NOVEL CIRCUIT FABRICATION TECHNIQUES FOR REDUCED ENVIRONMENTAL IMPACT

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INTRODUCTION

This paper proposes a novel technique for low cost circuit manufacture which it is hoped will offer significant reduction in environmental impact, both in terms of production process, and end of life. The technique is to use a pattern printed on paper by conventional offset lithographic techniques to form interconnection circuitry. Initial research is concentrating on the selection of appropriate conductive inks, and substrate materials. At present, components are attached using conductive adhesives, but the feasibility of placing components during the final printing pass, and using a form of conductive ink to provide the bond, will be investigated.

CONVENTIONAL APPROACHES TO CIRCUIT FABRICATION

Conventionally, to mount a silicon device a circuit board is prepared. This generally consists of etched copper on glass fibre laminate, tin plated and possibly carrying further layers of lacquer for protection and labelling. Many operations of cropping, drilling, etching and plating are involved in it's preparation. It is not cheap, and the production processes can have significant environmental impact.

The two major environment hazards posed by PCB manufacture are the waste effluent which is acidic and contains heavy metals, (especially copper), and the use of hydrocarbons in photoresist developer and stripper. Stricter pollution limits imposed by water authorities are one driving force to reduce copper in effluent. In theory waste effluent could be elimated by a totally additive process for copper deposition, which would also offer considerable cost savings, but a satisfactory process has not yet been developed.

Attempts to avoid the use of a circuit board as such include the use of both thick and thin film techniques, normally associated with higher cost, not lower. Resistors are formed on a ceramic substrate by depositing tracks of a suitable film , sometimes trimmed to precise values by laser etching. A film of higher conductivity is generally used for interconnection.

A NEW APPROACH

Many printing techniques are being carried across into circuit fabrication, both for depositing an etch-resistant film onto the layer of copper and for protecting the completed conductor pattern. However, these are in the main based on silk-screen methods. Although rapid in terms of other circuit fabrication methods, the process is slow and cumbersome by printing industry standards. For mass-production of printing, the present industry standard is offset lithography. Speeds exceeding 6,000 impressions per hour are typical of machines at the bottom of the range and very close image registration can be achieved as a matter of routine. This work has been exploring ways in which this mature technology can be bent to the production of circuits at a cost comparable with that of business cards.

Although the initial investigation has been confined to laying down simple connecting tracks, at a later stage printing of passive devices such as resistors should be straightforward, and printing of capacitors should be possible using lamination techniques to provide the insulating layer. Piezoelectric inks offer the prospect of fabricating piezoelectric devices through printing, and very recent developments in semiconductor ink, indicate the possibility of eventually printing active devices.

ENVIRONMENTAL ASPECTS OF SUBSTRATE CHOICE

Traditionally it has been desirable for substrate to be smooth, inert, refractory, have high heat conductivity, be compatible with silicon in thermal expansivity, and inexpensive. (Jowett(1)). In addition, high bandwidth circuit substrate must contain a minimum of water vapour as variations in atmospheric humidity could cause variation in circuit capacitance.

Fitted PCBs make up a large percentage by weight of many products, (70% for a hearing aid, 30% for a mobile phone (Zachariassen (2)), and present methods of disposal are limited to shredding and high temperature incineration. For a number of products it seems possible that cheaper,lighter, and more easily disposable substrate materials could be used. One alternative is to use the casing material of the product

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itself as the substrate, moving towards a monomaterial approach to design which eases recycling problems (Henstock(3)).

Smart card manufacture has established the practicality of bonding silicon to a plastic substrate and making reliable electrical connection to the chip. (McCrindle (4), Bright (5)). The French Telecarte has a failure rate of less than three per 10,000 units sold. There is a continuum between, at one extreme, the use of a rigid plastic substrate to satisfy mechanical support requirements, and at the other, the use of a paper substrate, offering possible economies in production through the use of low cost printing techniques, plus a lower environmental impact in terms of both a 'cleaner' production process and an easier to dispose of product at end-of-life. This project is investigating this range of substrate choice.

THE LITHOGRAPHIC PROCESS

Letterpress uses a raised pattern in the printing plate to pick up ink from a roller and press it directly onto the paper being printed. Lithography relies instead on the action of two wetting functions, and the surface of the plate is smooth and unembossed. The plate chemistry repels the water where the image is dark, allowing the greasy ink to stick. Contact with a single roller then allows the plate to attract water or ink forming the pattern to be printed.

The image is not transferred directly to the paper, but is rolled onto a "blanket" cylinder carrying a smooth but yielding surface. As it continues its rotation, the blanket presses the ink into the surface of the paper which now is carried on the impression cylinder, a hard and smooth support.

Ink used for the lithographic process can rely on evaporation or on oxidation to become fixed. The initial experiments have used a silver loaded ink, which is fixed through evaporation.

INITIAL RESULTS

Initial experiments have established the feasibility of the use of lithographic printing techniques for the production of electronic circuits on a paper substrate, and have produced a simple electronic device.

CONCLUSIONS AND FURTHER WORK

The work has established the possibility of using lithographic printing processes for production of electronic circuits. Lithographic printing techniques offer an additive method of circuit board production, removing the need to etch copper. While inappropriate for many applications it is believed that this may be an appropriate approach for the production of high volume, simple circuits at low cost.

Further work is being undertaken to establish the design constraints resulting from the use of paper substrate, through a program of environmental testing. The longevity implications of the use of paper circuitry will be investigated, as will issues of mechanical support and external contacts. The focus for these experimental investigations is two application studies.

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