

## TECHNOLOGY SEMINAR - 02

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The last seminar (TS01) focused on *Thermodynamics* of transforming *Heat Energy* obtained by burning a fuel into Mechanical Energy for propulsion or other purposes. This seminar will start with the thermodynamics of *Light Energy* and show its relationship to modern electronics.

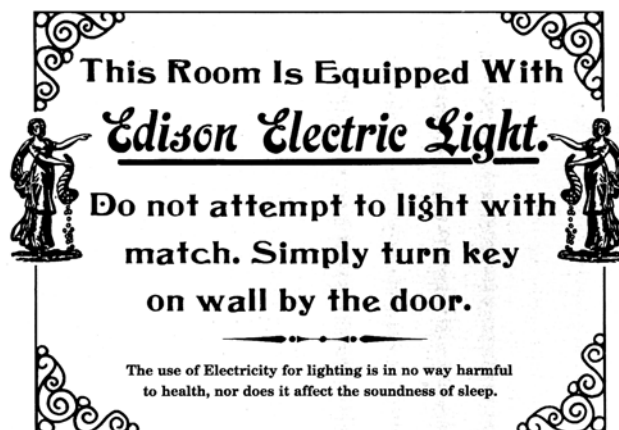
We will examine achievements of four pioneers of Technology:

- ◆ Thomas Alva Edison (1847-1931) - <http://en.wikipedia.org/wiki/Edison>
- ◆ Nikola Tesla (1856-1943) - [http://en.wikipedia.org/wiki/Nikola\\_Tesla](http://en.wikipedia.org/wiki/Nikola_Tesla)
- ◆ John Ambrose Fleming (1849-1945) - [http://en.wikipedia.org/wiki/John\\_Ambrose\\_Fleming](http://en.wikipedia.org/wiki/John_Ambrose_Fleming)
- ◆ Lee DeForest (1873-1961) - [http://en.wikipedia.org/wiki/Lee\\_DeForest](http://en.wikipedia.org/wiki/Lee_DeForest)

Also, we will touch on some opportunities they overlooked and failures of three of these men.

Bringing *light* into darkness was an ancient goal and numerous attempts to develop reliable and economical lamps make interesting history reading. Almost every lighting device required burning a fuel – such as wood, charcoal, lime, coal gas, natural gas, whale oil, paraffin or kerosene – indoors in or near the device. Disadvantages of smoke, smell and fire were obvious. Similarly, some of these devices were expensive to operate and, in some cases, to build.

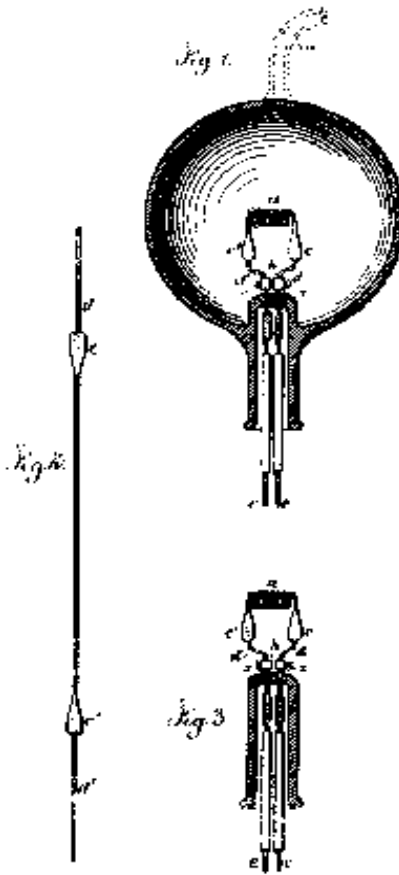
The goal of a safe and economical lamp for indoor use was finally attained in 1878 when Thomas Edison developed a practical *Electric Lamp* – as described in U.S. Patent No. 223,898, (<http://www.k9ape.com/publicservice/PSM/Edison%20Patent%20223898.pdf>), which is reproduced on the next pages. Edison's *Electric Lamp* operated on the principal of *incandescence* – that is its *filament* was caused to glow though application of heat energy – here generated by electric current. Edison was not the first inventor to try electricity for lighting or to recognize the value of incandescence. Others had failed at incandescence and still others built systems impractical for indoor use – such as carbon arc lamps. As his patent describes, Edison's success was in enclosing his incandescent filament in a glass *vacuum bulb* and then evacuating air in the *bulb* by using a very high vacuum so that the filament would not oxidize and fail.



