

## In-Class Exercise P-RAM SOLUTIONS

1. Describe the difference between resistance, resistivity, conductivity, and resistance. See equations 18.2, 18.3, 18.7, 18.8, 18.10
2. One emerging new non-volatile memory is P-RAM (phase change random access memory) or OUM (Ovonyx Unified Memory). This memory technology works by melting a material and quickly cooling it. It has two states: the crystalline (pre-melted) and amorphous (glassy material that forms after it is melted and quickly cooled). They have drastically different resistivities. So, when a voltage is applied the device will either have a large or virtually no current depending on the crystal state of the material. (See backside for a picture.)

Calculate the different currents in the crystalline and amorphous states of a P-RAM device using the information below.

- The resistivity of the crystalline state is approximately  $25\text{m}\Omega\cdot\text{cm}$
- The resistivity of the amorphous state  $25\ \Omega\cdot\text{cm}$
- The memory bit is really a spherical cap that is melted. However, approximate it as  $0.5\ \mu\text{m}$  cube.
- A reasonable read voltage is  $0.2\text{V}$

Crystalline State:

$$V = IR$$

$$I = \frac{V}{R}$$

$$R = \frac{\rho L}{A}$$

$$I = \frac{V \cdot A}{\rho L} = \frac{0.2\text{V} \cdot (0.5 \times 10^{-6}\text{ m})^2}{25 \times 10^{-3}\ \Omega \cdot \text{cm} \cdot \frac{\text{m}}{100\text{cm}} \cdot 0.5 \times 10^{-6}\text{ m}} = 0.4\text{mA}$$

Amorphous State:

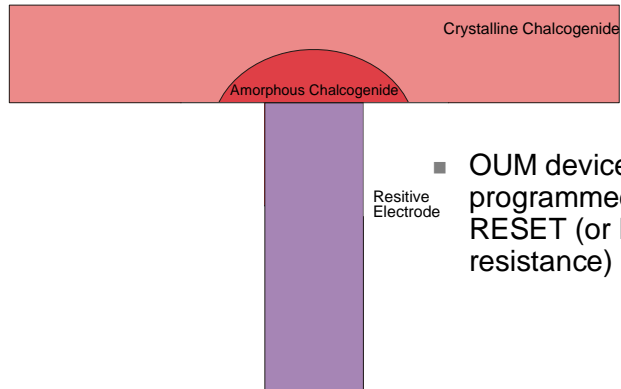
$$I = \frac{V \cdot A}{\rho L} = \frac{0.2\text{V} \cdot (0.5 \times 10^{-6}\text{ m})^2}{25\ \Omega \cdot \text{cm} \cdot \frac{\text{m}}{100\text{cm}} \cdot 0.5 \times 10^{-6}\text{ m}} = 4 \times 10^{-7}\text{ A}$$

*Note: This is an approximation of the current. The current is actually determined by the heater element, the chalcogenide element, and the metal connection lines in series.*

# Basic Schematic of OUM Device

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- Data storage region



- OUM device when programmed to the RESET (or high-resistance) state.