Testimony of

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Subcommittee on National Security, Emerging Threats and International Relations

on

"Counterterrorism Technology: Picking Winners and Losers"

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at

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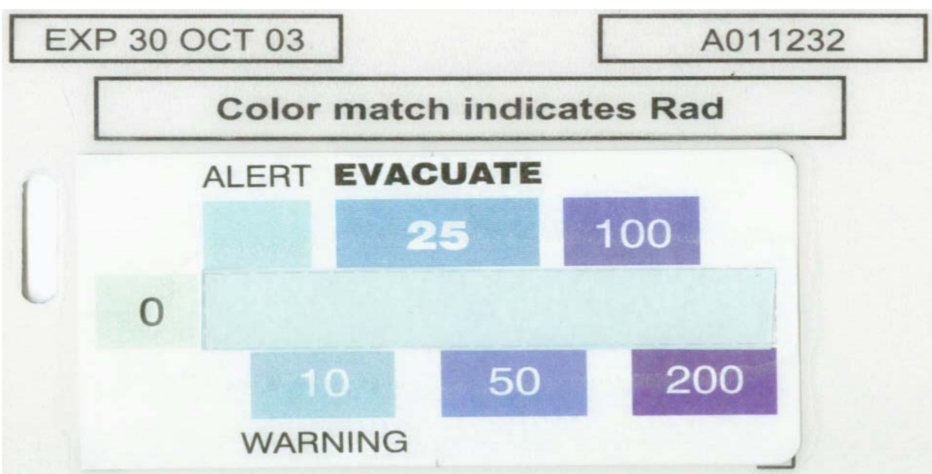
EXECUTIVE SUMMARY

After the events of September 11th, governments around the world have become acutely aware of potential terrorist attacks. Terrorists have a variety of weapons available to them - conventional explosives, chemical or biological agents, and a new weapon called a "dirty bomb". A dirty bomb is an ordinary explosive packed with radioactive material. When detonated, such a device could cause widespread panic and massive disruption while rendering the surrounding area uninhabitable for years.

In the event of such a detonation, it is imperative that first responders (police, firefighters, medical personnel, etc.) quickly assess X-ray radiation exposure among the affected to ensure that treatment is provided first to those who need it the most. JP Laboratories has developed a credit card sized radiation dosimeter called SIRAD (**S**elf-indicating **I**nstant **R**adiation **A**lert **D**osimeter) which can be used to monitor the high energy radiation released in case of a dirty bomb attack. SIRAD will also be beneficial to those who work with radiation on a daily basis (researchers, hospital workers, etc.) as well as those who live near nuclear power plants and need to measure their radiation exposure.

When exposed to radiation from a "dirty bomb" or nuclear detonation, the sensing strip of SIRAD develops a blue color instantly and the color intensifies as the dose increases (see the Figure below) providing the wearer and medical personnel instantaneous information on the victim's cumulative radiation exposure. It can take days to get that information by other methods currently available. In addition, SIRAD is inexpensive - under $10 each.



JP Laboratories has developed several products with federal funding. The development of SIRAD was funded by (1) the Department of Defense, Naval Sea System Command and (2) Technical Support Working Group (TSWG). TSWG recognized SIRAD's significance to first responders and has proceeded to make them aware of the dosimeter's availability.

1. WEAPONS OF TERROR

Terrorists can attack us with a variety of weapons such as:

*. Explosives/guns, such as TNT, RDX, bullets and rockets.
*. Biological agents, such as anthrax, ebola, plague and smallpox.
*. Chemical agents, such as cyanide, phosgene, nerve agents and vesicants.
*. Radioactive materials, such as cobalt-60 and cesium-137.

Effects of these weapons are compared in Table 1:

Table 1: Comparison of availability and potential damage from different attacks

Attack	**Availability**	**People** (killed)	**Property** (Damage)	**Duration**
Explosive	Easy	Yes	Yes	Short
Chemical	Difficult	Yes	No	Short
Biological	Difficult	Yes	No	Short
Dirty bomb	Very difficult	Few	Huge	Long
Nuclear	Almost impossible	Maximum	Maximum	Long

2. DEFINITION OF A DIRTY BOMB

A dirty bomb is not a nuclear bomb. It is a radiological dispersion device (RDD), a weapon which disperses radioactivity. It is an easy to build, conventional explosive packed with radioactive material. Figure 1 shows a simple crude form of a dirty bomb. When such a bomb is exploded, it will disperse radioactive material. A high dose of high energy radiation, such as X-ray emitted by radioactive dust, can cause can cancer.

