



# Investigation of Electromigration in Micrometer-Scale Metal Wires by In-Situ Optical Microscopy

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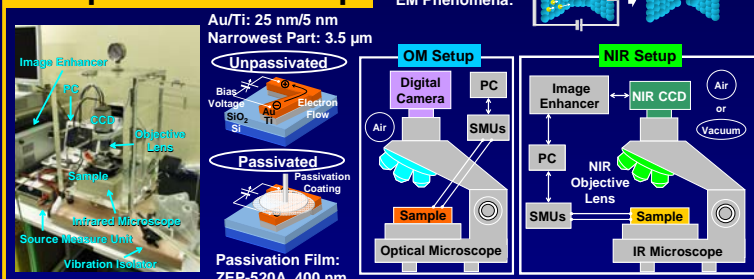
## 1. Introduction

- ◆ Fabrication Technique for Closely Spaced Electrodes by **Electromigration (EM)** [1, 2]
  - Joule heating and local temperature play a key role for the evolution of EM [3].
- ◆ **EM-Induced Gap Formation** in Au Wires [4, 5]
  - Scanning Electron Microscopy (SEM) & Transmission Electron Microscopy (TEM)
  - High Voltages and/or High Vacuum Environments
- ◆ **Heating in Al [6, 7] and Pt [8] Wires before and during EM**
  - In-Situ Temperature Measurements Using Thermal Emission Microscopy
  - Complicated Experimental Procedures and/or Expensive Facilities

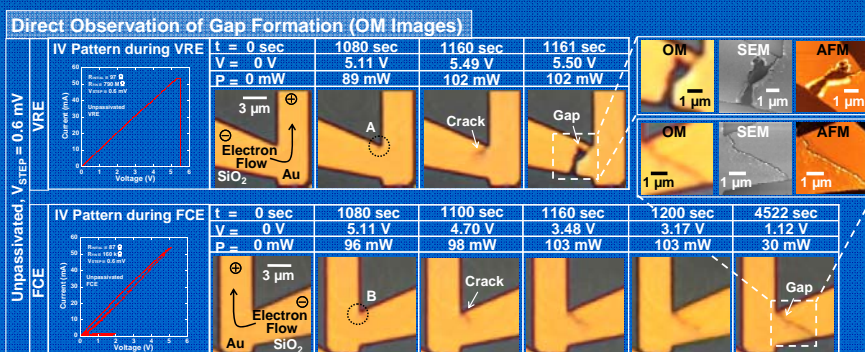
[1] H. Park et al., Appl. Phys. Lett., vol. 75, pp. 301-303, 1999. [2] D. R. Strachan et al., Appl. Phys. Lett., vol. 86, pp. 043109, 2005.  
[3] T. Taychatanapat et al., Nano Lett., vol. 7, pp. 652-656, 2007. [4] D. R. Strachan et al., Phys. Rev. Lett., vol. 100, pp. 056805, 2008.  
[5] M. L. Truonborst et al., J. Appl. Phys., vol. 99, pp. 114316, 2006. [6] S. Kondo et al., J. Appl. Phys., vol. 79, pp. 736-741, 1996.  
[7] S. Kondo et al., Appl. Phys. Lett., vol. 67, pp. 1686-1688, 1995. [8] D. R. Ward et al., Appl. Phys. Lett., vol. 33, pp. 213108, 2008.

**This Study: Investigation of Electromigration by In-Situ Optical Microscopy**

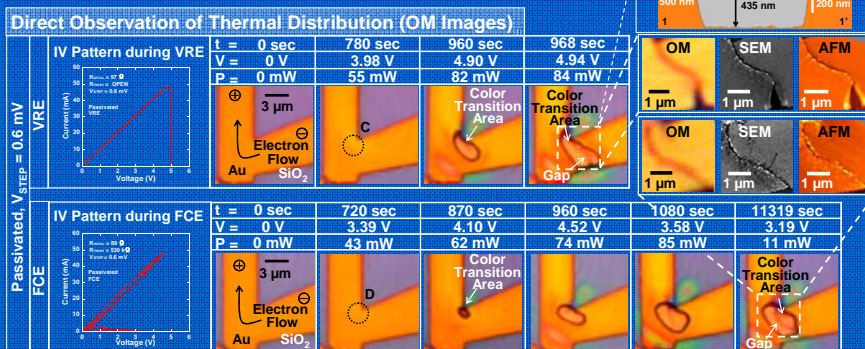
## 2. Experimental Setup



## 3. In-Situ Optical Microscopy (OM) of Electromigration



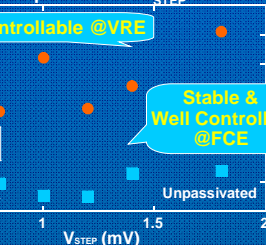
- VRE: The crack rapidly grew, and a gap was clearly formed.
- FCE: The crack slowly grew and uniformly extended.



