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BACKSCATTERED ELECTRONS IN THE POST-ACCELERATION COLOR TELEVISION TUBE

by

N. R. Whetten and A. B. Laponsky

Report No. 56-RL-1644 October 1956

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ABSTRACT

A possible method to improve the color purity and contrast in the post-acceleration color television tube is discussed. Color impurity and lack of contrast are caused by high-energy backscattered electrons from the aluminized phosphor screen. It was found that a thin layer of low atomic number material applied to the back of the screen reduces considerably the number of backscattered electrons. The corresponding reduction in light produced by the primary beam is less than 10 per cent.

BACKSCATTERED ELECTRONS IN THE POST-ACCELERATION COLOR TELEVISION TUBE

N. R. Whetten and A. B. Laponsky

INTRODUCTION

Backscattered electrons cause color impurity and lack of contrast in the General Electric post-acceleration color television tube. This report describes an investigation of backscattered electrons and a possible method of reducing the deleterious effects produced by these electrons. It is found that the relative number of backscattered electrons from an aluminized phosphor may be reduced by a factor of two or more by applying a layer of a low atomic number material such as boron to the back surface of the aluminized phosphor. The corresponding reduction in light output of the primary beam is less than 10 per cent. The improvement in color purity and contrast in the color tube may be greater than the factor of two indicated by the reduction in the number of backscattered electrons.

DISCUSSION OF THE PROBLEM

The post-acceleration color tube employs red, green, and blue phosphor stripes on a cylindrical faceplate (see Fig. 1). Parallel to the phosphor stripes is a grill of wires that deflects the electron beams from three electron guns onto the several phosphors. Focusing is such that electrons from the first gun land only on red phosphor stripes, those from the second land on the blue stripes, and electrons from the third gun land only on the green phosphor stripes. A strong post-acceleration electric field accelerates electrons from the grill region to the aluminized screen. The grill is operated at about 6 kv potential, the screen at 25 kv, and the grill-to-screen spacing is about 3/4 inch. The grill wires are 0.003-inch diameter and are spaced at roughly 30 per inch. A major advantage of this tube over the shadow-mask type tube is that 90 per cent of the electrons from the guns reach the screen, compared to 10-15 per cent in the shadow-mask color tube.

Backscattered electrons emerging from the back surface of the aluminized screen are in a strong electric field that accelerates the electrons back toward the screen. Since most backscattered electrons emerge with a velocity component parallel to the screen, they will reenter the screen at a location that may be distant from the original primary beam. The backscattered electrons land on red, green, and

