AN OVERVIEW OF RECENT DEVELOPMENTS IN CERAMIC AND POLYIMIDE TECHNOLOGIES FOR MULTICHIP MODULES

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Abstract: MultiChip Modules are gaining wide acceptance as a powerful method to interconnect several ICs in the same board. The increasing size of ICs, the higher power required to operate them and their physical closeness create new problems to the interconnect designers, mainly due to TCE mismatch between Silicon and PCB materials and to the need of a low dielectric constant of the interconnect media. Ceramic MCMs appear to be well positioned to provide a cost effective solution to today interconnect requirements.
The paper will review the latest development of DuPont in terms of materials and processes for the fabrication of Ceramic MCMs, either by extending the area of application of thick film hybrids, with limited investments, or by using Low Temperature Co-fired Ceramics (LTTC) technology, better known as Green Tape, with equipment developed "ad hoc" for large volume production, requiring an important capital investment.
The paper will also mention the latest DuPont developments on organic materials for MCMs, including Photosensitive and "low stress" polyimides.

Pregled trenutnega stanja razvoja keramične in poliimidne tehnologije za multičip module

Ključna besede: polprevodniki, vezja integrirana, moduli multichip, stanje razvoja, pregled, zmanjševanje velikosti, povezave vmesne, tehnologija povezav, gostota vezij, procesiranje signalov, hitrosti procesiranja, zmanjševanje razdalj, tehnologija debeloplastna, LTCC tehnologija, Green tape linija polavtomatska, tehnologija tankoplastna

Povzetek: Multičip moduli se vse bolj uveljavljajo kot način povezave nekaj integriranih vezij na eni tiskani plošči. Vse večja površina čipov, vse večja moč potrebna za njihovo krmiljenje, ter vse manjša razdalja med čipi povzročajo nove probleme načrtovalcem tiskanih plošč predvsem zaradi razlike v TCE med silicijem in materialom za PCB plošče ter potrebe za nizko vrednostjo dielektrične konstante povezovalnega medija. Keramični multičip moduli ponujajo tehnično in stroškovno zanimivo rešitev za vse omenjene probleme.
V članku pregledno podajamo trenutno stanje razvoja materialov in procesov za keramične multičip module v firmi DuPont. Gre bodisi za primer dodatne uporabe tehnologije debeloplastnih hibridov z majhno začetno investicijo, bodisi za uporabo nizkotemperaturno sintrane keramike (LTTC), bolj znane kot "Green Tape", na opremi razviti "ad hoc" za velikoserijsko proizvodnjo, ki pa zahteva večji investicijski zalogaj.
Na koncu omenjamo nekaj najnovejših rezultatov firme DuPont na področju organskih materialov za multičip module, kot so fotosenzitivni in "low stress" poliimidi.

Introduction

The evolution in electronics is linked to the continuous development of semiconductors where the reduction in size has to be matched by the evolution in interconnect technology. As the number of functions and the circuit density on the chip increases, the chips become larger with higher number of I/O's, requiring finer lines to interconnect the ICs on the substrate.

Faster signal processing is another characteristic of advanced ICs with typical clock rates of 50-100 MHz for actual microprocessors; single packaged chips mounted printed circuit board are too far apart to handle those clock frequencies, thus requiring either a further integration on the chip, or physically narrowing the distance between the ICs; alternatively possible solutions are to decrease the dielectric constant of the interconnect media or to use transmission line control.

Without entering in the discussion about the integration of semiconductor technologies, not always possible, nor always economical, the solution of interconnecting sev-

eral ICs on the same substrate, known as MultiChip Module (MCM), is certainly a powerful method.

The choice of the interconnect technology depends on several factors such as cost, performance, technology availability and so on; at the same time the interconnection density is also dependent on cost, component dimensions and, to a larger extent, upon the type of ICs used (pitch size and number of I/O's). MCMs require in general fine lines, small vias and multilayer structures to interconnect the ICs on the same substrate with maximum efficiency.

Via formation represents certainly one of the most critical steps in the process of miniaturisation of multichip modules. Fig 1 shows how line density (line pitch) is almost a function of via definition.

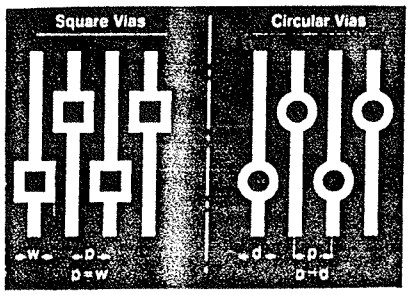

Fig. 1 Line pitch is a function of via definition

Today chips having more than 320 I/O's and with a pitch of 150 microns interconnected on a multilayer represent typically the new requirements for the "high end" of the interconnect market. Furthemore the interconnect substrate is not only to meet the performance, but needs to be cost competitive and to follow the IC price/time typical "learning curve".

MultiChip Modules have opened new opportunities to thick film technology which needs to be accompanied by a certain evolution of the technology itself, to respond to the new challenging requirements in terms of density, miniaturisation, signal speed, controlled impedance and so on. Furthermore ceramic MCMs can be fabricated at reasonable cost not only for the military market but also for commercial applications.

In this brief overview the major emphasis will be on DuPont developments on materials and processes for ceramic MCMs, including Low Temperature Cofired Ceramic (LTCC) technology, better known as "Green Tape". Some of these innovations, to be considered as extension of thick film technology, should allow the thick film hybrid manufacturers and users to extend the area of application of multilayer hybrid circuits without incurring in large capital investments, Furthermore the benefits and the convenience of LTCC technology for ceramic MCMs will be reviewed; Green Tape* requires an important investment in term of equipment and has to be considered as an evolution of thick film technology.

