A Study on the Acoustic Properties of the Constituent Films in Solidly Mounted Resonators Using Picosecond Ultrasonic Waves

Chung-Cheng Institute of Technology, National Defense University,
Dahshi, Taoyuan 335, Taiwan

Authors: Ta-Ching Li (Speaker), Shih-Piao Yu ,
Le-Ye Tang , Yung-Kang Hsiao, Nen-Wen Pu,
Ben-Je Lwo, and Chin-Hsing Kao

March 7th, 2006, for ISART

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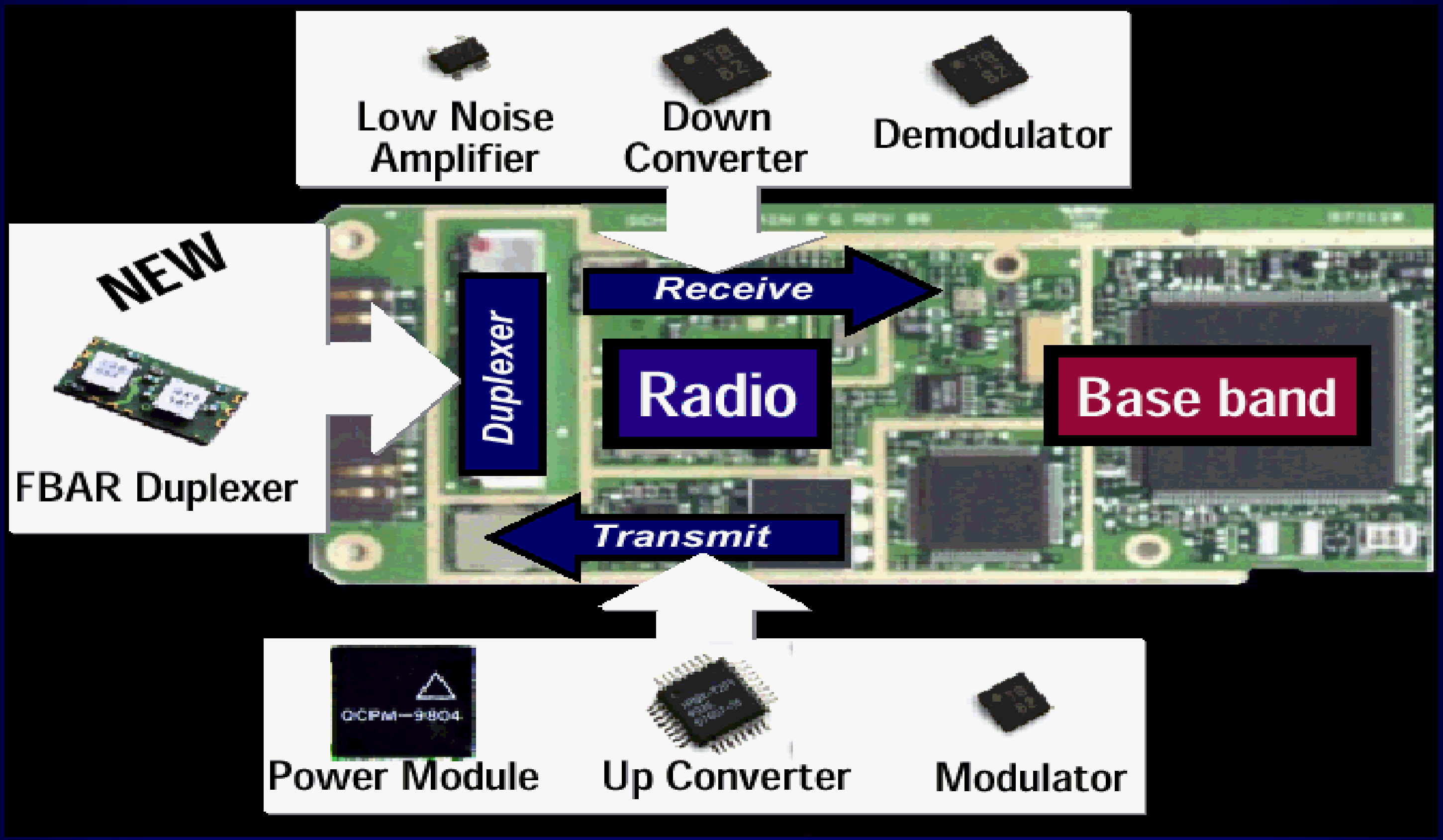
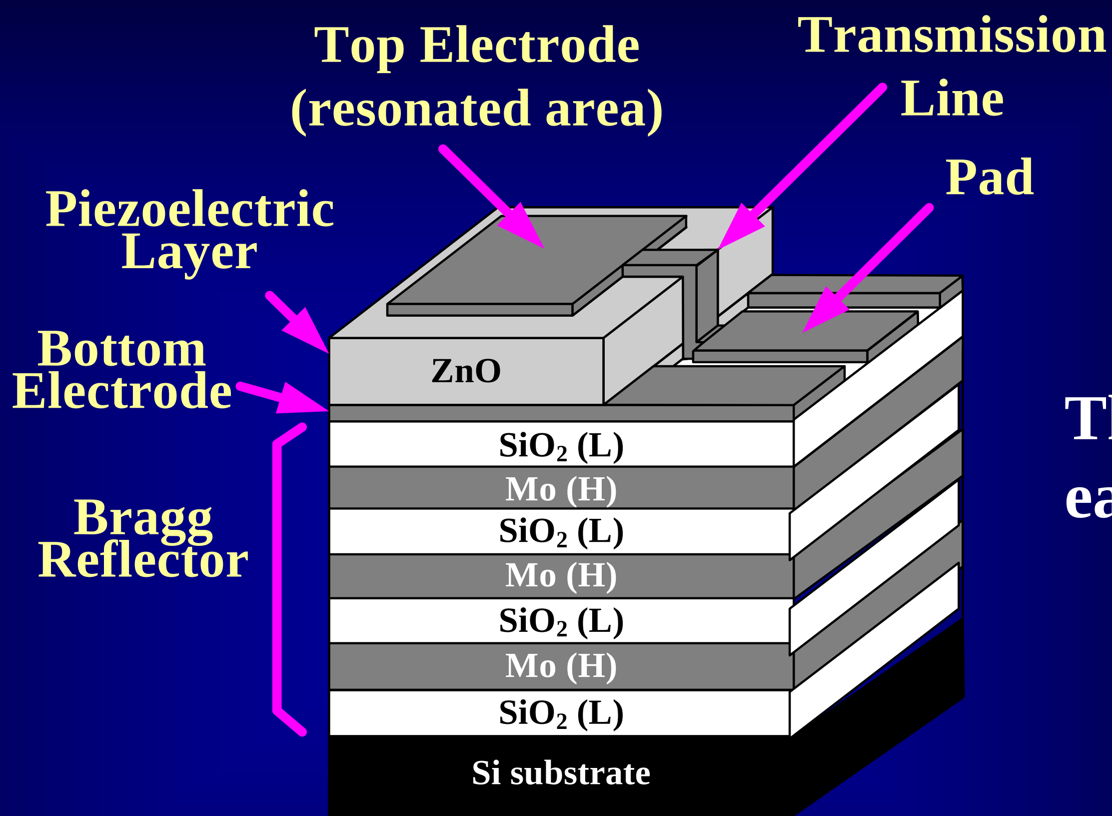
Introduction - SoC