T. A. EDISON.  
Electric-Lamp.

No. 223,898.

Patented Jan. 27, 1880.



*Witnesses*  
*Charles Smith*  
*W. D. Mackay*

*Inventor*  
*Thomas A. Edison*  
*For Lemuel W. Perrell*  
*1880.*

# UNITED STATES PATENT OFFICE.

THOMAS A. EDISON, OF MENLO PARK, NEW JERSEY

## ELECTRIC LAMP.

SPECIFICATION forming part of Letters Patent No. 839,720, dated January 27, 1906.

Application filed November 4, 1898.

To all whom it may concern:

Be it known that I, THOMAS ALVA EDISON, of Menlo Park, in the State of New Jersey, United States of America, have invented an improvement in Electric Lamps, and in the method of manufacturing the same, (Case No. 186,) of which the following is a specification.

The object of this invention is to produce electric lamps giving light by incandescence, which lamps shall have high resistance, so as to allow of the practical subdivision of the electric light.

The invention consists in a light-giving body of carbon wire or sheets coiled or arranged in such a manner as to offer great resistance to the passage of the electric current, and at the same time present but a slight surface from which radiation can take place.

The invention further consists in placing such burner of great resistance in a nearly perfect vacuum, to prevent oxidation and injury to the conductor by the atmosphere. The current is conducted into the vacuum-bulb through platinum wires sealed into the glass.

The invention further consists in the method of manufacturing carbon conductors of high resistance, so as to be suitable for giving light by incandescence, and in the manner of securing perfect contact between the metallic conductors or leading-wires and the carbon conductor.

Incandescent light by incandescence has been obtained from rods of carbon of one to four ohms resistance, placed in closed vessels, in which the atmospheric air has been replaced by gases that do not combine chemically with the carbon. The vessel holding the burner has been composed of glass cemented to a metallic base. The connection between the leading wires and the carbon has been obtained by clamping the carbon to the metal. The leading-wires have always been large, so that their resistance shall be many times less than the burner, and, in general, the attempts of previous persons have been to reduce the resistance of the carbon rod. The disadvantages of following this practice are, that a lamp having but one to four ohms resistance cannot be worked in great numbers in multiple arc without the employment of many conductors of enormous dimensions; that, owing to the low resistance of the lamp, the leading-wires must be of large

dimensions and good conductors, and a glass globe cannot be kept tight at the place where the wires pass in and are connected; hence the carbon is exposed, because there must be almost a perfect vacuum to render the carbon stable, especially when such carbon is small in mass and high in electrical resistance.

The use of a gas in the receiver at the atmospheric pressure, although not attacking the carbon, serves to destroy it in time by "air-washing," or the attrition produced by the rapid passage of the air over the slightly-coherent highly-heated surface of the carbon. I have reversed this practice. I have discovered that even a cotton thread properly carbonized and placed in a sealed glass bulb exhausted to one-millionth of an atmosphere offers from one hundred to five hundred ohms resistance to the passage of the current, and that it is absolutely stable at very high temperatures; that if the thread be coiled as a spiral and carbonized, or if any fibrous vegetable substance which will leave a carbon residue after heating in a closed chamber be so coiled, as much as two thousand ohms resistance may be obtained without presenting a radiating-surface greater than three-sixteenths of an inch; that if such fibrous material be rubbed with a plastic composed of lamp-black and tar, its resistance may be made high or low, according to the amount of lamp-black placed upon it; that carbon filaments may be made by a combination of tar and lamp-black, the latter being previously ignited in a closed crucible for several hours and afterward moistened and kneaded until it assumes the consistency of thick putty. Small pieces of this material may be rolled out in the form of wire as small as seven one-thousandths of an inch in diameter and over a foot in length, and the same may be coated with a non-conducting non-carbonizing substance and wound on a bobbin, or as a spiral, and the tar carbonized in a closed chamber by subjecting it to high heat, the spiral after carbonization retaining its form.

All these forms are fragile and cannot be clamped to the leading wires with sufficient force to insure good contact and prevent heating. I have discovered that if platinum wires are used and the plastic lamp-black and tar material be ignited around it in the act of carbonization there is an intimate union by com-

material be rolled around it in the act of carbonization there is an intimate union by combination and by pressure between the carbon and platinum, and nearly perfect contact is obtained without the necessity of clamps; hence the burner and the leading-wires are connected to the carbon ready to be placed in the vacuum-bulb.

When fibrous material is used the plastic lamp-black and tar are used to secure it to the platinum before carbonizing.