Since the via formation is a critical part of the multilayer interconnect fabrication, we shall review the DuPont techniques capable of resolving small vias, as experienced in practice from the hybrid users standpoint, taking real applications as examples.

Extensions of Thick Film Technology

Diffusion Patterning. In this overview "Diffusion Patterning" system of materials and process will be described; this technique allows to separate the via formation process from the screen printing of the dielectric (Fig. 2) Diffusion Patterning is the step taken by Blaupunkt to increase the complexity and the miniaturisation of their car radio circuits, by achieving finer lines and multilayer structures even for consumer applications.

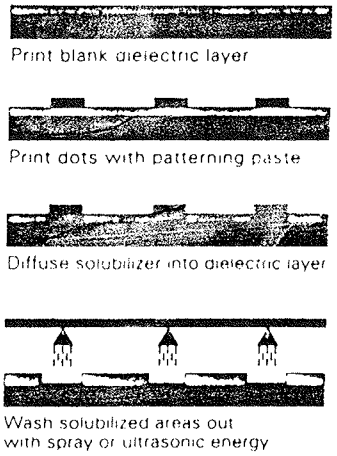

Fig. 2 Schematic of diffusion pattering process

FODEL Photosensitive Meterials. Another method to extend thick film capabilities is to use photosensitive dielectric and conductive pastes (FODEL); Dassault Electronique, after an evaluation of other available technologies, such as silicon-on-silicon, thin film/polyimides and high-and low-temperature co-fired ceramics, has chosen FODEL dielectric and conventional thick film gold for their existing hybrid macromodules. Fig. 3 describes the FODEL photoimaging process. Dassault are also qualifying FODEL dielectric and photosensitive conductor materials for their next generation of High Density MCMs-C.

Evolution of Thick Film Technology

Green Tape*. A new semi-automatic line for the production of approximately 1 million square inches of Green-

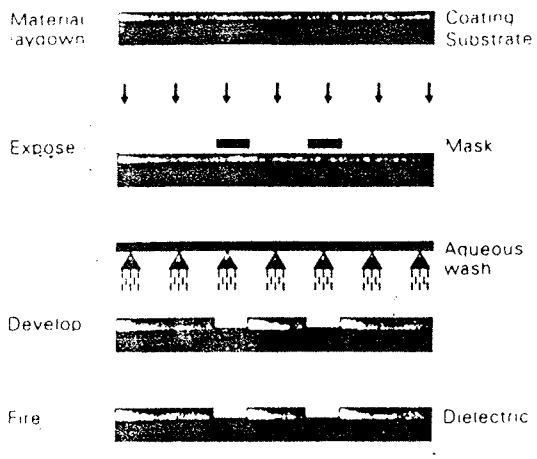

Fig. 3 *Substractive photo imaging*

Tape* circuits has been set up at Sorep in Chateauburg, France.

The line consists of machines specifically designed and assembled for the LTCC technology by Officine Baccini, a high precision thick film equiment manufacturer in Italy.

The key attribute of LTCC is that it offers to the designers the possibility of making multilayer structures with multiple shielding and voltage lines, without incurring in the cost penalty associalted with other interconnect technologies (fig. 4)

The excellent reliability and the good thermal dissipation combined with high density capability of Green Tape* circuits, make the LTCC technology a valid solution for MCMs, with performances similar to thin film circuits but at considerably lower cost. Other advantages of Green Tape* circuits are double side utilisation of the substrate, easy fabrication of "blind" vias and the possibility of special shaped substrates, including cavities for IC chips. The material is also suitable for designing modules with mixed analog and digital signal at high frequency; recent studies indicate that LTCC can be used within the range of 8-30 GHz with high stability.

One of the major advantage of LTCC technology is its potential adaptability to meet the evolving requirements from the market. DuPont offers dielectric tape foils at various thicknesses and dielectric constants. Green Tape* materials can also match TCE of GaAs and Silicon, allowing better reliability of large bare chips mounted on the substrate. Furthermore LTCC will allow to "bury" components, such as resistors and capacitors, in its structure eliminating the need of solder joints and reducing the number of decoupling capacitors.

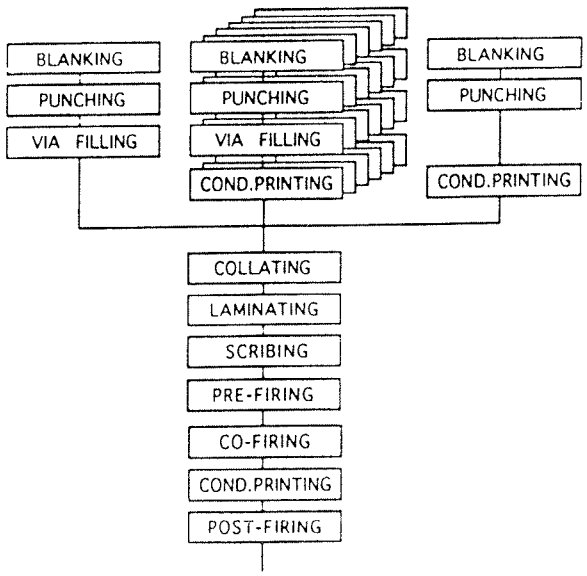

Fig. 4 *Process flow for single sided 8-layer LTCC circuit.*

Thin film/Polyimide technology

There will be a brief overview of DuPont recent developments on conventional and photosensitive poyimides as dielectrics for MCMs, type D, using thin film conductors. A brief discussion on the various type of polyimide materials available from Dupont and on their characteristics will follow.

As a conclusion some preliminary studies between photosensitive polyimides and a low K dielectric tape materials system will also be described.

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