SoC : System on a Chip
Picture: Agilent Technologies company

The SMR Structure



Thickness of each layer: $\lambda/4$

SMR(solidly mounted resonator)

Advantages:
1. Easy fabrication
2. Robust structures
3. Good power handling

Problems:
Need very accurate acoustic properties and thickness for applications at high frequency

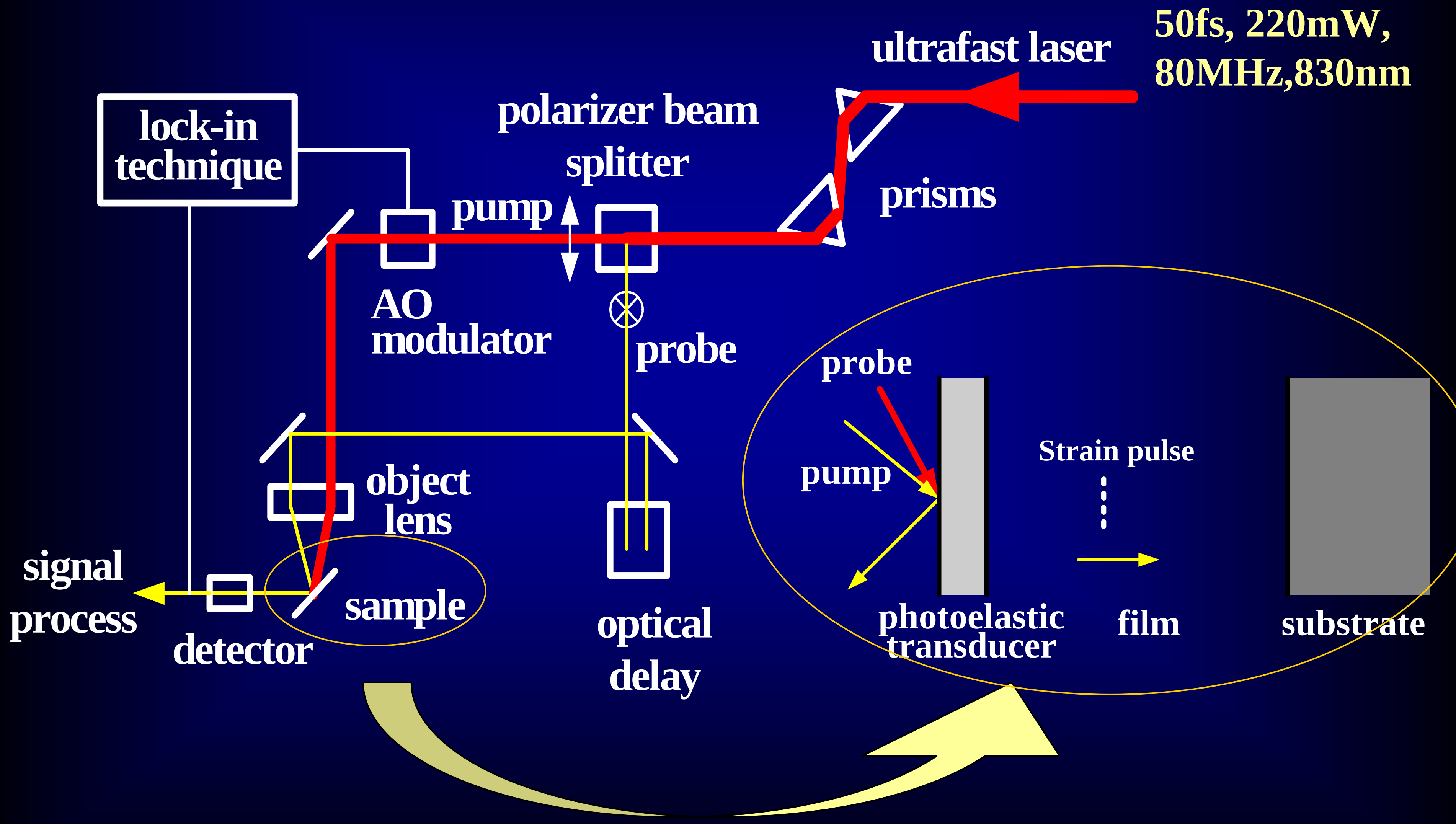
Motivation

- To analyze acoustic properties using high spatial resolution tool.
- To compare differences between bulk velocity and nanofilm velocity.
- To analyze thickness of the Bragg reflector using the picosecond ultrasonics

Algorithm

The Picosecond Ultrasonic Technology (1/4)

- **The setup**



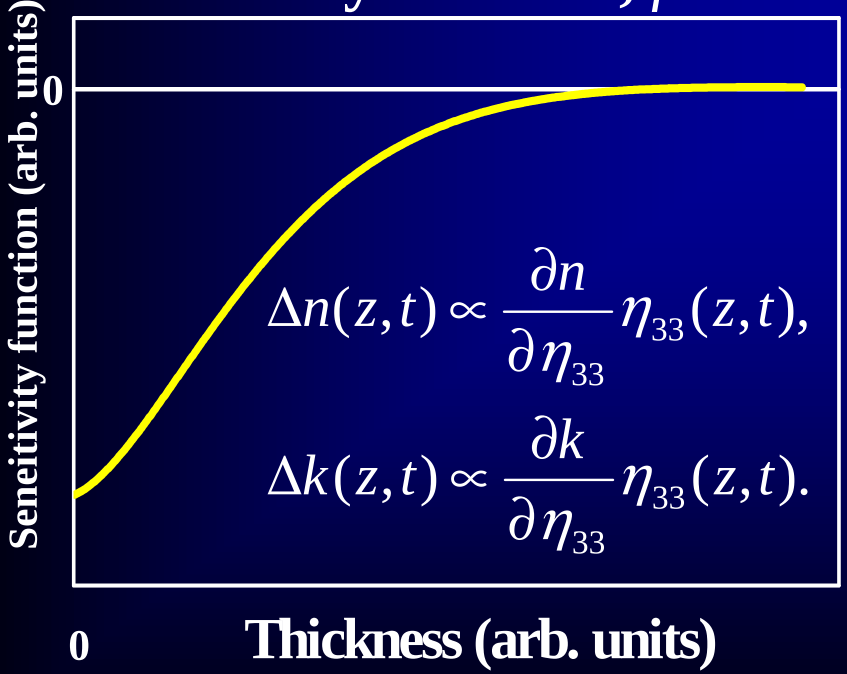
The Picosecond Ultrasonic Technology (2/4)