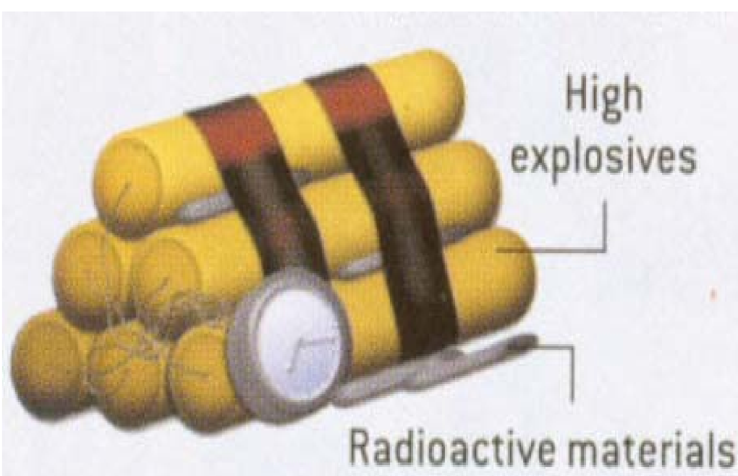


Figure 1. A simple crude form of a dirty bomb (Scientific American, November 2002)

3. EFFECT OF DIRTY BOMB

A simulated effect of detonation of a dirty bomb (3,500 curie of cesium-137 with ~50 lbs of explosive) at the lower tip of Manhattan Island is shown in Figure 2.

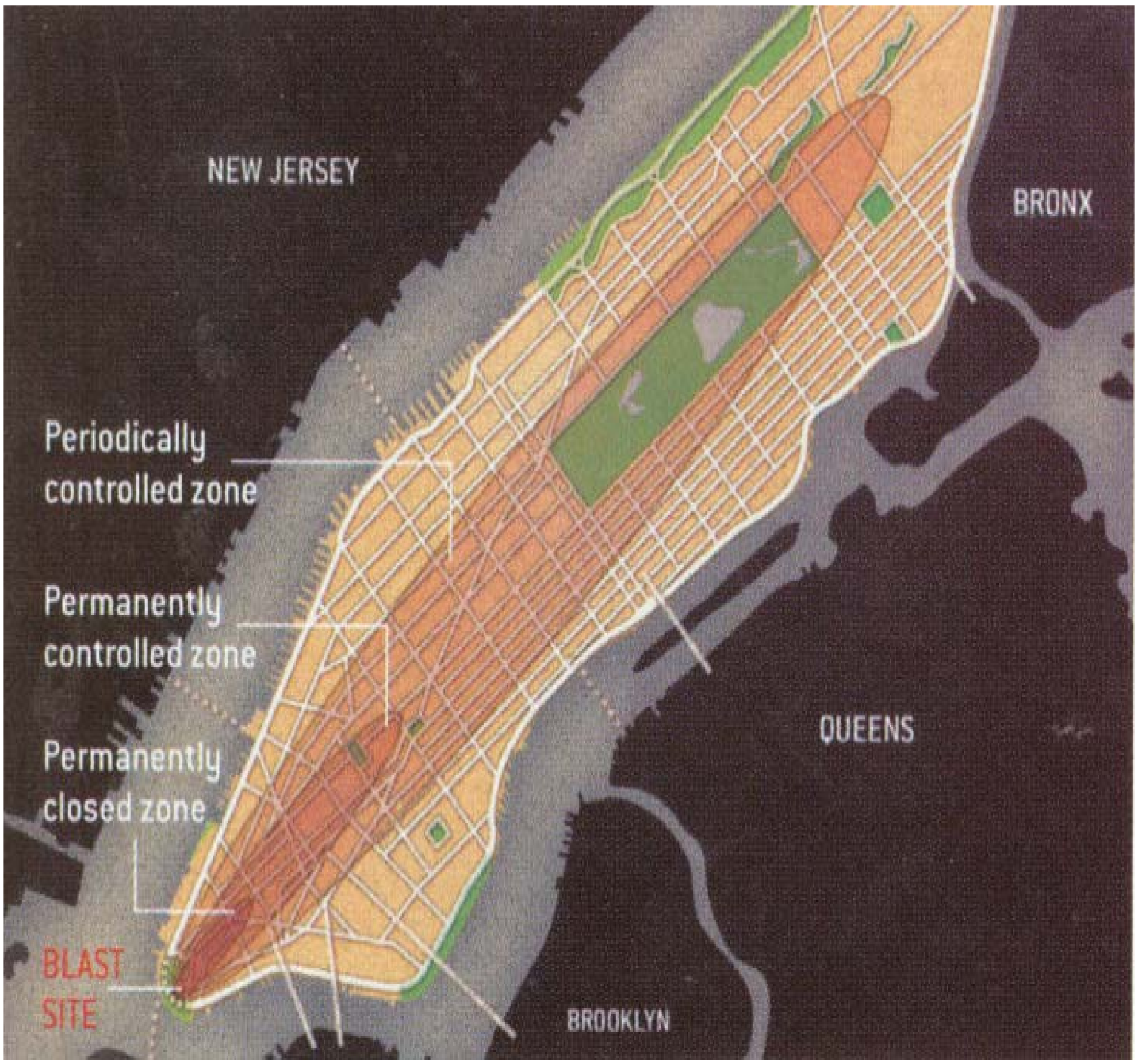


Figure 2. A simulated effect of detonation of dirty bomb (3,500 curie of cesium-137 with ~50 lbs of explosive) at the lower tip of Manhattan Island (Scientific American, November 2002)