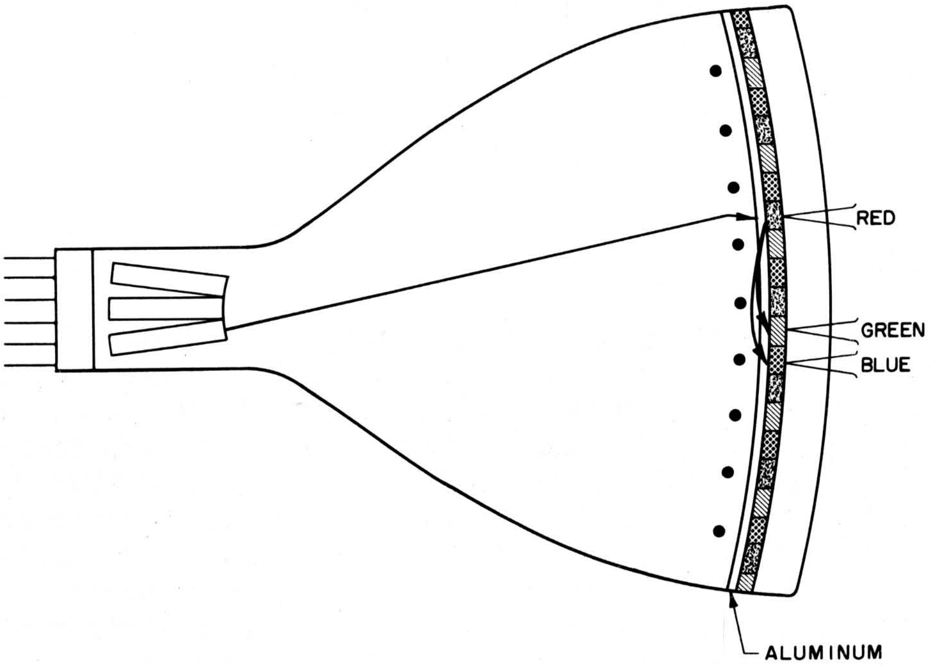

Fig. 1 Schematic diagram of the post-acceleration color television tube.

blue phosphor stripes indiscriminately, causing both color impurity and loss of contrast. The effect is especially noticeable when a bright spot is surrounded by a dark area; a halo of light is produced in the dark area surrounding the bright spot.

The color purity of the red is especially poor, as a result of the relative inefficiency of the red phosphor. A greater primary beam intensity must be used to produce a comparable red light intensity. Since the number of backscattered electrons is proportional to the number of primary electrons, there are more backscattered electrons from the red than from the blue and green phosphors. Backscattered electrons randomly arriving at red, green, and blue phosphors excite less red light than blue and green, due to the relative inefficiency of the red phosphor, and so more blue and green impurities are present than red.

Low-energy secondary electrons and backscattered electrons with less than 5 kev energy do not contribute to the color impurity and loss of contrast, as they have insufficient energy to penetrate the aluminum film and excite the phosphor. Backscattered electrons with a component of energy perpendicular to the screen of between 5 kev and 19 kev are effective in producing stray light, since in the conservative electric field they will reenter the screen with the same energy as they had on emerging from the screen--sufficient to penetrate the aluminum and excite the phosphor. Electrons with a component of energy perpendicular to the screen of 19 kev or more may either pass through the spacing between the grill wires to be collected at the gun end of the tube, or may strike the grill wires. Those that hit the grill wires may produce low-energy secondaries that are then accelerated back to the screen and arrive with 19 kev energy.

Another source of color impurity arises from primary electrons that strike the grill wires directly, producing low-energy secondary electrons at the grill wires. These secondaries may be accelerated to the screen in the strong electric field to excite the phosphor directly in front of the grill wires. Secondary electron emission from piano wire has been investigated previously,(1) and may be reduced by coating the wire with carbon.

The present work was undertaken to determine if the color purity of the tube could be improved by applying a coating of a low backscattering material to the screen. The low backscattering material should reduce the number of backscattered electrons exciting the phosphor screen without appreciably decreasing the light produced by the primary beam due to energy lost in traversing the low backscattering material.

BACKGROUND

Secondary electrons may be classified into two categories, the low energy secondaries or "true" secondaries, and the high energy or backscattered electrons. The two groups can be easily distinguished in a typical secondary electron energy distribution curve, such as the schematic curve presented in Fig. 2. Fifty electron volts is arbitrarily taken as the energy separating backscattered from true secondary electrons. The energy distribution of the backscattered electrons is

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1. A. B. Laponsky and N. R. Whetten, Memo Report No. EC-94, General Electric Research Laboratory (1954).

