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Thermal Conductivity meter in thin film at Nano scale by 2ω method

TCN-2ω

Simple evaluation of thermal conductivity in thin film

◆ Features

・Evaluation of thermal conductivity in thin film at nano scale

Theory of the instrument is based on the electric periodic heating and the thermoreflectance methods. The temperature increase on the sample surface can be analyzed on the basis of one-dimensional heat conduction model along thickness direction. Thermal conductivity can be simply evaluated along the thickness direction.

・Simple preparation of sample

Metal thin film(1.7mm×15mm×100nm) can be coated on the thin film without the lithography technique.

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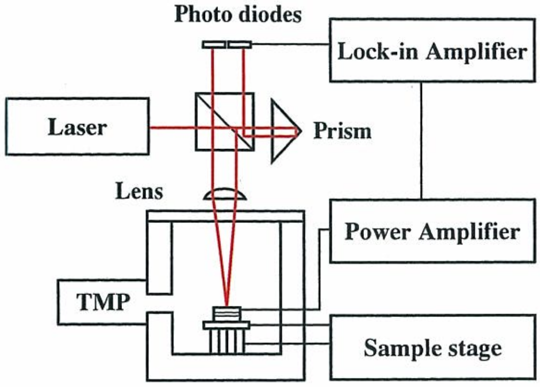
◆ Theory

Metal thin film is heated by the periodic heating method with the basic frequency (f / Hz). As a result, the response frequency with the thermal energy, $2f$ / Hz, is equal to two times as large as the basic one. In the case of the film composed of metal thin film (0) – thin film (1) – substrate (s) as shown in Figure, the temperature increase $T(0)$ on the upper surface for the metal thin film can be calculated on the basis of one-dimensional heat conduction model. Assuming that the energy completely arrived at the bottom substrate, $T(0)$ is following the equation,

$$\frac{T(0)}{q\,d_0}=\frac{1}{\sqrt{2C_s\lambda_s(2\omega)}}+\left(1-\frac{C_1\lambda_1}{C_s\lambda_s}\right)\frac{d_1}{\lambda_1}+\left(\frac{1}{2}-\frac{C_0\lambda_0}{C_s\lambda_s}\right)\frac{d_0}{\lambda_0}+\frac{i}{\sqrt{2C_s\lambda_s(2\omega)}}$$

(λ / W m^{-1} K^{-1}, C / J K^{-1} m^{-3}, q / W m^{-3}, d / m, $\omega(=2\pi f)$ / s^{-1})



Schematic figure of TCN-2ω.

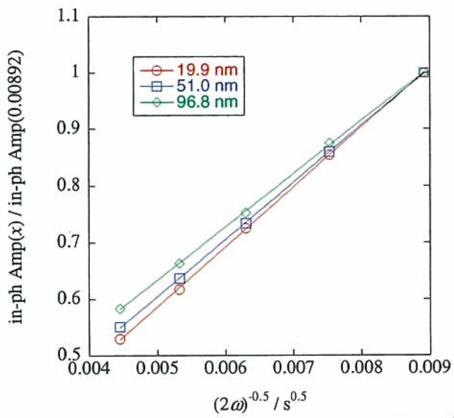
We note that the real part (in-phase amplitude) contains the information for the thin film. Assuming that the thermal energy completely arrives at the bottom substrate, the in-phase amplitude is proportional to $(2\omega)^{-0.5}$. Thermal conductivity for the thin film (λ_1) is estimated from

$$\frac{1}{\lambda_1}=\frac{1}{d_1}\left(\frac{C_1d_1+C_0d_0}{C_s\lambda_s}-\frac{d_0}{2\lambda_0}+\frac{n}{m\sqrt{2C_s\lambda_s}}\right)$$

(m:slope, n: intercept)

◆ SiO_2 thin film(20 - 100 nm) – Si substrate

d_1 / nm	λ_1/ W m^{-1} K^{-1}
19.9	0.82
51.0	1.03
96.8	1.20



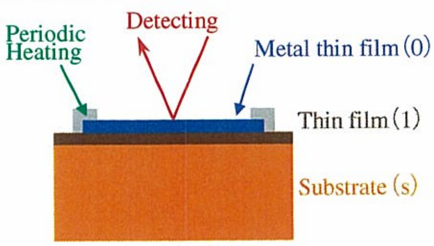
Experimental result for various SiO_2 thin films measured by TCN-2ω.

◆ Specification

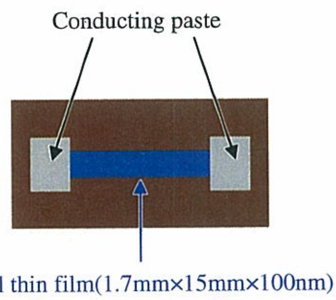
Measurement temperature	room-temperature
Sample size	wide 10 mm length 20 mm thickness 0.5 – 1 mm (Substrate)
Substrate	Si (recommendation), Ge, Al_2O_3 (High thermal conductivity)
Preparation	Gold thin film of thickness at 100 nm coats thin film.
Measurement range	0.1 ～ 10 W m^{-1} K^{-1} in thin film (When thermal conductivity of thin film is about 1 W m^{-1} K^{-1}, thickness of thin film is above 20 nm.)
Measurement atmosphere	in vacuum

◆ Application

- Low-k film
- Organic thin film
- Thin film of thermoelectric material



Evaluation in thin film.



Sample preparation.

● Specifications are subject to change without notice for further improvement.

Agent

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