If such a dirty bomb is exploded at the tip of Manhattan, there will be massive panic and disruption. Contamination will depend upon on the size of the explosive, amount and type of radioactive material and weather conditions. Radioactive dust will settle on people, buildings, and roads. Winds and air circulation systems in buildings will spread the radioactive dust even more. Rain will wash the radioactivity into soil, sewer systems and rivers.

EPA regulations require that contaminated areas should be cleaned if the risk is one death in 10,000 people. Because decontaminating certain areas might not be financially or technically possible, we might have to demolish or abandon several square miles of a city. We know from first hand experience that terrorists can destroy our buildings. With a dirty bomb, they could they force us to do it to ourselves on a much grander scale.

A dirty bomb could result in potentially trillions of dollars of losses if it is detonated in New York City, according to testimony before the Senate Foreign Relations Committee in March 2002 by Federation of American Scientists President Henry Kelly. Millions of people will leave the affected area in a state of panic, leading to potentially deadly accidents. It would be a logistical nightmare to relocate so many people in such a short time.

Everyone in and nearby the affected area will need to determine their exposure to radiation. With no other knowledge or preparation, people will rush to hospitals in droves. In order to determine radiation exposure, hospitals will need to obtain blood samples from every potential victim. That will be practically impossible to do with so many people affected. First responders will also be exposed to radiation. It is imperative they know how much radiation they have been exposed to so they can leave the affected area before they received a higher dangerous dose. In an unintended incident of a similar nature, almost 10% of the population of Goiania, Brazil demanded testing for radiation exposure in 1987 (see section **5.1 Goiania, Brazil**).

4. IS DIRTY BOMB AND ITS THREAT REAL?

There have been several incidents over the past 20 years which indicate the dirty bomb threat is real. (1) Chechnyan rebels directed a TV reporter to a park in central Moscow in 1995. When she reached there she found a package containing about 15lbs of explosives and cesium-137. This was the first known appearance of a dirty bomb. (2) Iraq tested a crude radiological device in 1987, according to frequently cited intelligence reports. (3) Operatives for Osama bin Laden in Sudan tried and failed to buy enriched uranium produced in South Africa on the black market. (4) American-led forces discovered some documents in Afghanistan which contained detailed information on the making and use of a dirty bomb in fall of 2001. (5) Police arrested Jose Padilla (Abdullah al Muhajir). Apparently, he received $10,000 from Al Qaeda to carry out a dirty bomb explosion. (6) A large number of radioactive items that can be used to make dirty bombs are unaccounted for in the USA and Russia. (7) About 280 confirmed cases of illicit trafficking in radioactive materials since 1993 been reported.

“There is a 10 to 40 percent chance that terrorists will conduct a successful attack with a crude ‘dirty bomb’ in the next five to 10 years”, said David Albright, president of the Institute for Science and International Security.

5. UNINTENDED COMPARABLE INCIDENCES

There are several unintended comparable incidences which indicate that a dirty bomb could create massive disruption.

5.1 Goiania, Brazil: A scrap merchant stole a radiation therapy source from a hospital (which was closed) in Goiania, Brazil in 1987. It contained a small amount (size of a cigarette lighter) of highly concentrated radioactive cesium chloride. He cut the source and the powder was released and contaminated the area. The radioactive dust was tracked throughout Goiania. Nearly two hundred people were exposed to high dose of radaition. Four died, including a four-year-old girl who had eaten a sandwich after playing with blue radioactive powder. She was buried in a lead coffin sealed in concrete. Pavements, buildings, etc. needed to be scrubbed and scraped. Contaminated soil had to be dug up and carted away. Some homes that couldn't be cleaned were carted away. Decontamination took six months. The radioactive material created 5,000 cubic meters of waste. More than 100,000 people (~10% population) demanded screening. Everyone wanted to be monitored. The long-term socio-economic effects were devastating. Goiania suffered a 20% drop in gross domestic product. Tourism dropped to zero. Demand for food and other products plummeted.

Photos of the scrap yard, demolition of a building and carting of contaminated soil.

