# STEM ED/CHM Nanotechnology at UMass Amherst

## Nanoscale Electrodeposition Guide

**Note:** The last page can be given to students as a guide for making calculations.

**The Nanoscale Context**: This activity provides an opportunity for students to apply an understanding of relationships among the amount of electric current flowing through a circuit, the time that the current is flowing, the number and diameter of ions that undergo chemical reduction, and the nanoscale thickness of a thin layer of a metal.

**The STEM Context**: Examples of opportunities to integrate this activity into the STEM curriculum include:

- the study of the distinction between neutral atoms and charged ions.
- the distinction between an electrolytic cell and an electrochemical cell.
- the conductivity of solutions of ionic compound, the nature and characteristics of electric fields.
- mathematical operations with scientific notation
- dimensional analysis operations with measurement units

National Science Education Learning Standards Examples

- Science as Inquiry Content Standard A; Grade 5-8 (Page 148): "Mathematics is important in all aspects of scientific inquiry."
- Physical Science Content Standard B; Grades 9-12 (Page 179): "A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms."

Massachusetts Science and Technology/Engineering Learning Standards Examples

- Physical Sciences; Grades 5-8 (Page 64): "Identify the basic forms of energy (light, sound, heat, electrical, and magnetic). Recognize that energy is the ability to cause motion or create change."
- Physical Sciences; Grades 6-8 (Page 68): "Differentiate between physical changes and chemical changes."
- Chemistry, High School (Page 71): "Describe oxidation and reduction reactions and give some everyday examples, such as fuel burning and corrosion. Assign oxidation numbers in a reaction."

Massachusetts Mathematics Learning Standard Example

- Measurement; Grades 7-8 (Page 65); "Demonstrate and understanding of the concepts and apply formulas and procedures for determining measures……"
- Measurement; Grades 9-10 (Page 75); "Describe the effects of approximate error in measurement and rounding on measurements and on computed values from measurements."

**Materials for the Activity**

**Zinc Nitrate**
**Battery Holder**
**Electrodes**

- Zinc electrodes
- Copper electrodes

**DC Ammeters or Digital Multimeters**
**On/Off Switches**
**Lead Wires**

- Banana plug on both ends
- Banana Plug on one end and Alligator Clip on the other end

**Voltaic Cell**
**Local Purchase:** Painter's masking tape, Scouring Pads, D Batteries, Stopwatches, 8 oz. Mason jar for the voltaic cell kit.

**Activity Strategies**

**Physical Science**: Discussing operations with scientific notation and the definition of an ampere will guide students through the series of calculations in this activity. Worksheet can be provided with or without the necessary formulas for each calculation.

**Physics** students can also evaluate the influence of the nature of the electric field generated by the copper and zinc plates on the distribution of zinc metal on the copper electrode. In addition, physics students can manipulate the structure of the electroplating cell and the electric circuit to produce a more even electroplating process.

**Chemistry:** Instead of providing students with the diameter of a zinc atom, students can calculate that diameter using the number of grams per mole of zinc, the density of zinc and Avagadro's determination of the number of atoms in one mole of a substance.

An example of the calculation of the diameter that uses dimensional analysis to determine the number of atoms in one cubic centimeter of zinc would be:

$$(1 \text{ mole}/65.39 \text{ g}) \times (7.14 \text{ g/cm}^3) \times (6.02 \times 10^{23} \text{ atoms/mole}) = 0.657 \times 10^{23} \text{ atoms / cm}^3$$

$$1 \text{ cm}^3 / 0.657 \times 10^{23} \text{ atoms} = 1 \text{ cm}^3 / 65.7 \times 10^{21} \text{ atoms}$$

The cube root of the number of atoms in a cubic centimeter would indicate the number of atoms along one edge of the cube.

The cube root of $65.7 \times 10^{21}$ atoms / cm$^3$ = $4.03 \times 10^7$ atoms/cm

That fraction can then be inverted to determine the diameter of a zinc atom.

$$1 \text{ cm} /4.03 \times 10^7 \text{ atoms} = 0.248 \times 10^{-7} \text{cm /atom} = 0.248 \times 10^{-9} \text{m /atom} = 2.48 \times 10^{-10} \text{ m /atom}$$