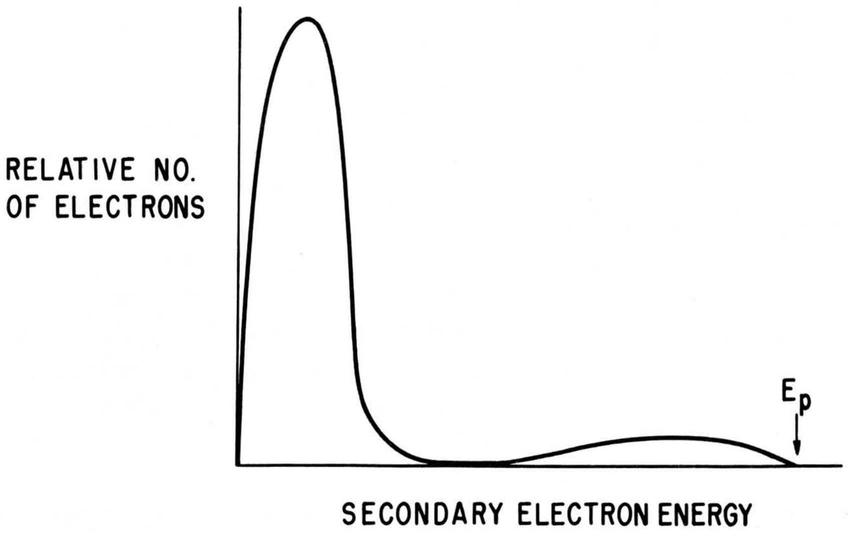

Fig. 2 A typical secondary electron energy distribution curve.

sometimes peaked near the primary electron energy for high atomic number materials,(2) but for low atomic number materials the curve is believed to be gradual and nearly symmetrical as in Fig. 2. The number of backscattered electrons from a target is usually much less than the number of low-energy secondaries.

The high-energy backscattered electrons from the screen cause the color impurity in the post-acceleration tube. Low-energy secondaries from the screen are not able to penetrate the aluminum and excite the phosphor. Backscattered electrons result from high-energy collisions between the primary electron and electrons in the solid. The primary electron itself may be scattered backward, or an electron in the solid may receive sufficient energy to emerge as a backscattered electron.

Figure 3 presents the backscattered fraction for a number of elements. The backscattered fraction η, or ratio of the number of secondaries with energy greater than 50 ev to the number of primaries, is given as a function of the atomic number Z of the target material. The backscattered fraction is seen to vary linearly with the atomic number, at least for atomic numbers less than 30. The lowest backscattered fractions are obtained for very low atomic number elements. For

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2. E. J. Sternglass, Phys. Rev., 95, 345 (1954).

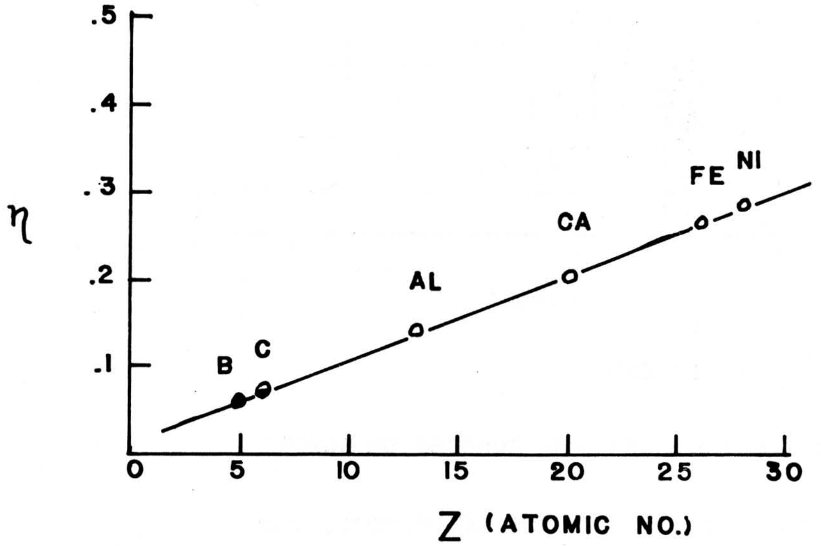

Fig. 3 The dependence of the backscattered fraction, η , on atomic number.

compounds, the backscattered fraction is believed to be dependent on the average atomic number of the atoms comprising the compound. For low atomic materials the backscattered fraction is nearly independent of the primary electron energy.

