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Ball Semiconductor Technology And Its Applications

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ABSTRACT

Instead of using conventional flat and rectangular chip technology, our idea is to make semiconductor devices and sensors on 1mm-diameter spherical silicon substrates. This paper describes five key enabling process technologies to recognize Ball devices.

Keywords:- Fabrication, clinometers, plasma furnace, quartz mask, MEMS, ball, gyroscope, accelerometer.

I. INTRODUCTION

Conventional semiconductor industry focuses on making integrated circuits on flat-surface wafers. Roundness, smallness, symmetry, closed surface topology, 3- dimensional feature, and about 3 times larger surface area than a 1-milimeter square chip are unique aspects of the spherical shape. We are aiming to realize unique spherical devices using these features. Our internal goal for manufacturing is to reduce its cost and to shorten the production lead-time using novel continuous fabrication process. We call this technology Ball semiconductor technology. In this paper, above five key enabling process technologies are introduced and an electro-statically levitated 3-axis accelerometer and an omni-directional clinometer are described as unique applications of the Ball semiconductor technology for Micro -Electro Mechanical System (MEMS).

II. BALL PROCESS TECHNOLOGIES

The fundamental concept of the Ball mass production line is manufacturing the Ball in a continuous, enclosed tube like a chemical plant. To realize this technology, we are developing a spherical single crystallization technology during free-fall through a plasma furnace, continuous processing technologies in small diameter tubes, a lithography technology for use on spherical surfaces, a layout design methodology, and a clustering technology to connect many Balls as a molecule.

III. SINGLE CRYSTALLIZATION

Single crystal silicon is used in the fabrication of semiconductors. Microprocessor fabricators have invested heavily in facilities to produce large single crystals of silicon. The first and foremost step in making Ball devices is the fabrication of single crystal spheres. This process consists of melting, solidification and polishing. In the melting step, polycrystalline silicon granules are preheated and melted in a high temperature atmospheric pressure plasma flame generated by Inductively Coupled Plasma (ICP) system.

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IV. NO- CONTACT HANDING OUT

The fabrication process of Ball involves deposition and etching of various types of films. Such processing requires that the balls do not hit the walls of the pipes, or each other, to prevent damage and contamination. To meet this requirement, we have developed two types of the process equipment. One is for the gas phase processes and the other is for the liquid processes. In the prototype of gas phase process system, a ball is floating inside a quartz tube in atmospheric pressure. The inner diameter of the tube is about 2 mm. The carrier gas of the precursor suspends the ball itself.

V. SPHERE-SHAPED LITHOGRAPHY

One of the high hurdles in Ball Semiconductor technology is spherical lithography, because no conventional exposure system was available for curved surfaces. This system includes two important concepts. One is the electrical pattern generation using Digital Micro-mirror Device (DMD) instead of the quartz mask, and the other is a spherical focal plane using an original micro lens instead of a flat focal plane. In general, it takes about a month and huge cost to make quartz masks. On the other hand, the mask-less lithography system could reduce R&D cycle time and cost dramatically. The flexibility of pattern designing and mapping has much benefit to produce small quantities and many varieties of devices even if it is the flat chip.

VI. LAYOUT DESIGN ON SPHERE-SHAPED SURFACE

Designing circuits on a sphere is another unique aspect of Ball Semiconductor technology. There are two main issues in 3D design over conventional 2D design. The first is the closed surface topology with the inability to look at the entire design surface as a whole. The second is that there is no perpendicular grid system, which can cover the entire surface of the sphere. So we need a unique display system with a specifically ruled grid system. we have developed a 3- dimensional layout design tool for spherical surface, ABLE. ABLE was created to have high flexibility featured in changing its viewpoint all the way around the sphere and moving its relative perpendicular coordinate in any desired direction. Recently, ABLE has been connected to the mask-less lithography system, so that designed patterns can be instantly exposed on the sphere. We are improving the tool by adding the functions of design rule check, electrical simulation capability and so forth.

VII. BUMPING AND CLUSTERING

Instead of utilizing “system-on-chip” technology to achieve system integration, our approach is to cluster different function Balls together like atoms of a molecule. To realize actual mechanical and electrical connection for input and output, a micro -ball bump technology is applied on the spherical surface. The material of the bump is currently gold and its size is about 80μm in diameter. The size and the position of the bumps are designed to match the requirement of the number of the pins and the height. Micro-balls are attached by a thermal press method.

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VIII. BALL PRODUCT TECHNOLOGIES

After successful development of the world first NMOS integrated circuit on the spherical surface, we are exploring ball unique products utilizing the smallness, the roundness and other features of the Ball. Benefited by highly symmetrical 3D structure, closed topology of the ball, and surface process capability to fabricate a 3D structure, the MEMS device is one of the most interesting applications of the Ball technology. The position of the core is controlled by a closed-loop servo system to keep in the center and feedback intensity tells the acceleration. Another inertia sensor, omni-directional clinometer is obtained by utilizing a similar structure. In this case, the inner core moves freely so that capacitance change tells us a tilting angle including upside down. In the case that the inner core will be electro-statically levitated and rotated, a gyroscope can be realized key. This principle of the gyroscope is well known to have the highest sensitivity among various gyroscopes. A process is a sacrificial layer etching using xenon difluoride (XeF2), which generates the gap. A beauty of the XeF2 etching is its extremely high selectivity between the Silicon and other materials. This etching process is performed at the final step of the process flow to avoid the damage of the shell from excessive stress of the micro-ball bump process.

IX. CONCLUSION

We have developed spherical single crystallization system, gas phase and liquid chemical process equipment using tubes and pipes, spherical lithography systems, 3D layout design tool and clustering technology to realize semiconductor devices and sensors on a 1mm sphere.

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