5.2 Georgia, 2001: Two men were admitted to a hospital with terrible radiation burns in December 2001 in Georgia. They had spent a night in a forest beside a small, warm, metal cylinder. Radiation detectors indicated that the cylinders contained concentrated strontium-90, which emits beta radiation. When beta particles interact with matter, they generate an intense heat. This kind of generator could run for decades without refueling as they could produce an internal temperature of over 800 degrees and convert that heat into electricity. The Soviets had built thousands of these generators. Therefore, the ingredients for a dirty bomb could be all over the former Soviet Union. U.N. investigators have established that the former Soviet Union is littered with forgotten cesium chloride. Unfortunately, no one knows whether any of it has already fallen into the wrong hands.

5.3 Chernobyl, Ukraine: The explosion of Chernobyl's nuclear power plant is well known. It released huge amounts of strontium-90, iodine-131 and other radioisotopes which forced the permanent evacuation of hundreds of square miles in the Ukraine. About 2,000 children developed thyroid cancer as a result of Chernobyl.

6. RADIOACTIVE MATERIALS AND RADIATION

Radioactive uranium, plutonium, cesium and cobalt emit high energy ionizing radiations. High energy radiations, such as x-ray/gamma-ray, electrons, protons and neutrons emitted by radioactive materials can produce cancer. X-ray/gamma ray and neutrons can pass right through the human body. High energy radiation can knock electrons from an atom. This process is called ionization and radiations which cause ionization are known as ionizing radiation. Ionizing radiations are also referred to simply as radiation in this report.

Ionization can damage cells and to DNA of human cells. Damaged DNA might mutate, can cause cancer. We can't see, smell or feel ionizing radiation but it can cause cancer.

Radioactive materials are available because we use them to destroy bacteria from food, sterilization of pharmaceutical & medical products, killing cancer cells, inspecting welds/joints and exploring for oil. About 21,000 licensed organizations in the U.S. use radiation sources.

6.1 Life of radioactive elements: The radioactive elements decay, i.e., loose their activity with time. The decay is measured in half life, time required for the radioactivity to reduce to the half. The half life of some of elements is shown in below:

Element	Half life
Uranium-235	Billions of years
Carbon-14	5730 years
Strontium-90	28 years (beta)
Ce-137	30.2 years
Co-60	5.27 years

As the half life of these and other radioactive elements is very long, contaminated area either should be cleaned or have to be abandoned.

7. EXPOSURE TO IONIZING RADIATION

We get exposed to ionizing radiation in a variety of ways:

- From cosmic rays
- From trace uranium under our feet
- From potassium-40 in the food we eat
  - 0.01% of potassium is radioactive
  - Second largest source of background radiation

DNA is most important part of cells. Damaged DNA can lead to cell malfunction/cancer or death. Our bodies have a highly efficient DNA repair mechanism. We evolved to live with low level of radiation. Rapidly dividing cells are more susceptible to radiation damage. Examples of radiosensitive cells are blood forming cells (bone marrow), intestinal lining, hair follicles and fetus. Hence, these develop cancer first. Our body has natural defenses against normal low level of radiation. Scientists agree that higher level (e.g., 50 times) than normal could easily overwhelm our defenses.

7.1 Effect of radiation on human: A very small amount of radiation could trigger cancer in the long term. It may take decades for cancer to appear. There is no doubt that radiation can cause cancer. The doubt is what level of radiation it takes to cause cancer. The risks of low-level radiation are fiercely debated. There's no question that high levels are dangerous. The US EPA mandates that contaminated areas be cleaned up so that there is a risk of, at the most, one in 10,000 (This additional risk is equivalent to having *25* chest x-rays over one's lifetime). On average, if *2,500* people are exposed to a single rem/rad of radiation, one will die of an induced cancer.

8. UNITS OF RADIATION

Radioactivity is measured in Becquerel (Bq). 1 Bq means one disintegration per second. It is also measured in Curie (Ci). 1 Curie = 3.7×10^{10} Bq or disintegrations. The radiation absorbed dose is measured in Gray, rad, rem and Sievert (Sv).

1 Gray (Gy) = 100 rads
1 Rad = Absorption of 100 ergs of energy per gram.
1 Rem = 96 ergs for soft tissue
1 Sievert (Sv) = 100 rems

9. TYPICAL RADIATION EXPOSURE LEVELS

Table 2 shows typical radiation exposures.

Table 2: Typical radiation exposures.

Chest X-ray	0.03 rad
Natural background	0.25 rad/year
Gastric fluoroscopy	0.4 rad
Radiation Workers	5 rads/yr (Limit)
CT (head and body)	1.1 rad
Hiroshiima/Nagaskai	20 rads (Average)
Acute radiation sickness	~100 rads
50% chance of death	>450 rads

10. EFFECT OF HIGH DOSE ON HUMAN

There are very little symptoms of exposure to low level of radiation. Effect of high dose is shown below.