By using the carbon wire of such high resistance I am enabled to use fine platinum wires for leading-wires, as they will have a small resistance compared to the burner, and hence will not heat and crack the sealed vacuum-bulb. Platinum can only be used, as its expansion is nearly the same as that of glass.

By using a considerable length of carbon wire and coiling it the exterior, which is only a small portion of its entire surface, will form the principal radiating surface; hence I am able to raise the specific heat of the whole of the carbon, and thus prevent the rapid reception and disappearance of the light, which on a plain wire is prejudicial, as it shows the least unsteadiness of the current by the flickering of the light; but if the current is steady the defect does not show.

I have carbonized and used cotton and linen thread, wool splints, papers coiled in various ways, also lamp-black, platinum, and carbon in various forms, mixed with tar and kneaded so that the same may be rolled out into wires of various lengths and diameters. Each wire, however, is to be uniform in size throughout.

If the carbon thread is liable to be distorted during carbonization it is to be coiled between a helix of copper wire. The ends of the carbon or filament are secured to the platinum leading-wires by plastic carbonizable material, and the whole placed in the carbonizing-chamber. The copper, which has served to prevent distortion of the carbon thread, is afterward eaten away by nitric acid, and the spiral soaked in water, and then dried and placed on the glass ladder, and a glass bulb blown over the whole, with a leading-tube for exhaustion by a mercury-pump. This tube, when a high

vacuum has been reached, is hermetically sealed.

With antistatices which are not greatly distorted in carbonizing, they may be coated with a non-conducting non-carbonizable substance, which allows one coil or turn of the carbon to rest upon and be supported by the other.

In the drawings, Figure 1 shows the lamp sectionally, *a* is the carbon spiral or thread, *c* or *c'* are the thickened ends of the spiral, formed of the plastic compound of lamp-black and tar, *d* and *d'* are the platinum wires. *h* & *h'* are the clamps, which serve to connect the platinum wires, cemented in the carbon, with the leading-wires *x* *x*, sealed in the glass vacuum-bulb. *x* *x* are copper wires, connected just outside the bulb to the wires *x* *x*. *m* is the tube (shown by dotted lines) leading to the vacuum-pump, which, after exhaustion, is hermetically sealed and the surplus removed.

Fig. 2 represents the plastic material before being wound into a spiral.

Fig. 3 shows the spiral after carbonization, ready to have a bulb blown over it.

I claim as my invention—

1. An electric lamp for giving light by incandescence, consisting of a filament of carbon of high resistance, made as described, and secured to metallic wires, as set forth.

2. The combination of carbon filaments with a receiver made entirely of glass and conductors passing through the glass, and from which receiver the air is exhausted, for the purposes set forth.

3. A carbon filament or strip coiled and connected to electric conductors so that only a portion of the surface of such carbon conductors shall be exposed for radiating light, as set forth.

4. The method herein described of securing the platinum contact-wires to the carbon filament and carbonizing of the whole in a closed chamber, substantially as set forth.

Signed by me this 1st day of November, A. D. 1879.

THOMAS A. EDISON.

Witnesses:

S. L. GRIFFIN,  
JOHN W. RANDOLPH.

With success of his incandescent electric lamp, Edison needed to construct the World's first electric utility, which he did on Pearl St. in lower Manhattan. As conceived by Edison, the utility would comprise a large number of coal-burning Direct-Current (DC) generators – each serving customers in a 1 to 3-block radius. The reason for this short distance is that DC transmission losses in Edison's configuration would be unacceptable for longer distances. The name of his company was *Edison General Electric Company* (EGE), which is the predecessor of today's *General Electric Company* (GE). It was managed by *Samuel Insull* (see a somewhat inaccurate and incomplete description at [http://en.wikipedia.org/wiki/Samuel\\_Insull](http://en.wikipedia.org/wiki/Samuel_Insull)). Insull became a very famous Chicago businessman whose career deserves your independent study.

Edison's DC-electricity distribution model was impractical because it required construction of a very large number of polluting power stations in crowded cities. He refused to consider an alternative.

Nikola Tesla was a Serbian immigrant who came to the United States to work for Edison. Unlike Edison who was largely unschooled, Tesla had a university education and was particularly skilled in mathematics. When Tesla proposed to Edison that EGE build Alternating Current (AC) power stations that could be built outside cities and tap energy resources such as dams on the Niagara River, Edison fired him. Without a salary, Tesla was destitute when he was discovered by George Westinghouse ([http://en.wikipedia.org/wiki/George\\_Westinghouse](http://en.wikipedia.org/wiki/George_Westinghouse)). Westinghouse believed him when Tesla claimed he could build an electricity utility without infringing Edison's patents. Please see Tesla's Patent No. 433,702 for his Electrical Transformer or Induction Device.

