

CCD近赤外イメージングによる金属細線の温度測定の検討

In-Situ Temperature Measurements of Current Heating Process in Metal Wires
Using Near-Infrared CCD

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Introduction

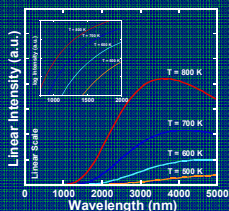
- In-Situ Optical Microscope Observations of Formation Process of Gaps in μm -Scale Metal Wires during Electromigration^[1]
 - Measurements of High Local Temperatures during the EM Process by Thermal Emission Microscopy^[2] and Thermography^[3, 4]
 - Complicated Procedure and Expensive Facility
 - In-Situ Temperature Measurements of Cr Wires Using Near-Infrared Thermography with a CCD Camera^[5]
- In-Situ Temperature Measurements Easily of Current Heating Process in Metal Wires**

[1] 桑原 洋介: 第55回応用物理学会秋季大会講演予稿集 (2009) 1p-ZQ-6.
[2] D. R. Ward et al., Appl. Phys. Lett. 93 (2008) 213108.
[3] S. Kondo et al., Appl. Phys. Lett. 67 (1995) 1606-1608.

[4] S. Kondo et al., J. Appl. Phys. 79 (1996) 736-741.
[5] D. Teyssieux et al., Rev. Sci. Instr. 78 (2007) 034902-1.

Measurement Setup Using Infrared Microscope with Near-Infrared CCD

Planck's Law Black Body Radiation

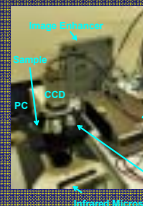
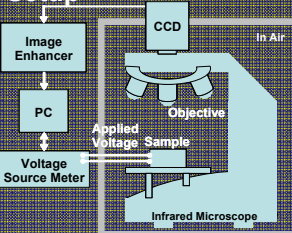


Radiation Density $P(\lambda, T)$

$$P(\lambda, T) = \frac{2c}{\lambda^4} \left\{ \exp\left(\frac{hc}{\lambda kT}\right) - 1 \right\}^{-1}$$

Units: (photons/m²·sec·μm)
c: Light velocity
λ: Electromagnetic wavelength
h: Planck constant
k: Boltzmann constant
T: Absolute temperature

Setup



Infrared Microscope
• BH-2-IR, Olympus
• Objective 100x
Near-Infrared CCD
• MC-781P-0030, Texas Instruments Corp.
Image Enhancer
• TS-100, MSJ Corp.

In-Situ Temperature Measurements of Metal Wires Using Infrared Microscopy

Thermal Sensitivity of the Setup

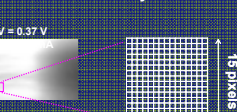
Images of Tungsten Filament Wire Using the Setup

Filament Voltage $V = 0.00$ V
Filament Current $I = 0$ mA

$V = 0.27$ V
 $I = 75.4$ mA

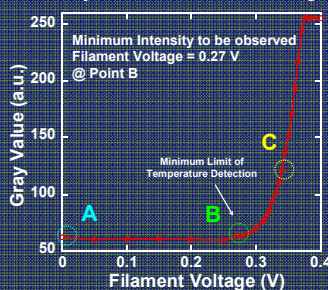
$V = 0.34$ V
 $I = 80.0$ mA

Estimation of Gray Value



Gray Value = Averaged Intensity of each pixel

Gray Value vs. Filament Voltage



Near-Infrared Images of Filament Wire (Color)

Filament Voltage $V = 0.00$ V
Filament Current $I = 0$ mA

$V = 0.27$ V
 $I = 75.4$ mA

$V = 0.34$ V
 $I = 80.0$ mA

Observations of Radiation from Graphite

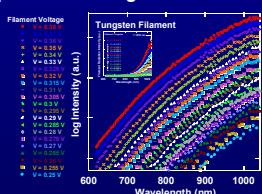
Applied Voltage = 0 V

$V = 4.5$ V

$V = 5.0$ V

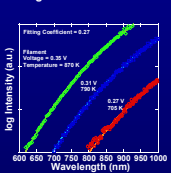
Estimation of Tungsten Filament Temperature by Planck's Law

Spectra of W Filament Wire Measured by MCA (Filament Voltage = 0.25 ~ 0.38 V)

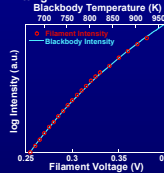


Fitting of Radiation Emission Intensity

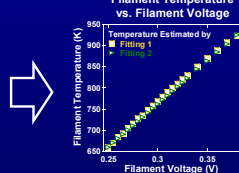
Fitting 1



Fitting 2



Good Agreement between Filament Voltage and Filament Temperature



In-Situ Imaging of Current Heating Process of Tungsten Filament Wire

Fitting of Spectra of the Tungsten Filament wire with a Blackbody Radiation

Limit of Temperature Detection Filament Temperature = 705 K \pm 5 K @ Filament Voltage = 0.27 V

This results allow to measure the temperature of metal wires using a standard near-infrared CCD.

Conclusions

- Development of the Setup for Measurement of Temperature Using Infrared Microscope with Near-Infrared CCD
- In-Situ Temperature Measurements of Current Heating Process of the Tungsten Filament Wire 705 K \pm 5 K @ Filament Voltage = 0.27 V
- In-Situ Imaging of Near-Infrared Radiation from Graphite Sheet
- Near-Infrared Imaging of Various Materials

These results suggest that the simple CCD system can easily obtain near-infrared images during heating.