0 to 25 rads:

- No detectable clinical effect in humans.

25 to 100 rads:

- Slight short-term reduction in blood cells.
- Disabling sickness not common.

100 to 200 rads:

- Nausea and fatigue.
- Vomiting if dose is greater than 125 rads.
- Longer-term reduction in number of some types of blood cells.

200 to 300 rads:

- Nausea and vomiting on the first day of exposure.

- Up to a two-week latent period followed by appetite loss, general malaise, sore throat, pallor, diarrhea, and moderate emaciation.
- Recovery in about three months unless complicated by infection or injury.

300 to 600 rads:

- Nausea, vomiting, and diarrhea in first few hours.
- Up to a one-week latent period followed by loss of appetite, fever, and general malaise in the second week.
- Followed by bleeding, inflammation of mouth and throat, diarrhea, and emaciation.
- Some deaths in two to six weeks.
- Eventual death for 50% if exposure is above 450 rems.
- Others recover in about six months.

Over 600 rem:

- Nausea, vomiting, and diarrhea in the first few hours.
- Followed by rapid emaciation and death in 2^{nd} week.
- Eventual death of nearly 100%.

It has been established that exposure to each rem/rad increases that risk by 0.05% (1 in 2,000 would die from the induced cancer).

11. NEED FOR A LOW COST, SELF-INDICATING, INSTANT RADIATION DOSIMETER

In the event of a detonation of a dirty bomb, it is imperative that people affected by the bomb and first responders (police, firefighters, medical personnel, etc.) need to quickly assess radiation exposure. If people affected by a dirty bomb know their radiation exposure, the panic and concern can be minimized. If they have a simple, low cost, instant, self-indicating radiation dosimeter, they will know their radiation exposure. If they are not exposed to radiation or received a very low dose, they don't need to worry and would not need to run to a hospital. However, those who have received high dose may go to hospital and physicians would know whom to treat first. The first responders will know their exposure and will leave the area before they get over exposed to high energy radiation. Hence, there is a strong need for a simple, low cost, instant, self-indicating radiation dosimeter.

We have developed such a dosimeter. A cross sectional view of the dosimeter and sensing strip used to monitor are shown in Figures 3a and 3b respectively. When exposed to radiation from a "dirty bomb" or nuclear detonation, the sensing strip (Figure 3b) of SIRAD develops blue color instantly and the color intensifies as the dose increases (see Figure 4 for photos of a sensing strip exposed to different dosage of X-ray), providing the wearer and medical personnel instantaneous information on cumulative radiation exposure of the victim. People who have not received high dose will not rush to hospitals. This will minimize the panic and people who received high dose will be treated first. It can take days to get that information by other methods. SIRAD is inexpensive (under $10/badge).

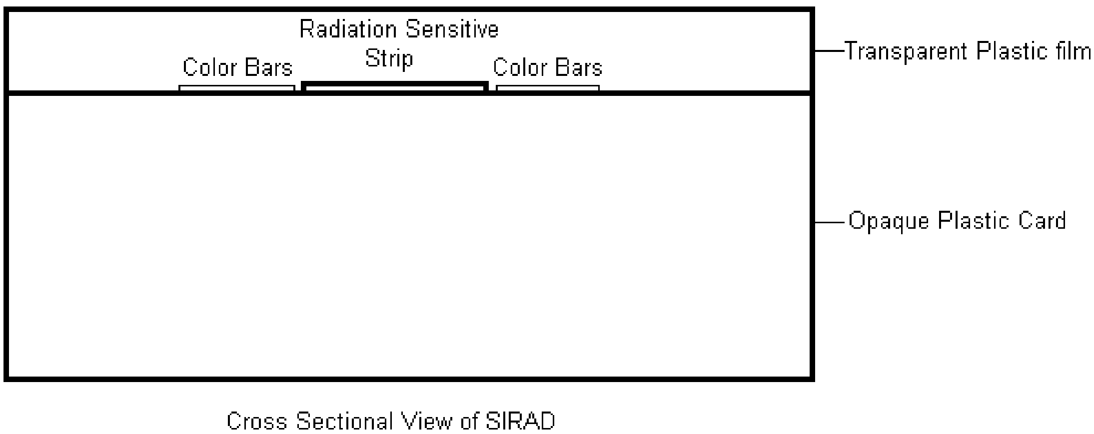


Figure 3a: A schematic cross section (not to the scale) of the dosimeter badge.

