Estimated Time
- Part A, 10 minutes
- Part B, 20 minutes
- Part C, 30 minutes

To Save Time
Build the PVDF monomer models before class and have students begin with Interpretations of the Data in Part A, on page 20.

Suggested Grouping
Part A: pairs
Part B: groups of six to eight
Part C: groups of three

Activity Objectives
Students will:
- construct a molecular model of the PVDF film and use this model to describe how PVDF acquires polarization
- describe how PVDF film produces an electrical signal
- explain how the degree and speed of bending affect the electrical output of PVDF

Part A
Materials (per pair)
- molecular modeling kit

Troubleshooting
If your students have not had recent experience with molecular model kits, briefly review the components of the kit and describe how they should make single and double bonds between atoms.

4 ACTIVITY

Exploring the Piezo Effect: The Inside Story

Researchers recently discovered that when they applied an electric field to melted chocolate bars, the chocolate immediately became stiff. When the researchers shut the power off, the chocolate immediately became runny again. To try to explain this, they considered what chocolate bars are made of: a suspension of sugar, cocoa powder, and milk solids with a small amount of water in an oily fluid—liquid cocoa butter. An earlier experiment had confirmed that suspended particles acquire induced charges and act as molecular dipoles in the presence of an electric field. The arrangement of the dipoles affects the structure and performance of the material in which the dipoles occur. In an electric field, suspended particles in the melted chocolate lined up and stuck to each other, making the chocolate become rigid.

PVDF film is also made up of dipole molecules. The way positive and negative charges are arranged in the film holds the key to its performance as a smart sensor material. Understanding how PVDF's chemical structure relates to the voltage it generates will help you design new applications for the film.

Think about these questions as you do the activity:
- ? What happens to the PVDF polymer when it undergoes polarization?
- ? What molecular orientations produce piezoelectric properties in a polymer?
- ? To what is the PVDF film reacting when it generates a voltage?

Design Connection If you were to use PVDF in a sensor, how could you regulate the strength of the electrical charge it generates?

Part A **Building the PVDF Monomer**
You are about to use molecular model kits to explore how PVDF is formed from individual atoms and small molecular units. Work in groups to make models from the molecular model kit. You'll begin by working with other members of your group and will later team up with the rest of the class.

18 Smart Sensors Module

Leading In to the Activity
Have students read the introductory material about melted chocolate on page 18. Ask them to suggest ways someone could replicate this experiment. Guide them to see that they would need to find a way to apply an electric field to a liquid. When they have generated some ideas about how this could be done, discuss safety issues they might encounter in setting up such an experiment. If you wish, have students briefly discuss what they have learned in physics or chemistry classes about how an electric charge moves through materials such as liquids and solids.

You could demonstrate a similar effect by mixing iron filings into vegetable oil. Applying a strong magnet to the outside of the container should cause the iron filings to line up and "stiffen" the vegetable oil.

Explain that the chocolate bar experiment is an example of how electrorheological fluids work. Rheology is the study of how matter flows and is deformed. Ask students if they can think of possible applications for the chocolate bar phenomenon. Applications currently being researched in universities and by automobile manufacturers include applying a current to change the viscosity of motor oil, which could give drivers better control over engine lubrication based on actual driving conditions.

Ask students why they think the lining up of dipoles stiffens the chocolate. If necessary, suggest that they describe the three phases of matter in terms of how "organized" the constituent molecules are. Help them see that the attractions between polar molecules help hold the dipoles together and thus stiffen the chocolate.

Recording Observations
Activity-Log Sheet 5 includes space for students to sketch isomers and identify positive and negative regions of the difluoroethylene molecule.