- VRE: The color transition area was enlarged due to Joule heating process by the EM.
- FCE: A gap was slowly formed and a gradual color transition was clearly observed.
- The temperature of the passivation film was estimated to be above 473 K [9].

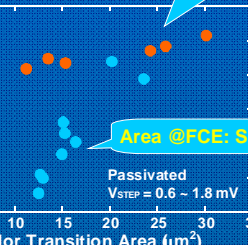
[9] ZEON CORPORATION, ZEP520A High Resolution Positive Electron Beam Resist Technical Report, Ver. 1.02, April 2003. Available at <http://www.zeon.co.jp/>.

Gap Width vs.  $V_{STEP}$



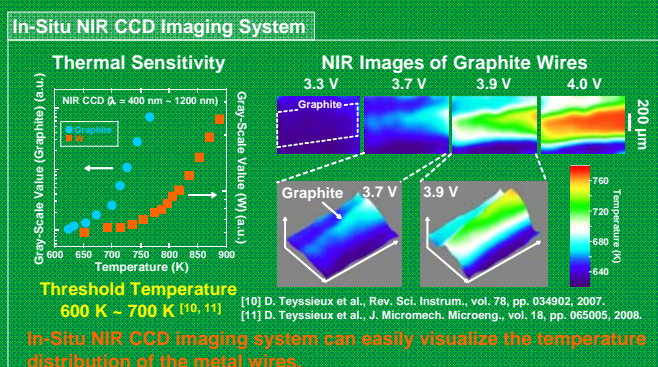
Gap @FCE: Uniform & Narrow

Power vs. Area

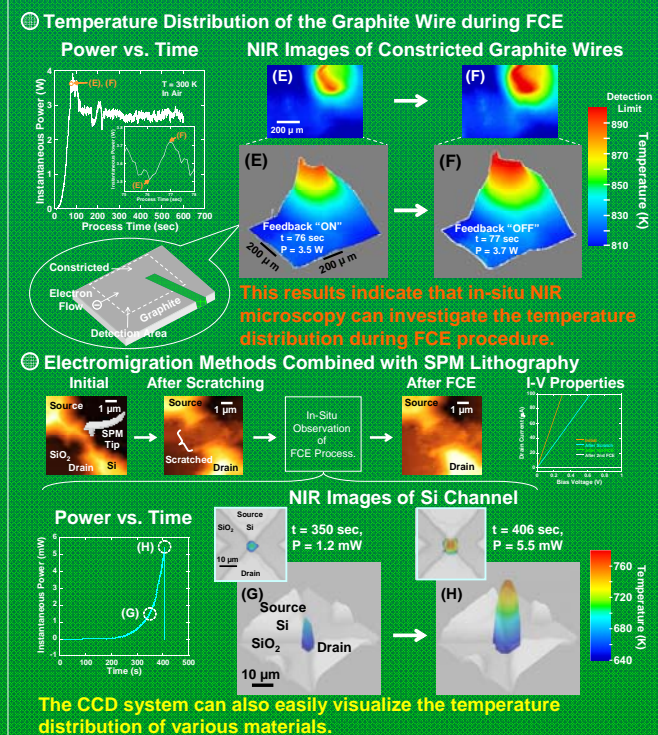


Area @FCE: Small

## 4. In-Situ Near-Infrared (NIR) Microscopy



### FCE Procedures in Graphite Wire and Si Channel



## 5. Conclusions

It is suggested that the simple NIR CCD imaging system can easily obtain NIR images during EM of μm-Scale metal wires.

- ◆ Gap Formation and Thermal Distribution during EM in μm-Scale Metal Wires Investigated by In-Situ Optical Microscopy
  - A gap was formed **rapidly** in VRE and **slowly** in FCE processes.
  - The color variation of the passivation film was **clearly visualized** around the gap and was **gradually caused** in the FCE procedure.
- ◆ A Hand-Made, In-Situ NIR CCD Imaging System
  - The threshold temperature for detection in the system is approximately 700 K. ⇒ Simple NIR CCD imaging system can easily obtain NIR images during EM.

**In-situ optical microscopy can simply and easily investigate EM process of various materials in ambient air.**