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## CATHODE ALLOY

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My invention relates to nickel alloys, particularly to alloys for the cores of oxides coated filamentary cathodes for electron discharge devices.

The base metal for cathodes coated with alkaline earth metal oxides must be of such a nature that it will react with the oxide coating to produce sufficient free active metal to sustain long and active electron emission. Good emission must be obtained initially and must be maintained at a high and substantially uniform level throughout life. Further, the base metal, particularly for fine filaments, must be ductile and yet be tough and have high hot tensile strength so that it can be drawn to very fine wires.

The object of my invention is an alloy for filament wires which has high strength and which with an oxide coating will produce a thermionic cathode having good electron emission both initially and throughout a long life.

Nickel now in common use for filaments is of the type commercially known as "Commercial Grade A Nickel." This nickel contains some reducing agents which diffuse to the surface of the filament when heated and react with the oxide coating to produce the alkaline earth metal upon which electron emission depends. However, the amount of these reducing agents is generally small, such as .03% to .10%, by weight, of the alloy and is insufficient to maintain emission for long periods of time. Commercial Grade A Nickel, further, is weak and in wire sizes as small as .001'' cannot be handled without considerable breakage.

The characteristic features of my invention are pointed out with particularity in the appended claims and the preferred embodiment thereof is described in the following specification.

I have produced according to my invention a nickel base for filamentary oxide coated cathodes that has unusually great hot and cold strength and produces an oxide coated cathode having good emission properties. I have found that the addition of carbon, silicon, aluminum and magnesium in certain proportions to nickel produces a filament that has a cold drawn tensile strength of more than 90 grams per milligram per 200 millimeters and when coated with barium-strontium oxides provides a cathode having a uniform high emission throughout life.

Contrary to popular belief, I have found that the addition of carbon to pure nickel does not harden the nickel, nor increase its hot strength. Nor does silicon, aluminum or magnesium added alone or in various combinations to pure nickel appreciably increase the tensile strength of filaments.

I have discovered, however, that the addition of carbon to nickel containing small amounts of aluminum, silicon and magnesium vastly increases the tensile strength of the nickel. The addition of these four elements to the nickel has produced a filament that has a tensile strength of more than 90 grams per milligram per 200 millimeters compared to the tensile strength of 45 grams per milligram per 200 millimeters for pure nickel with 1% aluminum and .4% silicon, or 55 to 65 grams per milligram per 200 millimeters of commercial "Grade A Nickel" containing .05% Mg, .05% Mn, .05% Si, .05% Fe, and .05% C. These measurements were made on wire .001'' in diameter.

While I am not certain why the combination with nickel of aluminum, silicon, magnesium and carbon in accordance with my invention gives such high tensile strength, it is my belief that the silicon and magnesium form carbides with the carbon and that the combination of these carbides and nickel form crystalline structures that are very strong.

The nickel alloy that has this high strength and that has been successfully used in commercial production of radio tubes contains about 0.2% carbon, 1.00% aluminum, 0.45% magnesium and 0.4% silicon with the balance commercial electrolytic nickel. This alloy is melted, molded and drawn to the desired wire size, commonly one mil wire, and coated with the usual alkaline earth carbonates. The four constituents of my novel alloy cooperate to produce good initial and long life emission as well as high tensile strength. The aluminum maintains emission throughout life of the cathode by acting as the most active reducing agent but it diffuses slowly and considerable time is required for activation of the coating with the aluminum. The aluminum remains in the core and maintains a high level of emission for many hundreds of hours of use.

Both the aluminum and the silicon increase the specific electrical resistance of the nickel. The proportions specified so increase the resistance that for a given current, voltage and filament length the diameter of the wire may be materially increased. A high specific resistance and large wire size presents a large emission area. This large surface area increases the perveance of the tube and decreases the necessary operating temperature of the filament for a given tube output.

The aluminum and magnesium permits full activation at low temperature; the magnesium, because of its high mobility in the core, rapidly diffuses to the surface and quickly reacts with the outside coating and gives good initial emission. Although the supply of magnesium is soon exhausted it lasts long enough for the aluminum under operating conditions to commence reaction with the oxide coating and carry on a high level of emission throughout the life of the filament. My improved filament core activates the usual oxide coatings at low temperatures and may be operated at an unusually low temperature. This low temperature operation is beneficially reflected in the increased life of the filament, the magnesium and aluminum apparently serving to sustain the high emission at the low operating temperature.

Since the aluminum and silicon content of the nickel can easily control the specific resistance and size of the wire, nickel filaments prepared according to my invention may be easily adapted to any tube with fixed structural dimensions. While 1.0% aluminum and 0.4% silicon has been mentioned, the aluminum may within the scope of my invention be varied from 0.5 to 1.5% and the silicon varied from 0.25 to 0.75%. This range of aluminum and silicon is sufficient to adjust the specific resistance of the wire to the usual commercial types of radio tubes. While 0.4% magnesium has been found to be optimum, magnesium content from 0.07 to 1.25% may be used. Because of the high volatility of the magnesium in the melt the precise amount of magnesium in the finished filament is difficult to establish. Carbon in excess of 0.5% makes nickel containing the magnesium, silicon, and aluminum too hard to work, whereas carbon less than 0.1% is insufficient to give the necessary strength.

Good results have been obtained in manufacture by melting blocks of commercial electrolytic nickel in a magnesia crucible at a temperature of 1560 to 1600°. Then pieces of a carbon-nickel is added to the melt until the melt becomes quiescent. The additional carbon is added sufficient to carry the nickel through the rolls and through the swaging and drawing operations with a final content of about 0.2%. Alternatively the melt may be deoxidized by stirring with a graphite rod until it becomes quiescent and then the specified amount of carbon added. The required amount of silicon, preferably "commercially refined silicon" is then added to the melt and pieces of pure aluminum cut from an aluminum rod are then dropped into the melt. The magnesium is finally added. Because of the high volatility of magnesium at nickel melting temperatures, special precautions are necessary to introduce as much as 0.40% into the nickel. A master alloy of 70% magnesium, 30% nickel preferably is wrapped in a nickel capsule, attached to the end of a pure nickel rod and heated over the melt until the magnesium commences to give off its characteristic white fumes and then the capsule is plunged to the bottom of the melt and then after brief stirring the melt is promptly poured into its molds. The ingots may then be cleaned of surface impurities by grinding and swaged and drawn to the desired wire diameter in accordance with the usual practice in drawing nickel wire. The drawn wire or rolled strip metal may then be coated with barium-strontium carbonates mounted in electron tubes, degassed, activated and sealed off in the usual manner.

I claim:

1. A cathode core alloy consisting of by weight 0.5 to 1.5 percent aluminum, 0.25 to 0.75 percent silicon, 0.07 to 1.25 percent magnesium and containing 0.1 to 0.5 percent carbon and the balance substantially pure nickel.

2. An alloy consisting of by weight about 1.00 percent aluminum, about .40 percent silicon, about .45 percent magnesium and the balance nickel containing .20 percent carbon.

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