Teacher's Guide: Flash Ignition of Carbon Nanotubes

Dean J. Campbell

Department of Chemistry and Biochemistry, Bradley University, Peoria, IL 61625

campbell@bradley.edu

Note: Additional information about these and related demonstrations can be found in: Campbell, D. J.; McCann, J. T.; Xia, Y. "Classroom Scale Demonstrations Using Flash Ignition of Carbon Nanotubes", *J. Chem. Educ., in press.*

Single-walled carbon nanotubes can be ignited in air by the intense light pulse from a camera flash. Demonstrations based on this phenomenon rely on the very small dimensions of the carbon nanotubes to work, illustrating the concept of the unique properties associated with nanoscale structures. Another concept addressed by this phenomenon is the importance of surface area to the rate of chemical reaction. Extremely finely divided carbon structures such as carbon nanotubes can trap sufficient energy from a camera flash to ignite, while more bulky carbon structures will not. The demonstrations described herein are designed to demonstrate this nanoscale phenomenon in a large classroom setting.

Materials needed

- Single-walled carbon nanotubes – each individual tube is impossible to see, but many tubes together appear as very low density black fluff. To maximize the surface area of the nanotubes, AP-grade (AP stands for "as prepared") tubes are recommended.*
- External camera flasher - the coaxial connector at the end of the flasher cable can be modified with a push button for use as a trigger. To be further removed from the combustion and avoid blocking the view of spectators, attach the flasher to some sort of stick or pole.
- Lab goggles and lab gloves
- Ring stand with fireproof clamp or ring
- Scissors or razor blade
- Parafilm® laboratory film or latex glove
- Nested crystallization dishes or beakers
- Spatula
- Forceps

- Permanent marker
- Foldback binder clips
- Aluminum foil
- Empty colorless 2-liter soda bottle
- Newspaper
- Flash paper – available at some magic supply stores
- Spray adhesive

*An excellent web page listing nanotube suppliers is: Tomanek, D. Carbon Nanotube Yellow Pages: http://www.pa.msu.edu/cmp/csc/nanotube.html (accessed July, 2005).

Hazards

The carbon nanotubes have a very low density and can be easily become airborne. The health issues associated with nanostructures are still under scrutiny, but skin contact with and inhalation of the nanotubes and their combustion byproducts should be avoided. Fume hood use can help minimize exposure. Gloves are recommended to help prevent hands from being covered with nanotubes and adhesive. Flash paper is extremely flammable and should be treated with the respect due to all pyrotechnic materials. Care must be taken to prevent accidental ignition from heat, sparks, etc. Do not inhale the contents of the spray adhesive can. After cooling down, the burnt materials can be disposed in the trash. Although the light flashes are brief, they can be hard on the eyes. It is recommended that the light flashes are directed away from the audience.

Experimental procedures

A. Nanotubes on a Drum

NOTE: This demonstration may be performed on an overhead projector.

1. Stretch a Parafilm® sheet (or other plastic film like a latex glove) over the opening of a crystallization dish or beaker. Parafilm® can be stretched to less than one-fifth of its original thickness. A 5 cm x 5 cm sheet can be easily stretched to cover a 7 cm wide dish. To improve the visibility of the thin sheet on an overhead projector, a permanent marker can be used to draw on the film either before or after stretching.

2. Place a small amount (roughly one cubic centimeter) of nanotubes on the film. A spatula is acceptable for moving the tubes, but the tines of an open forceps are also useful for transferring the fluffy material. It is best to do this away from any drafts that could blow the nanotubes

away. Another crystallization dish or beaker can be placed over the first to make sure that the carbon nanotubes are contained. Make sure that all flammable materials are removed from the vicinity of the demonstration. The demonstration is ready.

3. Hold the camera flasher right over the nanotubes. Fire the flash and move it away quickly. There will likely be an audible popping sound from the photoacoustic response of the nanotubes. The nanotubes will ignite, causing the film to melt and/or burn. A film under tension will widen its own holes, making for a more dramatic film failure.

B. Flash-ignited flash paper

1. Suspend a hook (wire or a bent paper clip) from a ring or clamp mounted on a ring stand. Suspend a foldback paper clip from the hook.

2. Cut a 1 cm x 4 cm strip of flash paper using scissors. Combustion of this small quantity of paper appears to be fairly innocuous.

3. Lay the strip of flash paper on newspaper or some other disposable surface. The strips are very light, so tape one end down to avoid blowing them around with the spray adhesive. Spray a light coating of spray adhesive onto the strip. To achieve a thin coating, it may help to direct the bulk of the spray near, but not directly on, the strip. Too much adhesive seems to interfere with the combustion of the strip. Alternatively, a light coating of glue from a glue stick has been used by one of the reviewers of this paper as an adhesive.

4. While the adhesive is still sticky, use a forceps to pick up the strip and place it into a container holding the nanotubes. The tubes will likely stick to the adhesive-coated side of the strip much better than the uncoated side. Gently lift the strip over the container, allowing some of the excess, unbound fluff to fall back into the container. The nanotubes remaining on the strip should be allowed to project away from the strip surface to maximize contact with the air. Pressing the tubes down on the paper will reduce their contact with air and drastically reduce their chances of flash-induced combustion.

5. GENTLY hang the nanotube-laden flash paper strip from the clip on the ring stand.

6. GENTLY hang the second foldback paper clip from the bottom end of the flash paper to keep the strip fully extended. Larger clips will be more dramatic when they fall.

7. An additional safety option would be to cut the colorless 2-liter plastic bottle open near its top and place it over the flash paper/clamp assembly. This will help to contain the nanotubes in the vicinity of the demonstration. Place the aluminum foil below the flash paper to reduce the slim

chance of flames spreading from the burning paper. Make sure that all exogenous flammable materials are removed from the vicinity of the demonstration. The demonstration is ready.
8. Hold the camera flasher very close to the nanotube-laden flash paper. Orient the flash bulb parallel to the direction of the strip so that the maximum flash energy is directed to as many nanotubes as possible. Fire the flash. There will likely be an audible popping sound from the photoacoustic response of the nanotubes, and the flash paper should ignite into a bright flare. As the paper rapidly burns, the large foldback paper clip drops to the foil-covered countertop with a dramatic clank.

I look for the opportunities to use this demonstration in the context of kinetics, materials chemistry, nanotechnology, or even organic chemistry. I introduce the demonstrations by explaining what a carbon nanotube is: effectively a graphite sheet rolled up into a tube with a diameter on the order of nanometers. Then I mention that a few years ago an undergraduate student was trying to photograph a sample of nanotubes, and found that the camera flash ignited the tubes. The tubes absorb light so well they get very hot. At the same time, they are nanoscale structures that are extremely finely divided, which has two effects: the heat cannot be conducted away from the tube very easily and these hot tubes are in intimate contact with the oxygen in the surrounding air, enabling the tubes to burn rather rapidly. At this point I explain how the demonstration is set up. For the demonstration involving the flash paper I try to make some pun connecting the camera “flash” to “flash” paper. I run the demonstration, encouraging them to try to listen to the popping noise the tubes make when they ignite. Firing the camera flash before (and directed away from) the actual demonstration helps them to realize that the popping noise is not due to the flash itself. I do not perform much student assessment of this demo (other than asking the students if they have questions) as the concepts presented seem to be fairly straightforward.