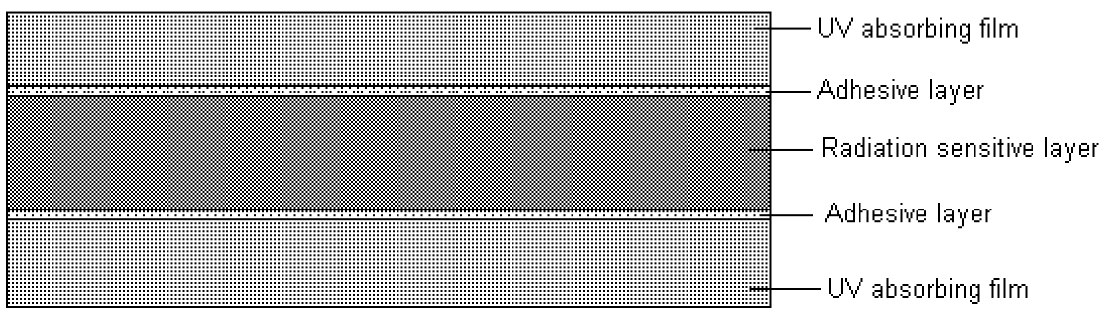


Figure 3b: A schematic cross section (not to the scale) of the element used to make the badges.

A photograph of a SIRAD badge and its sensing strip exposed to different dosages are shown in Figure 4.

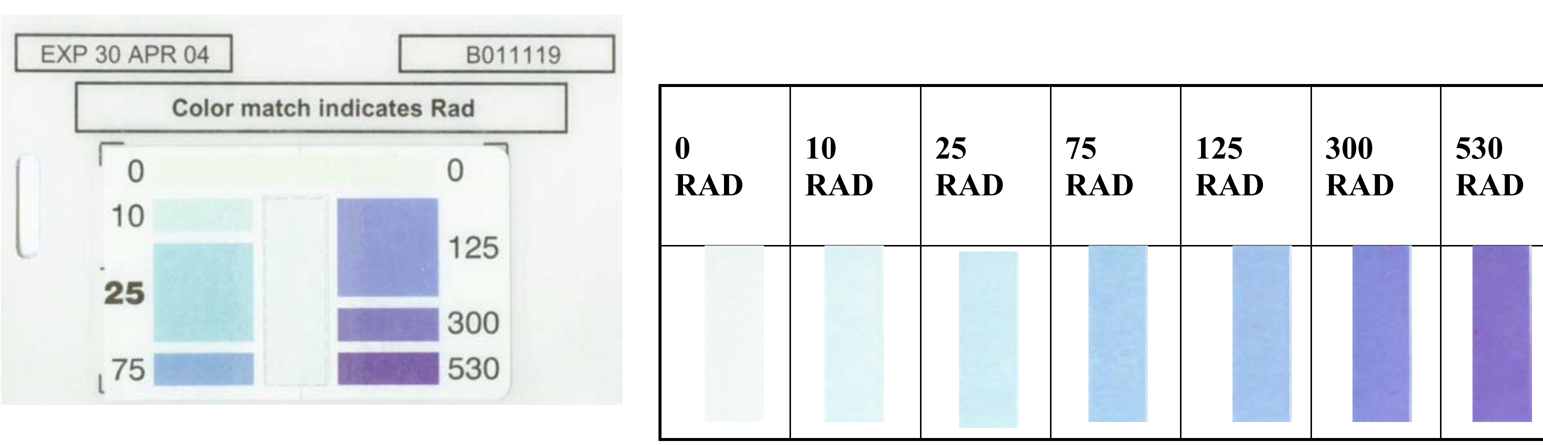


Figure 4: A photo of 0-530 rads badge (the left hand side) with its elements irradiated with different dosages of 100 KeV X-ray (strips on the right hand side).

12. MATERIALS AND MECHANISM OF RADIATION MONITORING

Materials used in the radiation sensitive element/strip of the dosimeter badge are a unique class of compounds called diacetylenes (R-C≡C-C≡C-R, where R is a substituent group). Dr. Gordhan Patel has been working on diacetylenes since 1974. Diacetylenes are colorless solid monomers. They usually form red or blue colored polymers/plastics, $[=(R)C\text{-}C\equiv C\text{-}C(R)]_n$, when irradiated with high energy radiations, such as X-ray, gamma ray, electrons, protons and neutrons. As exposure to radiation dose increase the color of the strip made from diacetylenes intensifies proportional to the dose. One can estimate the dose from color reference chart printed on each side of the strip.

The polymerization occurs via 1,4 *trans* addition reaction as shown in the Figure 5 below. In the solid state, diacetylene molecules are packed like the steps of a ladder as shown schematically on the left hand side of Figure 5. Polymerization is mainly initiated by the formation of radicals. Radicals are produced by ionizing radiation, such as gamma ray and electrons. The radicals propagate to form highly conjugated backbone polymer chains (the right hand side of Figure 5). The solid monomers are colorless or white, partially polymerized diacetylenes (polymer conversion below about 10%) are blue or red and polydiacetylenes (polymer conversion higher than 10%) are metallic, usually copper or gold color. Polydiacetylenes are highly colored because the "pi" electrons of the conjugated backbone are delocalized. The color intensity of the partially polymerized diacetylenes is proportional to the polymer conversion.