- **The detection mechanism**

$$\Delta R(t) = \int_0^{\infty} f(z)\eta_{33}(z,t)dz$$

The optical reflectance changes

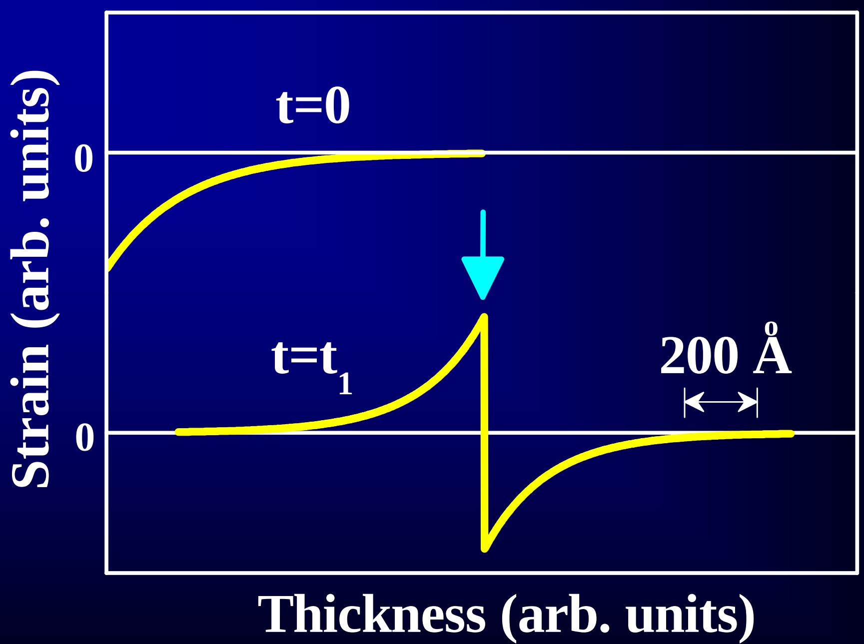
sensitivity function, *f*



$$\Delta n(z,t) \propto \frac{\partial n}{\partial \eta_{33}} \eta_{33}(z,t),$$

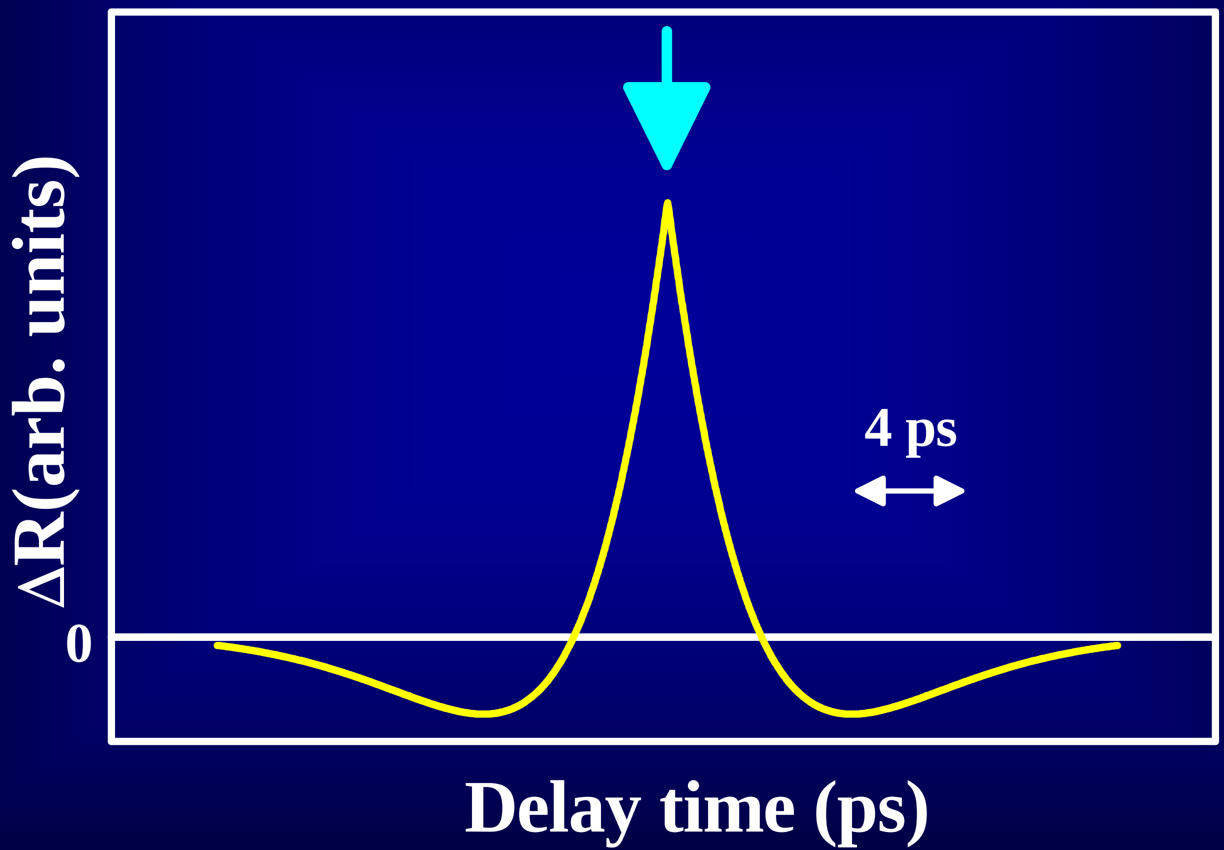
$$\Delta k(z,t) \propto \frac{\partial k}{\partial \eta_{33}} \eta_{33}(z,t).$$

elastic strain, η_{33}

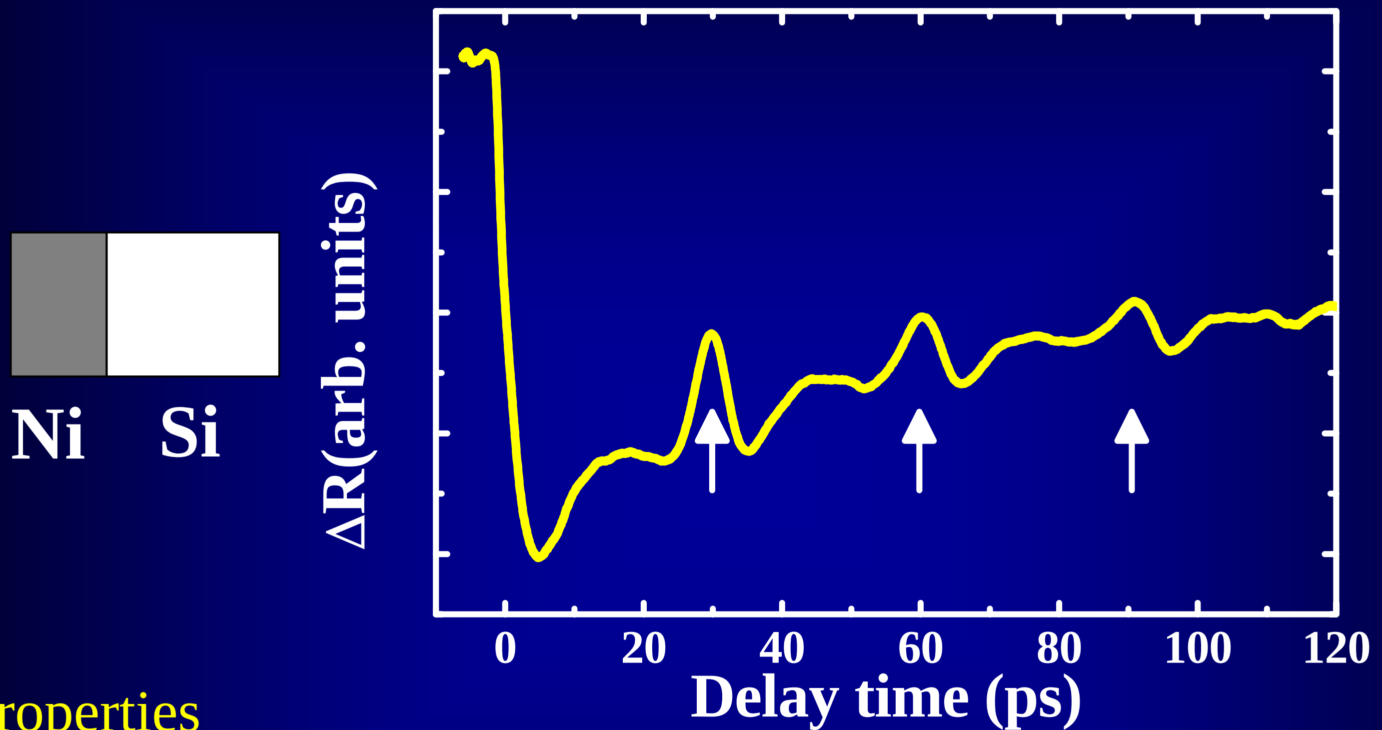


The Picosecond Ultrasonic Technology (3/4)

