DYNAMIC CHARACTERISTICS MEASUREMENT OF THIN SEMICONDUCTOR LAYER

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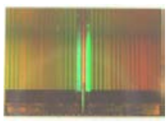
1 Introduction

In this study, the vibration test method was proposed to investigate the dynamic characteristics of the ultra-thin multi-layered semiconductor wafer. The theoretical model was proposed for the vibration analysis of the wafer cantilever beam on which device layer was printed. Young's modulus and loss factor of the thin device layer were determined from the measured frequency-dependent bending stiffness and loss factor variation of the each layer. The results were examined and the comparison to the results of the nanoindentation test was performed to verify the feasibility of the proposed method. Using the presented procedure, the dynamic characteristics of the thin device Young's modulus and loss factor can be directly obtained.

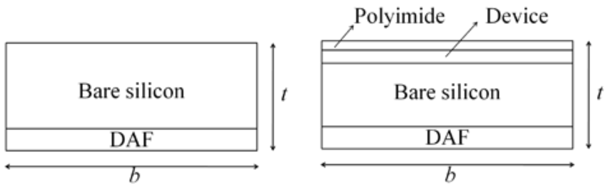
2 Experiments

2.1 Specimen preparation

Table. 1. Specimen specification

	Bare silicon				Device printed wafer			
								
Width (mm)	9.1				9.1			
Length (mm)	12.96				12.96			
Total thickness (μm)	30	50	80	100	Including PI and device layer thickness			
					30	50	80	100
Mass (mg)	9	13	22	28	9	13	21	27
With DAF	Additional 2 mg on total mass and 20 μm on total thickness							

The flash memory wafer was used as the test specimen in this study. Table. 1 shows specification for the specimens. The wafer consists of several layers. The silicon is used as the substrate material. The device is printed on the silicon and was covered by polyimide(PI) to protect the pattern of device. DAF attached to under surface of the silicon is an adhesive layer.



(a) (b)

Fig.1. Cross sectional schematics for the specimens (a)bare silicon only (b)device printed wafer

2.2 Experimental setup

Fig.2 shows the experimental setup used for the vibration measurement. The wafer was attached to the shaker in the cantilever beam setup. The cantilever beam was excited at the clamped end using the shaker attached to the clamping device. The random input signal was applied to the amplifier to drive the shaker in the frequency range up to 1.6 kHz. The vibration of the beam was measured using one accelerometer(Endevco 65-100-Z) and one laser doppler vibrometer(Polytec optic sensor head OFV-503) at x_0 = 0 and x_1 = 12 mm, respectively. To investigate the effect of the thin layer on the bare silicon beam bending stiffness, accurate determination of the transfer function was required. From the measured vibration responses, the transfer function between the input base excitation and the resulting response of the beam was obtained using

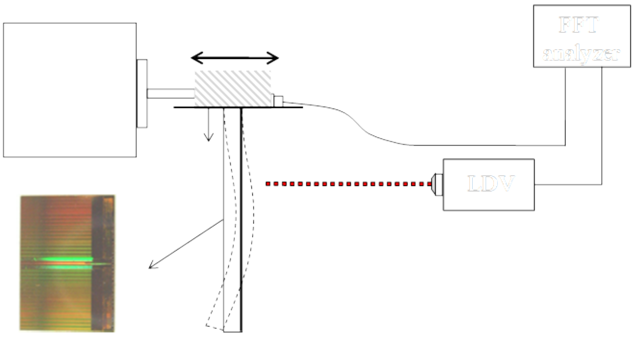


Fig.2. Experimental setup for the vibration test

the FFT analyzer. This transfer function was used in the beam transfer function method to calculate the bending stiffness of each layer, from which Young's modulus of the thin layer is estimated.

3 Vibration analysis using wave approach

The equation of motion for vibrating beams is

$$D\frac{\partial^4 w}{\partial x^4} + M\frac{\partial^2 w}{\partial t^2} = 0, \tag{1}$$

where w is the transverse displacement, $D=EI$ is the bending stiffness, in which M is the mass per unit length of the beam. Using the wave approach, the vibration of the beam is given as

$$\hat{w}(x) = \hat{A}_1 \sin \hat{k}_b x + \hat{A}_2 \cos \hat{k}_b x + \hat{A}_3 e^{\hat{k}_b (x-L)} + \hat{A}_4 e^{-\hat{k}_b x} \tag{2}$$

where $\hat{k}_b$ is the wave number and $\hat{A}_i$ (i=1,…,4) are unknown constants to be determined from the boundary conditions. To obtain dynamic properties, the predicted responses are compared to the measured values.

After applying boundary conditions the transfer function in equation (3) is given as a function of the wave number. To solve this equation, the Newton-Raphson method is applied, then the complex bending stiffness of the beam is obtained.

In the two-layered beam, the combined complex bending stiffness of the beam is given as

$$\frac{D_c}{D_s} = 1 + \frac{E_f}{E_s}\left(\frac{h_f}{h_s}\right)^3 + 3\left(1+\frac{h_f}{h_s}\right)^2 \frac{E_f h_f}{E_s h_s + E_f h_f} \tag{3}$$

Where $\hat{E}_s$ and $\hat{E}_f$ are the complex moduli of the substrate and thin layer, respectively. Similarly, the combined complex bending stiffness of three-layered beam for unit width can be obtained.

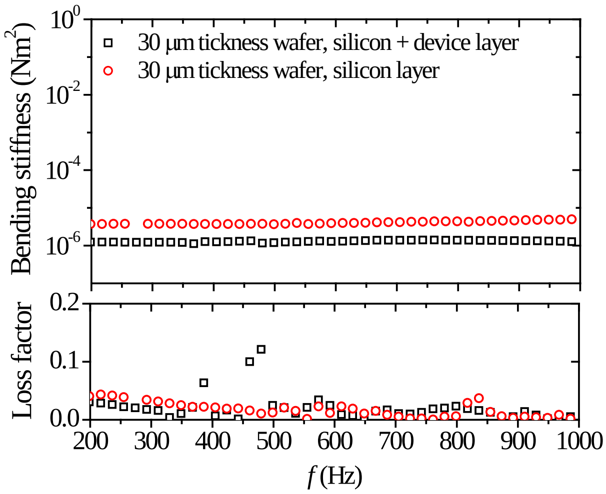


Fig.3. Measured bending stiffness and loss factor

4 Conclusion

In this study, the proposed method showed its usefulness and it can provide direct measurement of dynamic characteristics of thin layer without removing the substrate since the contribution of thin layer to the bending stiffness is significant. The vibration test provides not only the Young's modulus of thin film but also the loss factor that has a great influence on the dynamic behavior of materials.

References

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