

Lesson Outline for ALEX

General Lesson Information

Title: Direct ink writing (DIW) method to 3D print thermoset polymers

Overview/Annotation- *A short summary or description of the lesson including activities and science concepts.*

Direct ink writing (DIW) is an additive manufacturing method of thermoset polymers including different types of epoxies, silicone rubbers, polyurethanes, and other critical materials. This class of polymer is characterized by strong covalent bonds that cannot be melted by heat. As a result, the commonly available polymer 3D printers are unable to process these materials simply by heat treatment.

Therefore, thermoset polymers which are widely used in aerospace, automobile, electronics, and biomedical fields, require a different printing process. DIW is an emerging 3D printing technology for thermosetting polymers that extrudes a liquid-phased mix of the polymers before their bonding is formed. Different categories of materials could be printed by this technique as long as the liquid mix satisfies the essential rheological properties.

From this lesson, the students will learn the important distinction of polymer categories and their suitable printing methods.

Setting or format (outdoors, in groups, lab, etc.): Regular classroom

Intended group size (if groups are used): 5-7 students

Intended grade level(s): 8-12

Approximate Time of Lesson (*Ideally break down into 20-50 minute periods*):

Lesson: 30 minutes

Demonstration: 20 minutes

Researcher Biography

Name & Professional Title:

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Brief Description of Research Interests:

Additive manufacturing, Smart materials, Adaptive structures, Soft electronics and robotics

Associated Standards and Objectives

Content Standards- *List Alabama Course of Study Standards that connect to lesson*
ME 383: Advanced Manufacturing Processes
ME 440: Failure of Engineering Materials
ME 583: Additive Manufacturing

Primary Learning Objectives- *Sentences beginning with “Students will be able to...” that describe what students will do in the lesson that relates to how students will be assessed.*

Students will be able to:

- Differentiate the major classes of polymers
- Understand the rheological properties of materials
- Explain different additive manufacturing methods
- Understand the chemistry of polymer bonds and solidification

Additional Learning Objectives- *Any learning outcomes that are not directly related to the content standards but may relate to other local or national standards*

Preparation Information

Total Duration- *How many minutes will the lesson last?*

50 minutes

Materials and Resources- *List of materials teacher will need to gather or prepare for lesson*

- Syringe and nozzle for extrusion
- Base and curing agent of thermoset polymers
- Heat gun for curing

Technology Resources Needed- *What technology will teacher and students need for the lesson?*

- A computer and projector to show slides and videos

Background and Preparation- *Description of information (science content, use of materials, etc.) teacher and/or students will need to know prior to this lesson; list steps for any preparation prior to the lesson*

- The teachers will be provided with all the equipment for a printing demonstration
- The exact amount of material composition and mixing method will be provided
- The timing for printing and curing will be explained

Procedures and Activities

Step-by-step description of lesson that would allow another teacher to successfully complete the lesson (suggest possible reflection or comprehension questions along with examples of correct answers or common misconceptions)

Engagement (sparking interest, introducing phenomenon, engage students' everyday experiences)

1. Different application fields of polymers.
2. Explain general chemical bonds for two major categories of polymers.
3. Emphasize thermoset polymer applications in vehicle, biomedical, and energy sectors.
4. Different 3D printing methods based on the type of polymers.
5. Introduce silicone rubber materials and their constituents.
6. The rheological property that allows DIW printing.

Main activity (suggest possible reflection or comprehension questions along with examples of correct answers or common misconceptions)

1. After understanding the materials needed for 3D printing, show the fundamental components.
2. Show a list of chemical agents that should be mixed in the liquid phase.
3. Use a table to indicate the quantity of each agent to get the covalent crosslinking.
4. Show a weighing scale and demonstrate how to measure weight.
5. Take a mixing cup to fill with the precise quantity of chemical agents using the scale.
6. Mix the chemicals using a spatula for a certain duration.
7. Pour the mixture into a syringe and fit a nozzle of a specific size.
8. Push the syringe and draw 3D printed lines on a glass slide.
9. Draw multiple layers on top of each other in this process to make a wall-like feature.
10. Use a heat gun to thermally cure the printed architecture.

Wrap up and Reflection (wrap up activity, reflecting on learning, informal assessments of student learning)

1. Ask the students about the difference between 3D printing processes.
2. What would be the effect of different sizes of nozzle?
3. How to change the rheology of the materials?
4. Where do they think this 3D printing method would be valuable?
5. How will the printing method work in an industrial setting?

Final product/Summative evaluation (e.g. quiz, presentation, essay, etc., may occur during a later class period)

1. An MCQ-based quiz on the materials and printing methods.