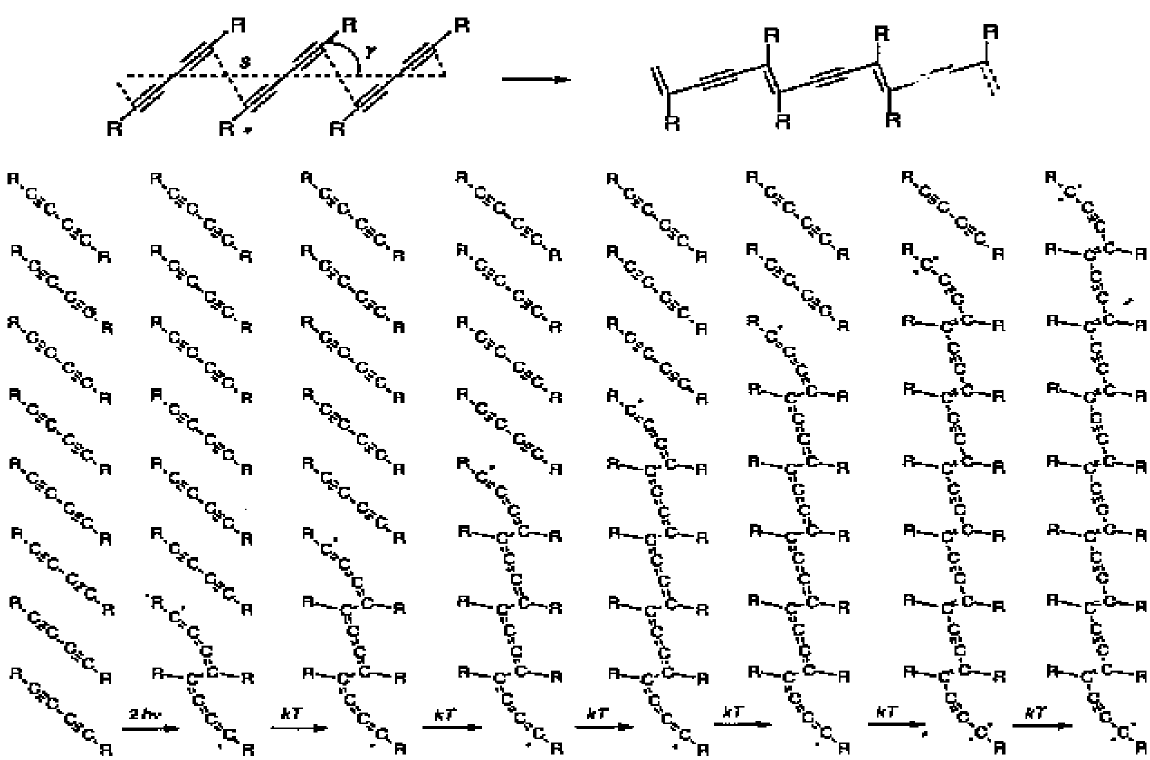


Figure 5. Polymerization of diacetylenes.

13. COMPARISON OF RADIATION DOSIMETERS

A variety of radiation detectors and dosimeters can be used for monitoring radiation exposures. They are compared in Table 3 below.

Table 3: Comparison of different radiation detectors and dosimeters.

	Electronic (Geiger..)	**Quartz Fiber**	**Film (AgBr)**	**TLD**	**SIRAD**
Approx. Price	$100	$50	$25	$25	$5
Sensitivity	Most	Good	Sufficient	Sufficient	Low
Dose range (rads)	NA	0-5	0-10	0-10,00	2-1,000
Response Time	Instant	Instant	Needs Developing	Needs analysis	Instant
Size	Bulky	Bulky	Small	Small	Smallest
Ambient	NA	NA	Protect Light	Protect UV	Almost none
Shock	Sturdy	Fragile	Sturdy	Sturdy	Sturdiest
Radiation	X-ray	X-ray	Most	Most	Most
Archiving	No	No	Yes	No	Yes
Shelf life	NA	NA	Month	Months	Months-year

14. WHAT "SIRAD" WILL NOT DO

SIRAD is not and will not do the following:

- It will not detect a dirty bomb.
- It will not detect radioactive material.
- It will not deter a terrorist attack.
- It is not a radiation detector (it is a dosimeter).
- It will not monitor low dose (less than 1 Rad).
- It will not monitor dose of pre-radiated material or people.
- It will not prevent radiation induced cancer.
- It will not protect people from radiation.
- It will not prevent property damage.