Simulated echo response



The Picosecond Ultrasonic Technology (4/4)

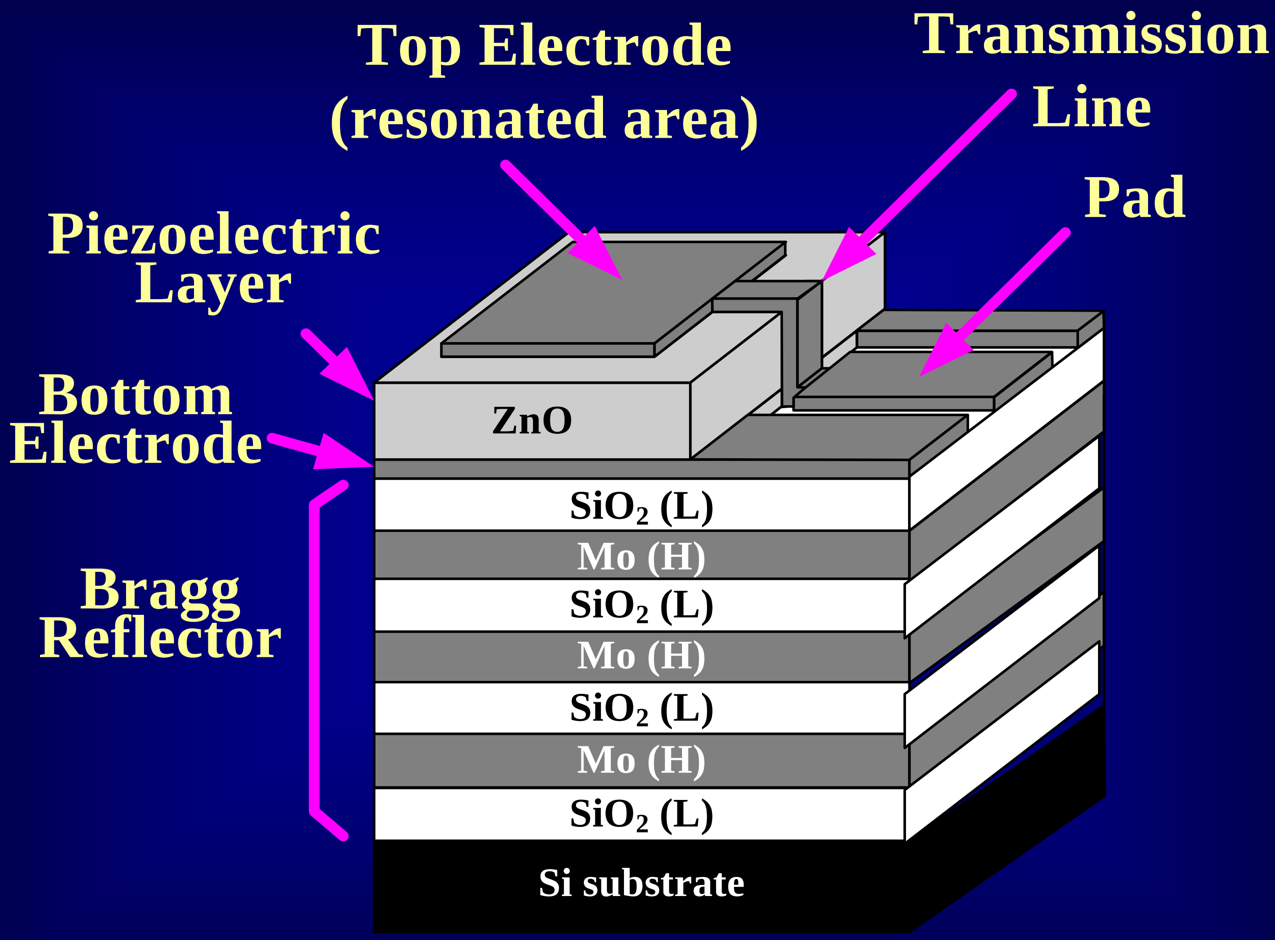


Properties

1. The periodic echo signals
2. The decreased magnitudes of the sequential signals
3. The broader FWHM width of the sequential signals
4. The peak polarity of the signal can be used to judge the difference on the acoustic impedance of the adjacent materials

