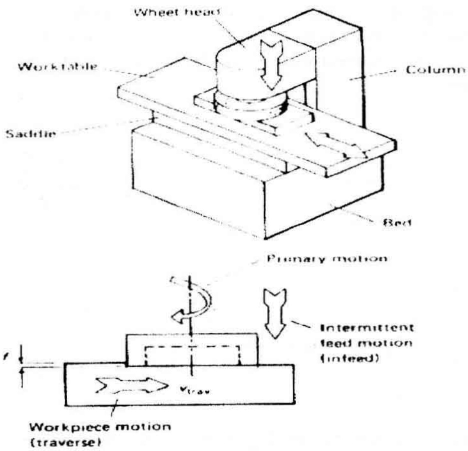


Figure 4. Vertical surface grinding machine.

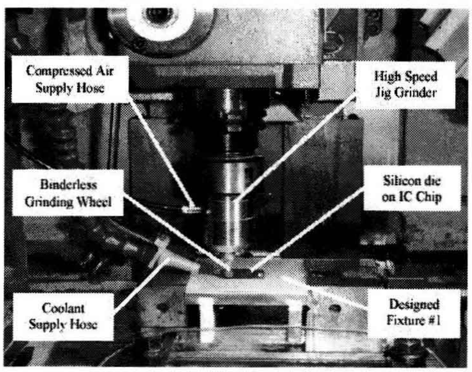
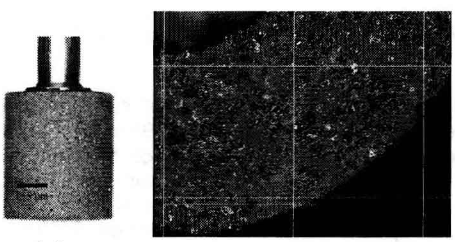


Figure 5. 3-axes CNC Maho precision machining centre.



(a) (b)

Figure 6. Winter diamond grinding pin (a) magnified view of the bottom surface showing low concentration of diamonds within the square bounded by an area of 1mm x 1mm (b).