15. WHAT SIRAD WILL DO

In an event of dirty bomb explosion, SIRAD will do the following:

- It will monitor high dose (>5 Rad) which can induce cancer.
- It will provide an early warning to people to leave affected area.
- It will minimize the rush to the hospital.
- It will minimize strain on health care system.
- It will minimize fear/panic/havoc/turmoil.

- It will warn the first responders of the radiation exposure.
- It will help people in taking preventive care.
- It will make affected people vigilant of cancer

16. ADVANATGES OF SIRAD

SIRAD badge offers the following advantages over those available commercially.

- It is a simple, lightweight, inexpensive device.
- It is a self-developing instant dosimeter.
- It does not require power. It is always ready to use.
- No special equipment is required to read the dose.
- It is highly sensitive (monitor about a few rads).
- Dose can be estimated with an accuracy better than 20% with a color-matching reference chart.
- Dose can be determined with accuracy of ~10% with a spectrophotometer or an optical densitometer.
- It can be used over a wide dose range (1 - 5,000 rads). Higher dose can also be estimated.
- The color development will be essentially independent of the energy and the dose rate.
- It will monitor all kind of high energy radiations, such as X-ray, gamma ray, electrons, and neutrons.
- It will be tissue equivalent and hence no corrections will be required.
- No toxic chemicals are used.
- It is unaffected by ambient conditions, e.g., temperature, and humidity.
- No effect of temperature of irradiation (-20 to 60^{o}C).
- Reasonable protection from sunlight.

17. JP LABS, TSWG AND FEDERAL FUNDING

JP Laboratories Inc. is a product research and development company. We develop new products/processes and license them to other companies for manufacturing and marketing. Though we are a small company, our research interests are very diverse from chemistry to physics to metallurgy to biology. We have several major areas of research and development: (1) Color changing indicators for perishables, such as foods, (2) Color changing indicators for monitoring sterilization of medical supplies, (3) Radiation sensitive devices, (4) Synthetic lipids (5) Etching and metallization of plastics and (6) Synthetic blood. We have received some federal funding for most of the products listed above.

After the attacks of September 11th, TSWG solicited proposals for products to combat terrorism. The proposal to TSWG was submitted in collaboration with Dr. Gordon Riel and Robert Rogalski of Naval Surface Warfare Center, Carderock Division, West Bethesda, MD. 12,000 proposals were submitted, of which approximately 60 were selected for funding. SIRAD was amongst the first few to receive funding.

I recently had the opportunity to meet many first responders at the "Technologies for Public Safety in Critical Incidence Response" Conference in St. Louis, MO from September 23-25, 2003. TSWG has helped many organizations put a number of products and processes into the hands of first responders to fight terrorism. We believe TSWG can do an even better job if it becomes an independent agency with a larger budget.

18. FEDERAL FUNDING RELATED TO SIRAD DOSIMETER

Funding from the Navy and TSWG was specifically for development of the radiation dosimeter.

1. DHHS: National Cancer Institute.
   Title: Film Dosimeter for Neutron Therapy.
   Contract # R44-CA-49347.
   Period: Sept. 30, 1990 - Aug. 31, 1992.
   SBIR phase I&II (~$550,000).
   (Basic technology to make the radiation sensing strip, for monitoring radiation therapy, was developed under this grant).

2. DoD: Naval Sea System Command.
   Title: A Low-Cost Self-Indicating Radiation Dosimeter.
   Contract # N00024-95-C-4052.
   Period: April 1, 1995 to Dec. 10, 1997.
   SBIR phase I&II ($~800,000).
   (The first prototype SIRAD was developed under this contract).

3. TSWG/DoD: Naval Surface Warfare Center, Carderock Division.
   (A subcontract for $105,000 from the Technical Support Working Group).
   Contract # N00167-03-M-0037.
   Period: February 1 – April 30, 2003.

4. TSWG:
   Title: Smart Radiation Dosimeter.
   JP Laboratories' proposal to develop the next generation of SIRAD badge, which is self reading and displays false positive signals, has been selected for funding by TSWG and a contract is at the final stage of negotiation.

In addition to the above federal funding, JP Laboratories has made a significant investment of its own to bring this product to market. SIRAD has become our highest priority.

ACKNOWLEDGEMENT

We acknowledge funding from DHHS, DoD and TSWG as listed above (**18. FEDERAL FUNDING RELATED TO SIRAD DOSIMETER)** as well as help from the following individuals.

- Gordon Riel, Naval Surface Warfare Center, Carderock Division
- Rob Rogalski, Naval Surface Warfare Center, Carderock Division
- Shannon Rowe, JP Laboratories, Inc.
- Paresh Patel, JP Laboratories, Inc.

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