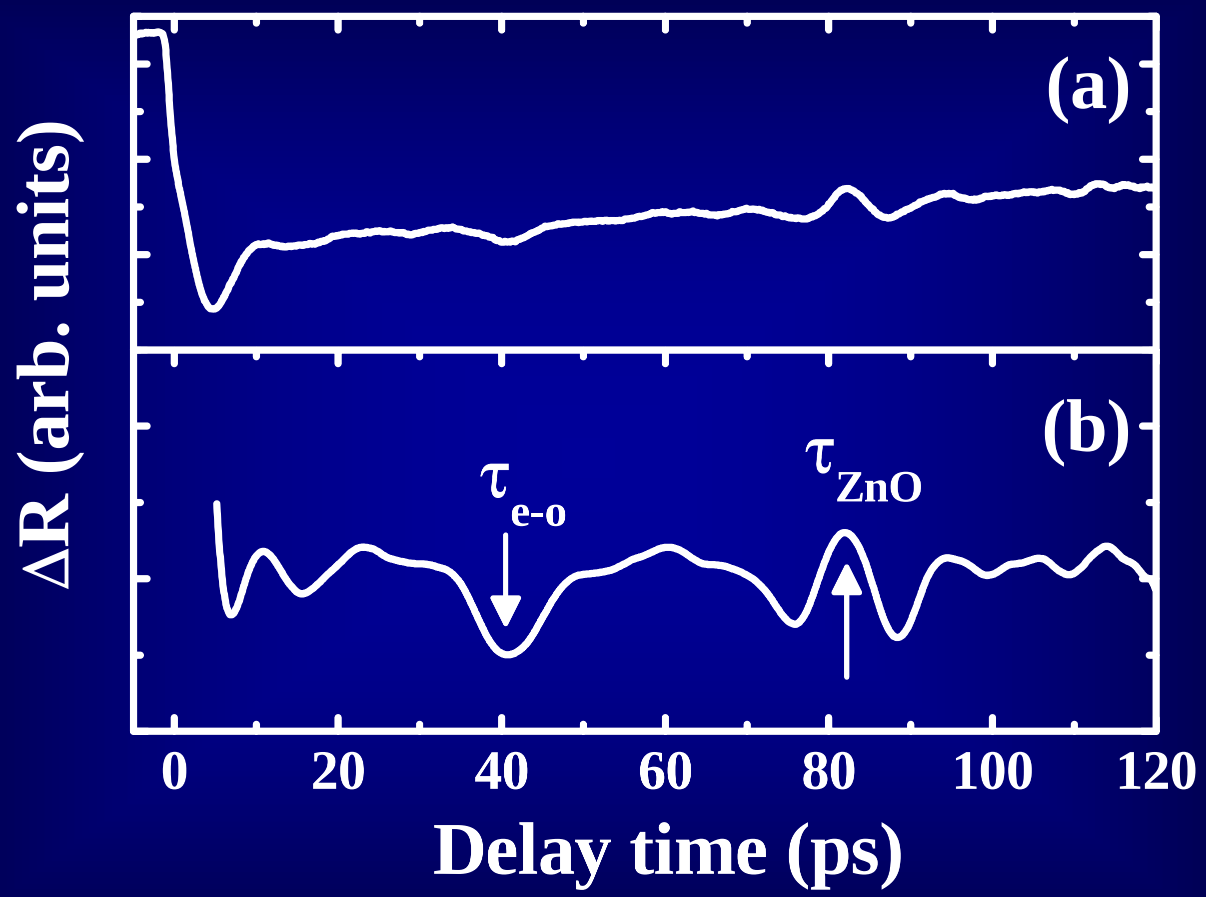
Experimental Results

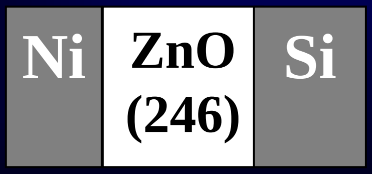
The SMR Structure



The constituent films are including ZnO, Mo, W, Ni, SiO_2.

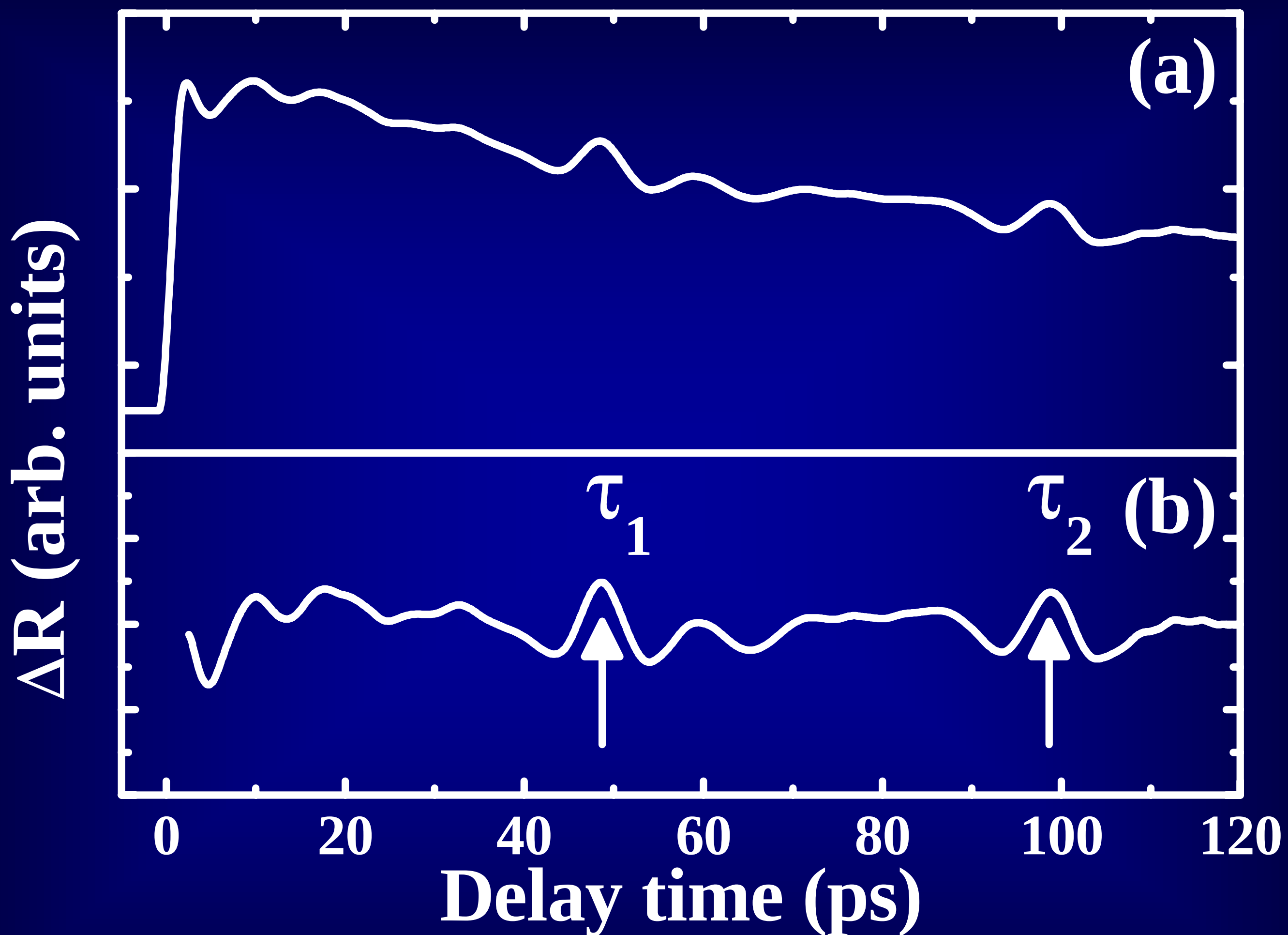
Constituent Films- ZnO





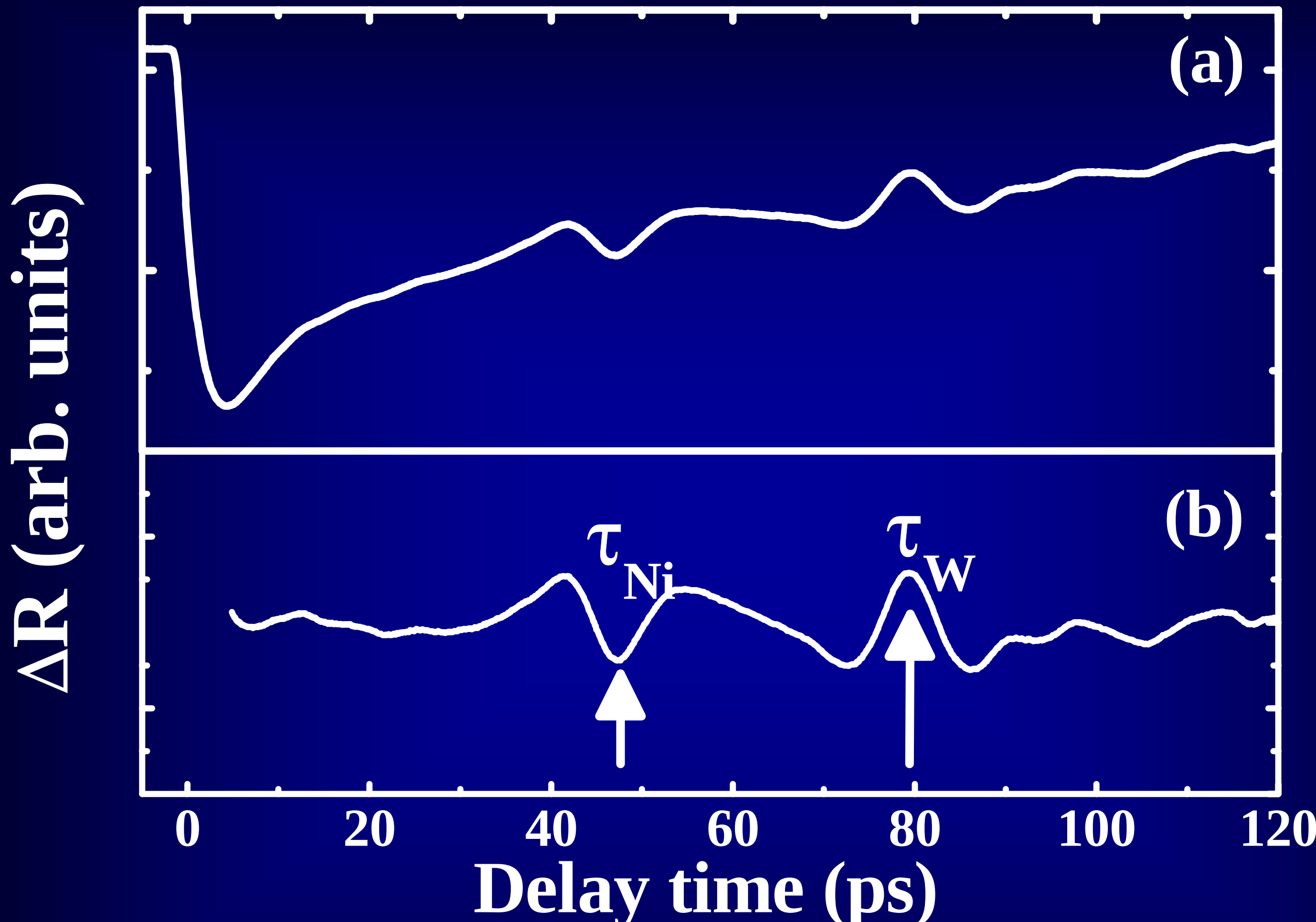
The velocity of ZnO nanofilm is 6560 m/s.
(reference velocity: 6330 m/s)