Westinghouse then edged out EGE for a contract to supply Chicago's *World's Columbian Exposition* of 1893 with electricity and incandescent light bulbs that did not infringe Edison patents ([http://en.wikipedia.org/wiki/World%27s\\_Columbian\\_Exposition](http://en.wikipedia.org/wiki/World%27s_Columbian_Exposition)). Edison was fired by EGE and the company was renamed GE.

Edison would later lose all his money in an unrelated business venture and became dependent on Henry Ford ([http://en.wikipedia.org/wiki/Henry\\_Ford](http://en.wikipedia.org/wiki/Henry_Ford)) for support. Nevertheless, he is remembered for his very important inventions and as a founder of the *research laboratory*, where experiments were conducted on an organized basis.

Westinghouse and Tesla became very successful; however, Tesla diverted his attention to attempting to transmit electric power without wires. Tesla lost all of his money in failed business ventures and died in poverty – supported in the end by Westinghouse. As with Edison, Tesla left us with a rich legacy of hundreds of patents – including those for inventions that are the foundation of the modern AC electric power utility.

Before being fired by EGE, Edison undertook a study of electric light bulb performance. One problem with his early bulbs was that the insides of the glass vacuum bulbs would darken with a black coating that diminished the lamps' light output. Edison modified a test bulb by adding a metal *plate* electrode near the filament. He then connected a battery between the *plate* and the filament and discovered that if the plate was connected to the battery's *positive* terminal, then a current would flow. Conversely, if he reversed battery polarity, then no current would flow.

This phenomenon of *rectification* would come to be called the *Edison Effect* ([http://en.wikipedia.org/wiki/Edison\\_Effect](http://en.wikipedia.org/wiki/Edison_Effect)); however, Edison made no significant use of it.

Edison's discovery of the *Edison Effect* came at the time when Italian-Irish Guglielmo Marconi ([http://en.wikipedia.org/wiki/Guglielmo\\_Marconi](http://en.wikipedia.org/wiki/Guglielmo_Marconi)) was commercializing what we now call *radio*; but, then was called *Wireless Telegraphy* with the cooperation of the British Post Office and the British Admiralty. English Physicist John Ambrose Fleming performed experiments on the *Edison Effect* and developed the first vacuum tube wireless telegraphy *detector* ([http://en.wikipedia.org/wiki/Fleming\\_valve](http://en.wikipedia.org/wiki/Fleming_valve)) that would convert received radio-frequency energy into telegraphy signals that could be heard and recorded. His patented invention was adopted for commercial use and Fleming went on to a very successful scientific career.

While the Fleming Valve was a major advance in radio technology, it did not solve a need to amplify radio signals so that distance and reliability could be increased. That solution came at the hand of Lee DeForest – a Yale University graduate and an important pioneer in radio technology.

De Forest discovered in 1906 while working at *Armour Institute of Technology* (predecessor to *Illinois Institute of Technology*) that if he placed a metal *grid* electrode between the *plate* electrode and filament of a Fleming Valve and connected a voltage signal source – such as a radio antenna – between the *grid* and the filament, then he could *modulate* the current flowing in the *plate* circuit so as to cause large changes in *plate* current and hence an *energy gain*. He called his three-electrode valve the *Audion* tube.

Unlike Edison and Fleming, DeForest's *Audion* tubes did not have a high vacuum because he believed some gas was necessary. While his *Audion* tubes would work to *demodulate* radio signals and amplify them, they had poor characteristics and reliability. His *Audion* tubes became obsolete by 1920 as others developed *vacuum triode* electron tubes that made *Audion* tubes obsolete, modernized radio and led to a revolutionary development of modern electronics.

DeForest went on to make other inventions; but, these were not nearly as important as his *Audion* tube. While he earned money from his inventions, he then lost most of it because he was a poor businessman. Nevertheless, he is remembered as one of the founders of the *Institute of Radio Engineers* (now the *Institute of Electrical & Electronics Engineers* (<http://en.wikipedia.org/wiki/IEEE>)) and a father of modern radio and electronics.



The discoveries of Edison, Tesla, Fleming and DeForest in the forty years between 1878 to 1918 chart a path of innovation that brought us to the beginnings of our modern world. While interesting in their own right, these achievements and the men that made them are also worth studying for what these technologists did not do with their inventions.



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