Coat that Fuel Pellet

Be a Nuclear Scientist! Share Your Fuel Coating with Argonne Education!

Argonne scientists have discovered a new way to coat nuclear materials that are used to help create electricity in nuclear power stations. Nuclear reactors are devices for creating a nuclear chain reaction to generate electricity. Inside an operating nuclear reactor, the environment is extreme. Reactor components are exposed to a combination of intense radiation (energy that can be harmful) and heat as well as coolant. That's why, in order to operate reactors safely, scientists need to design their components with materials that can withstand these conditions. Inside nuclear reactors, the radioactive fuel, which has been pressed into small pellets and stacked inside of fuel rods, provides the energy that is turned into electricity. Coating these components can help improve the operation and safety of nuclear reactors.

Top left: Nuclear fuel pellet; Bottom left: Pellets arranged in fuel rods (Source: Nuclear Regulatory Commission). Right: Inside Idaho National Laboratory's Advanced Test Reactor (Source: Argonne). Banner credit: Wikimedia Commons.

Materials:

- Printed "Properties of Kitchen Ingredients" and "My Coatings" sheets & pencil (or make your own)
- Pellet-like candy with a bright dye (Examples: M&M's, Skittles, jelly beans)
- All-purpose flour, sugar, corn starch, water, cooking oil (any type)
- Spoons, bowls, microwave-safe coffee mugs or glasses
- Timer
- Microwave

Optional Materials: Additional kitchen ingredients (see instructions)

Introduction

You can find coatings everywhere – from the non-stick coating on a frying pan, to the epoxy coating inside a metal can of vegetables, to the coating on a tablet screen that keeps your oily fingerprints away. Scientists and engineers design coatings, and the ways to apply them. They choose or invent coatings that have chemical properties that are useful for solving the problem at hand, for example, to protect an item from water, chemicals, heat, or even air.

Argonne Materials Science Engineer Anil Mane prepares silicon wafers testing of new coatings for large area detectors, which are useful for many scientific applications (Source: Argonne),

Argonne scientists and engineers develop coatings for a variety of uses, including materials for electronics or renewable energy sources. One important use of coatings is to protect pellets of nuclear fuel from leaking in the extreme environment inside a nuclear reactor. For this problem, scientists want to develop a coating where energy can efficiently escape from the fuel pellet to make electricity, but keep the fuel itself inside.

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In this activity, you will be the nuclear scientist at home. You will design a coating that can help protect a pellet-shaped object (candy) from water, heat, and microwave radiation in your kitchen!

In this activity you will:

- Explore the chemical properties of ingredients found in your kitchen.
- Design a coating that protects a candy's dye from escaping when soaked in water or heated in the microwave.
- Explain why your coating worked the best, and others not so much!

Alyssa Skulborstad (2009 Undergraduate Summer Intern) conducts measurements of a new coating developed at Argonne National Laboratory using a "microhardness" test machine. This new coating process produces a valuable, hard, wear-resistant layer on steel materials. (Source: Argonne)

Basic Coating Procedure

Start with this basic coating technique

Making your first coating of flour + water.

1. Add about 2 tablespoons (TBS) of flour to a small bowl.
2. Slowly add water, a few drops at a time, while mixing constantly with a spoon until a sticky dough forms.
3. Using your fingers and/or a spoon, coat one of your candies. Try to make the thinnest coating you can. For a real fuel pellet, you would want it to be thin enough that the fuel's energy would still escape, but thick enough to cover the pellet entirely so that no fuel can escape.
4. Test your coating by adding your coated pellet to a mug of room temperature water. This is your "reactor" environment. Set a timer. The goal is to have it last 5 minutes without any dye from your candy leaking into the surrounding water.

How did it go? Think you can do better?

Explore Kitchen Compounds

A kitchen is basically a chemistry lab. As you mix ingredients, you can create compounds with interesting properties. Let's explore some common ingredients and think about their properties.

List your ingredients. Try to classify them as being composed of **water**, **carbohydrates** (sugar, starch, fiber), **lipids** (fats), **polypeptides** (proteins), **minerals** (table salt), or combinations of these. In the kitchen, you will encounter many examples of combination food types. (An egg, for example, has protein, but also a lot of water in it!) If an ingredient has a label, you can read it for this information. If not, you can look it up on the internet. Find two additional ingredients in your kitchen to classify under "My Ingredients" to use in your experiments.

Explore the properties of kitchen ingredients. (Source: Wikimedia Commons)

Write what you know or observe about the ingredients' properties. In particular, think about the challenge: we are designing something that won't come apart in water, will stick well to the pellet, and later won't be destroyed by heat in a microwave. Observe the ingredient's texture and how well it might mix with other ingredients to make a coating that will hold up to the testing.

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We tested out a control jelly bean (with no added coating) and one with a coating. Ours failed -- coating came apart and red dye escaped!

Step 1: Create a Pellet Coating That Survives 5 Minutes in Tap Water

Place water at room temperature in a microwave safe mug. This is your "reactor". You may only use 2 ingredients for the pellet coating. If any candy dye escapes the pellet into the surrounding water during the 5 minutes, the coating is no good! Try another coating mixture.

Record your failures and successes on the "My Coatings" sheet.

Did you find any coatings that do a good job of repelling water? If so, you've created a ***Hydrophobic*** coating (literally meaning "fear of water", since it tends to repel or fails to mix with water).

Safety Note!

For the next steps, be sure to asks an adult's permission to use the microwave.
Make sure you put water in your container, as it is dangerous to heat the pellet by itself.

Step 2: Create a Pellet Coating That Also Survives Microwaving

Time to go further. Can your pellet survive water and heat/radiation? After soaking 5 minutes in water, if it is still intact with no leaking, place the entire microwave safe mug (with water and pellet) inside the microwave and heat for 30 seconds. Then remove it and allow your pellet to sit for 5 minutes in the warm water on the counter. If any dye escapes the pellet into the surrounding water during the microwaving or the 5 minutes of sitting afterward, the coating is no good! Try another coating mixture.

Record your failures and successes on the "My Coatings" sheet.

Did you design a coating that does a good job of protecting the candy from the heat? If so, you've created an **Insulator** (a substance that doesn't readily allow the passage of heat).

Put your reactor (mug of water with coated candy) inside the microwave and cook it for 30 seconds. Then carefully remove the mug and let sit for 5 minutes, observing if the coating comes apart or the dye leaks.

Step 3: Create a Second Pellet Coating That Survives Water/Microwaving

What properties of your ingredients helped it survive both the water and the microwave? Test your idea by creating another coating recipe where you change one of the ingredients to something with similar properties and see if it also works!

Step 4: Share Your Fuel Coating with Argonne Education

Take a picture of your best coated pellet that survived the water and microwave test. Make a list of the ingredients you used and send it to Argonne Education at learninglabs@anl.gov, or have an adult tweet it out to @Argonne and #ArgonneAtHome.

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Properties of Kitchen Ingredients

Kitchen Ingredients	***Ingredient Type***	***Known/Observed Properties***
Tap Water	*Water*	*Liquid, clear, dissolves a lot of things, mixes with others* *Additional properties:*
All-Purpose Flour	*Carbohydrate*	*Powder, can dissolve in water, but not well* *Additional properties:*
Cooking Oil		
Sugar		
Corn Starch		
My Ingredient:		
My Ingredient:		

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My Coatings

Coating Ingredients (List 2)	***Notes or Observations about Coating Procedure***	***Did it survive 5 minutes in tap water?***	***Did it survive 30 seconds in microwave and 5 minutes sitting afterward?***
Flour + Water			

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