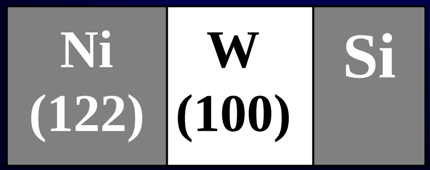
Constituent Films- Mo



The velocity of Mo nanofilm is 7300 m/s.
(reference velocity: 6430 m/s)

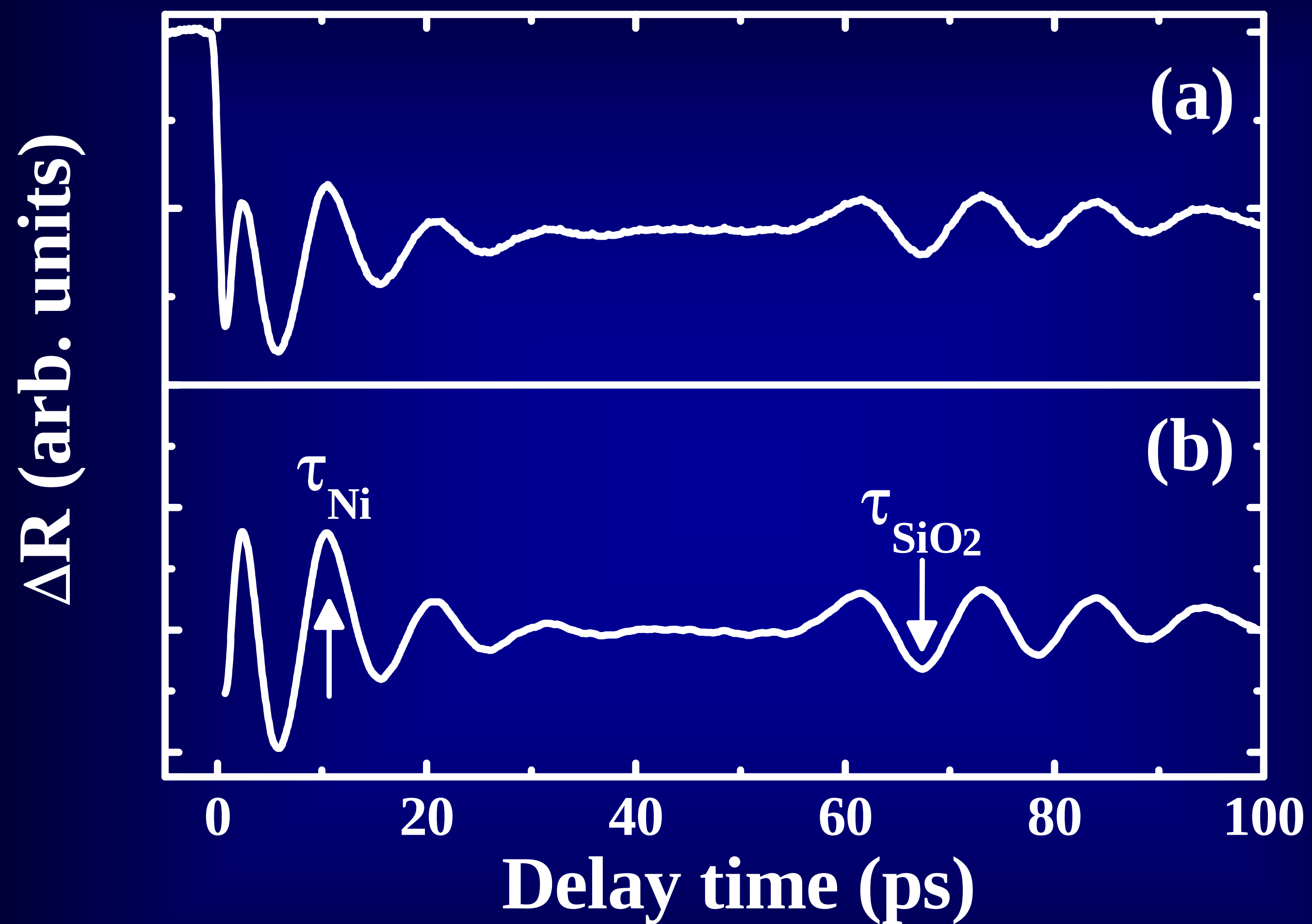
Constituent Films- Ni & W

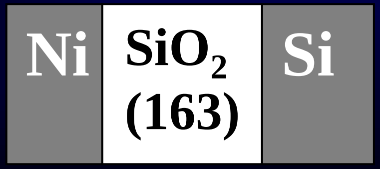




The velocities of Ni and W are 5190 m/s and 6250 m/s,respectively. (reference velocities: 4970, 5230 m/s)

