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Static Sparks Can Ignite Flammable Solvent Vapors

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Abstract

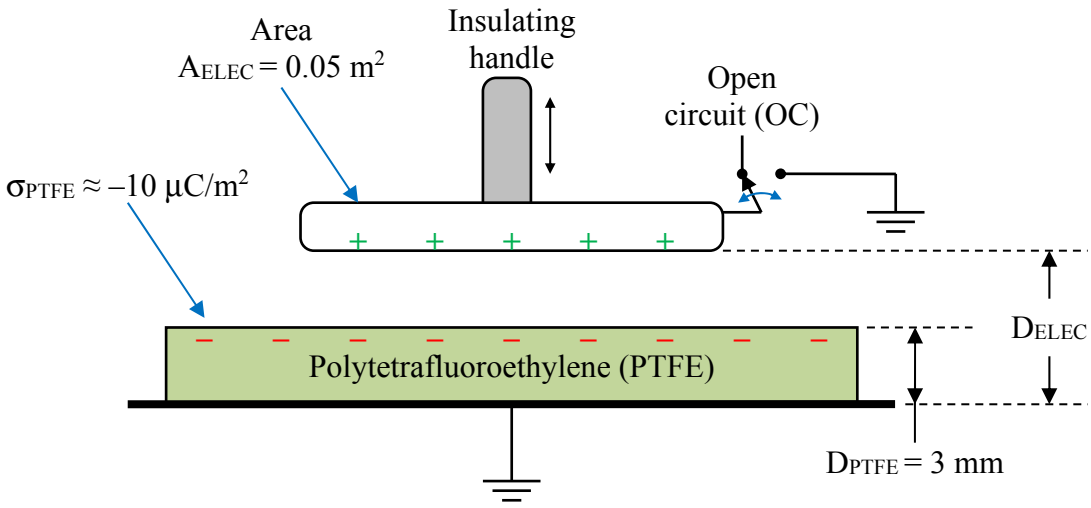

Figure 1: Static charge is induced on the electrically isolated electrode by placing it in contact with the charged PTFE and temporarily closing the switch to ground.

Static sparks release stored electrical energy. In this demonstration, a piece of PTFE in Figure 1 is rubbed vigorously with a natural fiber such as cotton or wool to triboelectrically charge the surface to about –10 μC/m^2. Next, the isolated electrode is placed in contact with the charged PTFE and the switch is momentarily set to ground the electrode. By grounding the electrode, a charge $Q_{ELECTRODE}$ in (1) of +0.5 μC is induced onto the electrodes.

$$Q_{ELECRODE} = -\sigma_{PTFE} A_{ELEC} \approx -\left(-10\frac{\mu C}{m^2}\right)\left(0.05 m^2\right) = +0.5\mu C \tag{1}$$

The stored energy $E_{ELECTRODE}$ in (2) of this charge is about 0.4 mJ.

$$E_{ELECRODE} = \frac{Q^2_{ELECTRODE}}{2C_{ELECTRODE}} \approx \frac{Q^2_{ELECTRODE}}{2\varepsilon_0 \kappa_{PTFE}\left(\frac{A_{ELEC}}{D_{ELEC}}\right)}$$
$$\approx \frac{\left(+0.5\times10^{-6} C\right)^2}{2\left(8.9\times10^{-12}\frac{F}{m}\right)(2.1)\left(\frac{0.05 m^2}{0.003 m}\right)} = 0.4\times10^{-3} J \tag{2}$$

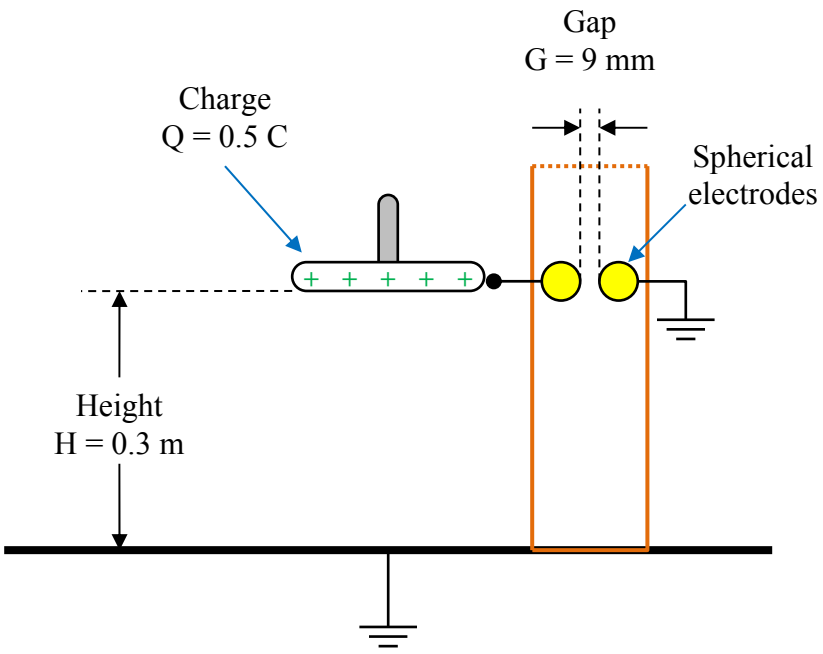

Figure 2: Lifting the charged, isolated electrode increases the stored electrical energy. Touching the charged electrode to the isolated spherical electrode releases the stored energy in a spark.

Two spherical electrodes form a spark gap in an acrylic cylinder which holds a small volume of acetone vapor. The charged, isolated is lifted to a height of about 0.3 meters above the grounded surface. The stored electrical energy $E_{ELECTRODE}$ in (3) of the electrode increases to about 85 mJ.

$$E_{ELECRODE} = \frac{Q^2_{ELECTRODE}}{2C_{ELECTRODE}} \approx \frac{Q^2_{ELECTRODE}}{2\varepsilon_0\left(\frac{A_{ELEC}}{D_{ELEC}}\right)}$$
$$\approx \frac{\left(+0.5\times10^{-6}\,\mathrm{C}\right)^2}{2\left(8.9\times10^{-12}\,\frac{\mathrm{F}}{\mathrm{m}}\right)\left(\frac{0.05\mathrm{m}^2}{0.3\mathrm{m}}\right)} = 85\times10^{-3}\,\mathrm{J} \qquad (3)$$

With the first of the two spherical electrodes grounded, when the charged electrode touches the second electrode, an electrical spark between the spherical electrodes released the electrical stored energy.

When the cylinder contains flammable acetone vapors having a minimum ignition energy of 1.15 mJ, the spark releases sufficient energy to ignite the vapors. The apparatus safely vents the ignition through the open top of the cylinder. An apparatus similar to this may be used to measure the minimum ignition energy of vapors.