Flexiboard: CMOS-MEMS chiplet integration with soft materials towards autonomous programmable matter

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Since quarter century, LSI semiconductor industry was aware of importance of intellectual property (IP), a set CAD design of a dedicated function, to avoid redesigning the same function from a scratch, and thereby to reduce development time. Recently, a new word "chiplet" has been introduced. Instead of electronic design, physical LSI chip itself is diced into small pieces and is densely connected with other LSI components. With physical LSI chiplet, even faster development is expected because the chip is already there. In MEMS world, the author has been working since 1997 based on the the same concept, to densely integrate LSI chip(let)s with MEMS device [1]. In this invited talk, a newly established technology to integrate such chiplets on a flexible MEMS body (what we call "Flexiboard") will be presented [2].

The targeted function is to realize a small (less than 4mm-diameter) 3-D object, which we call "catom". The catom is the core element in a Programmable Matter project, aiming at reprogrammable 3-D shape creation and interface by autonomous attaching and detaching between catoms. In the project, a planar comb-type electrostatic actuator has been demonstrated to be useful [3]. However, the difficulty has been how to create a "true 3D" catom body. All the surface of the catom must be covered with components to realize dedicated function. It has been evident that any conventional semiconductor fabrication method could not realize 3-D CMOS-MEMS, because the technology is planar. The authors' group proposed a method of "maki-gami" (roll paper) scheme; a flexible board containing electrical wiring and specific MEMS structure (such as interdigitated MEMS electrostatic actuator electrode) was first fabricated. Then silicon CMOS-MEMS chiplets has been integrated by flip-chip bonding (Fig.1). Two functions has been added to the flexiboard by the chiplet bonding: high-voltage (90V) solar-cell power supply [4] for µN-class electrostatic attaching, and a mechanical support to keep the electrostatic actuator electrodes flat to ensure face-on-face attachment of catoms (Fig.2).

The technological difficulties, among others, has been wiring lithography process of Au material, and batch integration of multi-chiplets. First, the parylene-C body of flexiboard was only a couple of microns, so very small shock and / or chemical treatment could break the body. We have solved the problem by three-layer deposition (Cr/Au/Cr). On the Au (main wiring body) layer attached by first Cr adhesion layer to parylene, another Cr layer has been deposited. The lithography was first made on the top Cr, and the patterning has been done by using the Cr as a hard mask (Fig.3). Thanks to this new process design, we could obtain the flexiboard with a very clean surface (e.g. during top Cr etching, all particles-like small contamination has been lifted-off). The second problem was solved by introducing a mechanical chipboard, a Deep-RIE recessed silicon micro framing structure; the chiplets have first been placed in the silicon frame and then flip-chip bonded. The alignment accuracy between chiplets has been mechanically ensured within the precision of the Deep-RIE (Fig.4). We have been successful to make a first demonostration of attach-detach function by integrated HV solar-cell (Fig.5).

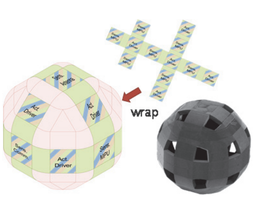

Fig.1 "Catom"

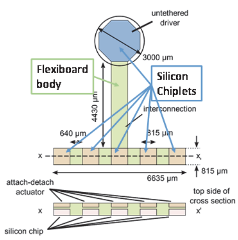

Fig.2 Flexible+chiplets design

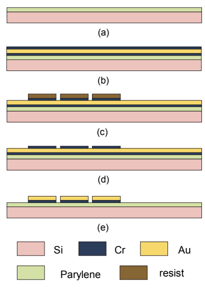

Fig3 Flexible process

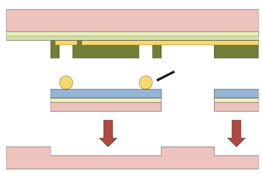
Fig.4 Batch chiplet integration concept

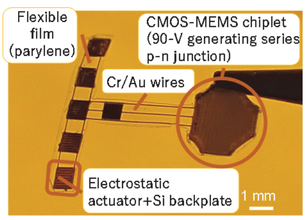

Fig.5 Fabricated integrated flexiboard

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