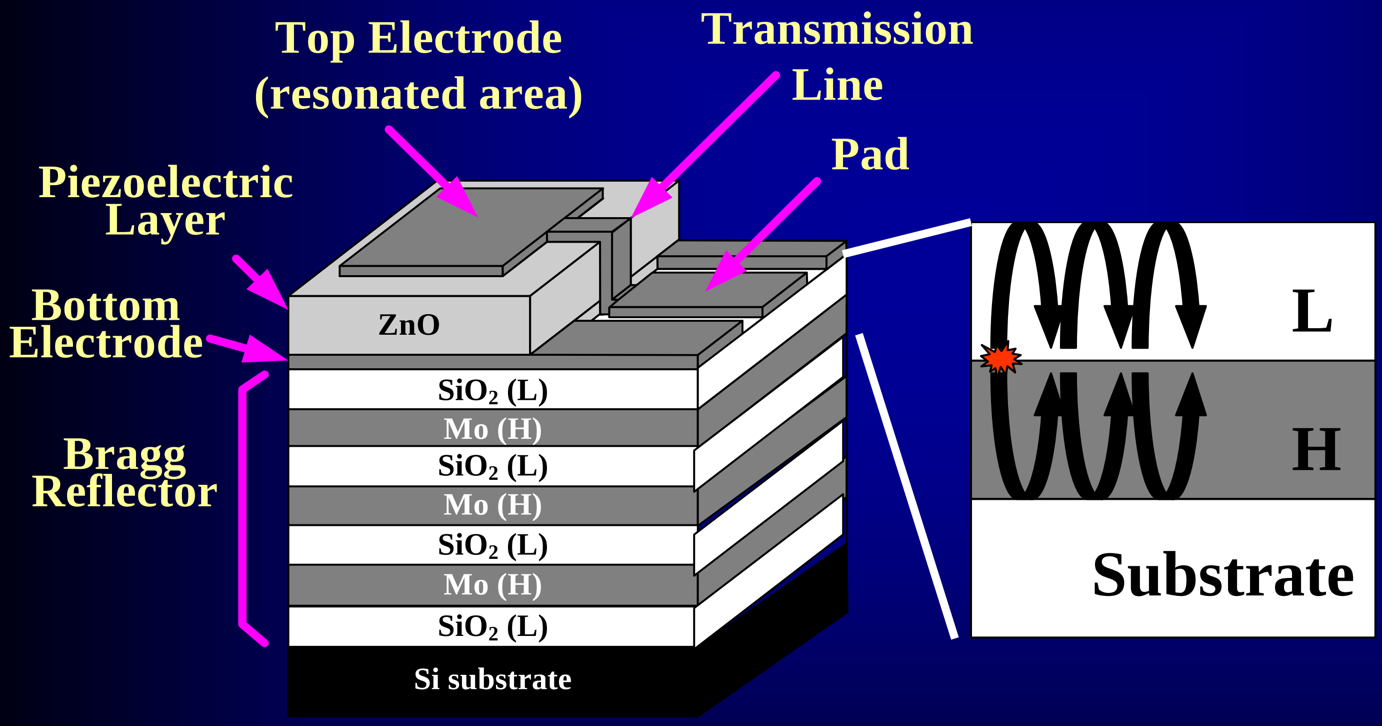
Constituent Films- SiO_2





The velocity of SiO_2 nanofilm is 5450 m/s.
(reference velocity: 6500 m/s)

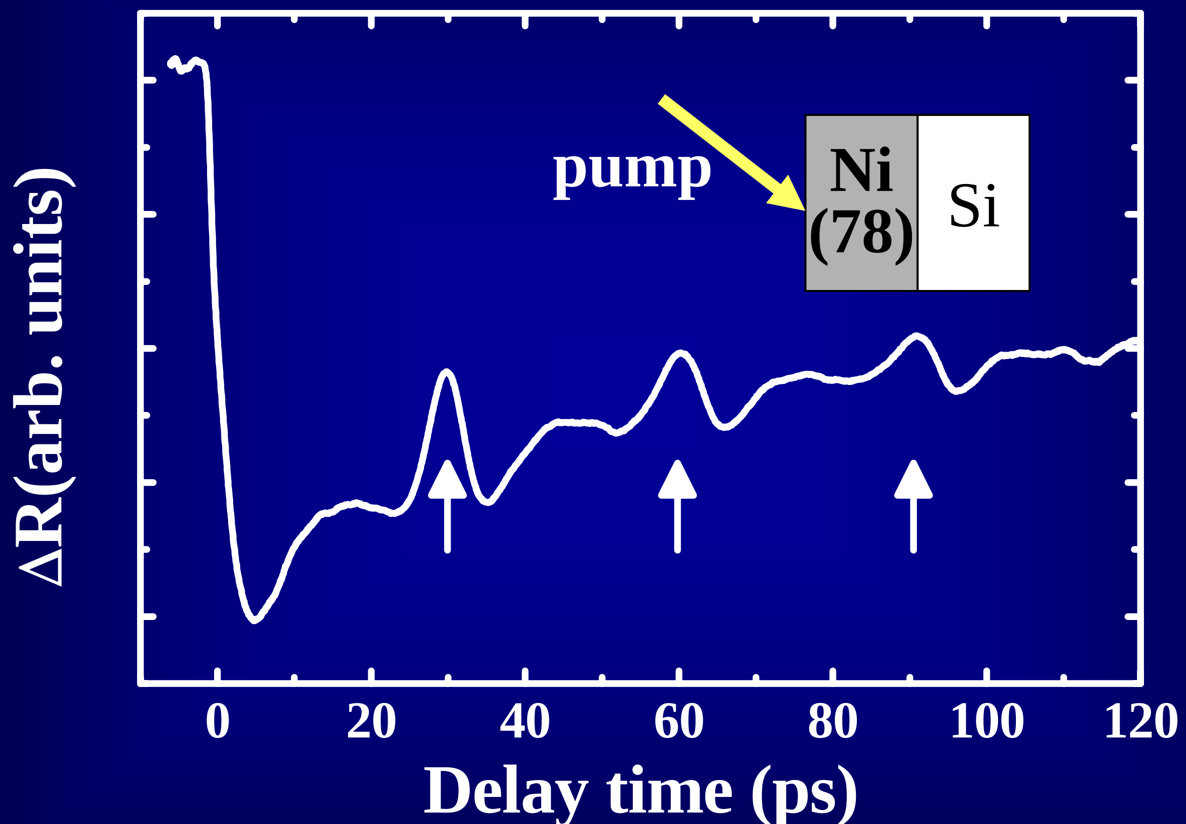
Thickness analysis (1/4)



$$t_L = \frac{\lambda_L/4}{v_L} = \frac{1}{4f}$$

$$t_H = \frac{\lambda_H/4}{v_H} = \frac{1}{4f}$$

Thickness analysis (2/4)

