Flexible wireless pressure sensor module

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Summary: *A flexible Packaging scheme, which embedded chip packaging, has been developed using a thinned silicon chip. Mechanical characteristics of thinned silicon chips are examined by bending test and finite element analysis. Thinned silicon chips ($t<50\mu m$) are fabricated by chemical etching process to avoid possible surface damages on them. These technologies can be use for a real-time monitoring of blood pressure. Our research targets are implantable blood pressure sensor and its telemetric measurement. By winding round the coronary arteries, we can measure the blood pressure by capacitance variation of blood vessel.*

Keywords: *flexible embedded chip packaging, implantable blood pressure sensor, real-time monitoring*

1. Embedded chip packaging

Flexible silicon chips has been realized through chemical etching in order to realize the embedded chip packaging technology. Silicon chips are fabricated thinner than 50μm for mechanical flexibility. Using these thinned silicon chip, bending test and numerical analysis performs flexible package, which has flexible IC, is developed and mechanical characterization.

Normally, it is impossible to anticipate the mechanical deformation of silicon like as rigid and brittle materials. But if their thickness become thinner than 50μm, silicon is no more than rigid and brittle body, silicon overcome the mechanical deformation in elastic region [1,2].

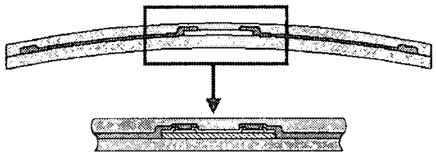
Thinned silicon chip is fabricated by chemical etching to remove the possibility of surface damage and stacked directly on Kapton film by thermal compressive bonding and adhesive bonding. Due to low profile between thinned silicon chip and Kapton substrate, electrical interconnection is accomplished by electroplating. (*Fig. 1*)

Proposed package cannot be predicted by the beam deflection theory. Because the package has heavy drooped compare to their thickness [3, 4]. Therefore, we carried out the numerical analysis for mechanical characteristics, as proposed package will be sticked on given round surface. (*Fig.2*)

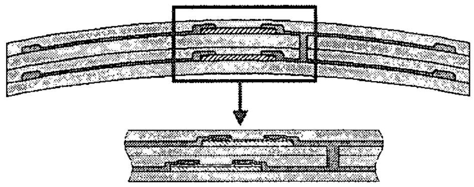
Through the results of numerical analysis, it could be estimated that the suggested package can be loaded to surface that has curvature with less than 5mm. And this is proved to be true through the bending test.

During the bending test silicon sample is loaded by support tip and real-time image of the sample is captured. Maximum displacement along the X direction (δ_x) and minimum radius of curvature (ρ) of each thickness is measured by captured image.

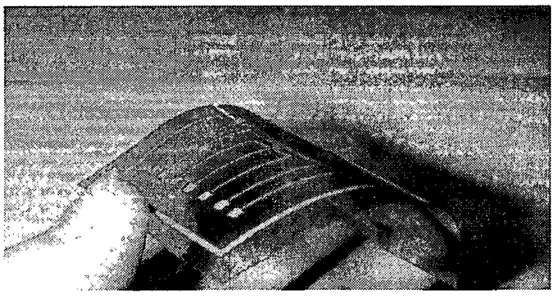
Due to embedded chip in substrate, high packaging density and implantable feature can be accomplished by maximized usage of packaging area.



(a) Embedded chip packaging (ECP)



(b) Multi-level ECP



(c) Flexible Chip and Board

Fig. 1 Embedded chip packaging scheme: thinned chips in multi-layer

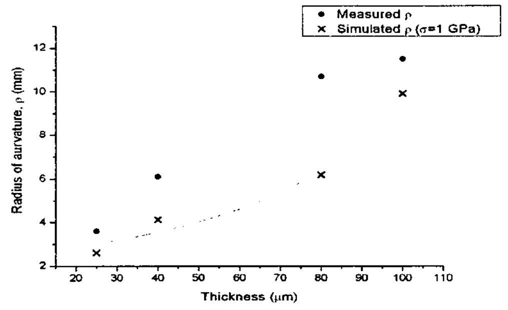
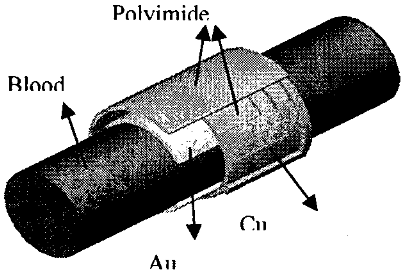


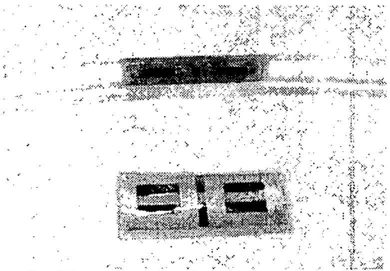
Fig. 2. Radius of curvature based on measured displacement

2. Wireless blood pressure sensing.

According to the medical science reports, blood vessel disease like as blood vessel shrinking or blocking are increased in last decades. [5] So, this paper reports the development of wireless blood pressure sensor using flexible embedded chip packaging scheme. *(Fig.3)*



(a) Schematics of pressure sensor



(b) Photograph of sensor device

Fig.3 Flexible blood pressure sensor

Applied pressure varies distance between electrodes, changing the capacitance. For living body interposition, sensor material must be gratified by biocompatibility. It is the reason why we should treat polyimide such as substrate and gold as a conductor. Actually coronary artery's diameter is about 2~3mm. We prepared 3mm diameter silicon tube for in vitro experiment and pressure sensor size is 15mm x 9.4mm (Fig.3.b)

The resonance frequency of the LC circuit formed by the capacitor and the inductor changes as capacitance changes.

$$\varepsilon_{eff} = \frac{240\varepsilon_0}{80+3d}(d+1) \qquad (1)$$

$$C = \varepsilon_0 A \frac{240}{80+3d} \qquad (2)$$

where d is distance between two electrodes, A is area of electrode, ε_0 is permittivity of vacuum, C is capacitance of blood. According to the equation (2) blood vessels capacitance variation is affected by blood vessel's shrinkage variation.

This change is sensed remotely through inductive coupling method.

$$f_0 = \frac{1}{2\pi}\frac{1}{\sqrt{LC}} \qquad (3)$$

where f_0 is resonance frequency, L is inductance and C is capacitance of blood vessel.

Fig.4 indicates the measurement results of blood pressure variation according to found the resonant frequency. It depends on the capacitance variation on LC resonator.

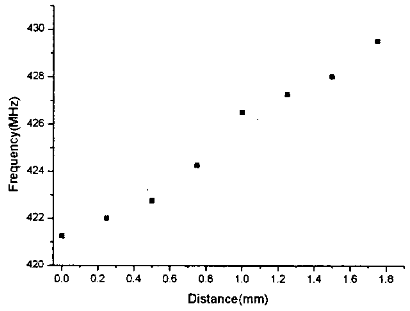


Fig 4.Resonant freq. Vs. Distance between electrodes

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