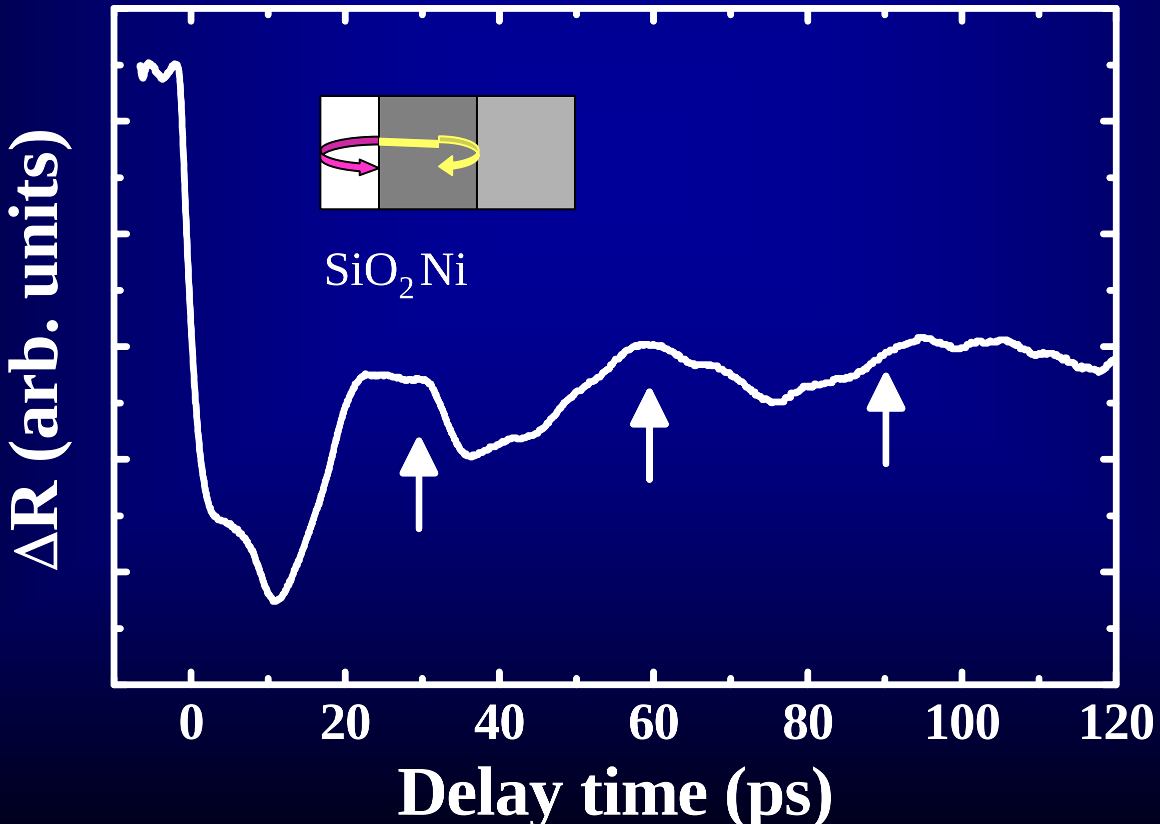


The reflectance change of the single layer of λ/4 Bragg reflector

Thickness analysis (3/4)

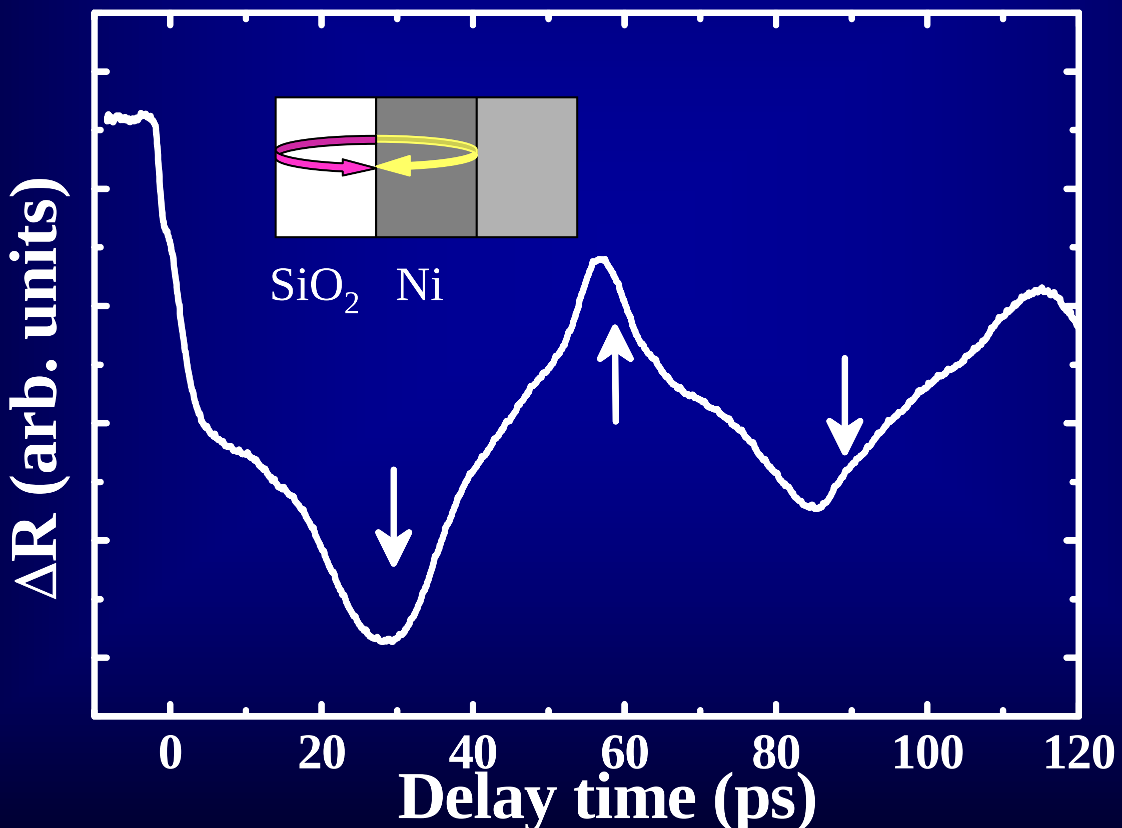
The reflectance change of double layers of Bragg reflector

SiO_2 thickness is smaller than $\lambda/4$



Thickness analysis (4/4)

SiO_2 thickness is close to $\lambda/4$



Conclusions

1. The sound velocities of the SMR constituent nano films, including ZnO, Mo, Ni, W, SiO_2 etc., were measured through the picosecond ultrasonics.

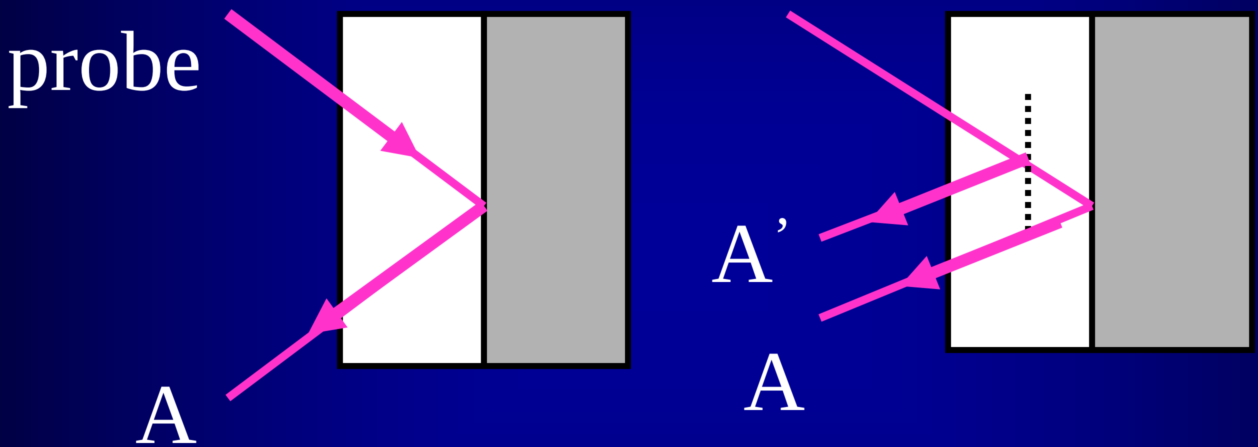
2. The nanofilm velocity is different with the bulk velocity, and accurate velocity can be obtained by measuring

3. The accurate thickness of $\lambda/4$ Bragg reflector can be precisely determined by matching the picosecond ultrasonic echo signals.

Acknowledgement

This project is sponsored by the National Science Council of Taiwan, R.O.C., under grant No. NSC 94-2216-E-014-003.

Thanks for your attention!


probe
A
A'
A