It is evident from Fig. 3 that a low atomic number target could be used to obtain a low backscattered fraction. It may not be apparent that a coating of a low atomic number material would substantially reduce the backscattered fraction from a composite target, since backscattered electrons originate throughout the composite target. It is also questionable whether a low Z material sufficiently thick to reduce the backscattered fraction would not greatly reduce the primary light intensity. This project was undertaken to attempt to answer these questions, and to determine if it would be possible to reduce the backscattering in order to improve color purity in the post-acceleration tube.

EXPERIMENTAL PROCEDURE

The backscattered fraction of aluminized phosphors with coatings of low atomic number materials has been measured using an electrostatic retarding potential method (see Fig. 4). Primary electrons from the electron gun strike the aluminized phosphor target. Only those secondaries

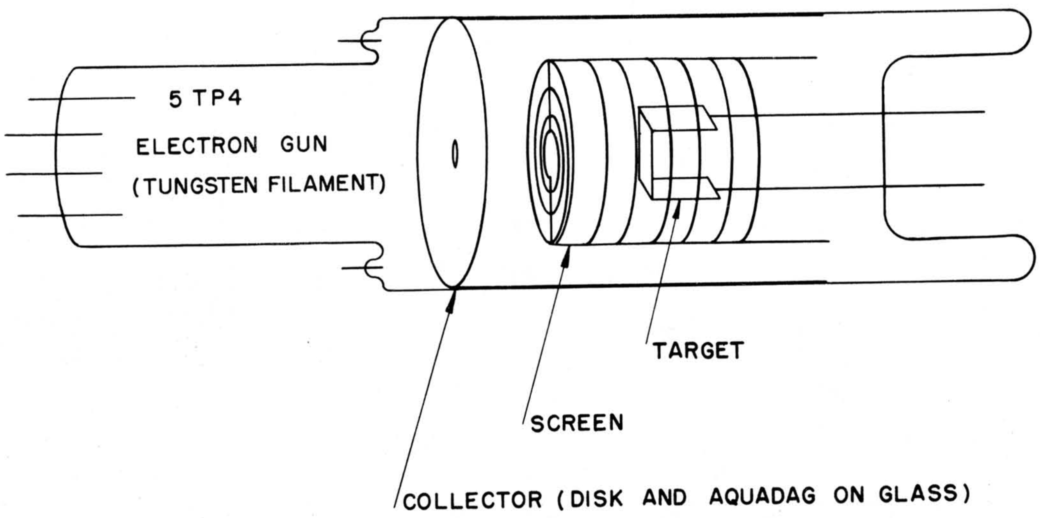

Fig. 4. Schematic diagram of the tube for backscattering measurements.

with greater than 50 ev energy are able to overcome the 50-volt retarding field from the target to the grid surroundnig the target. The collector is held positive with respect to the grid to collect the backscattered electrons. Secondaries formed at the collector are prevented from returning to the target by the negative grid.

To obtain the primary current, the total current to the collector, grid, and target is measured. The current due to the backscattered electrons is the current to the grid and collector alone.

Low atomic number materials have been applied to an aluminized phosphor surface by a number of different methods. These are discussed below.

1. Boron Spray Method: This was the earliest technique used. (3) Fine powdered boron was suspended in water and sprayed onto an aluminized phosphor, allowing the target to dry between successive coatings. Early measurements showed a considerable decrease in the backscattered fraction, but also a substantial decrease in the light output of the primary beam. The excited phosphor was speckled in appearance. The reduction in light output and speckled appearance was attributed to the unevenness

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3. N.R. Whetten and A.B. Laponsky, Memo Report No. EA-1, General Electric Research Laboratory (1955).

of the boron coating. Clumps of boron resulted in substantial energy losses of the primary electrons that had to penetrate the clumps, while other areas were covered by little or no boron.

2. Pyrolysis of Diborane Gas: Boron was deposited on the aluminized phosphor surface by the thermal decomposition of diborane gas, B_2H_6. The backscattered fraction was substantially decreased by the boron deposited by this technique. However, the diborane apparently penetrated the aluminum film to deposit boron in the phosphor, so that light output measurements could not be made. It might be possible to prevent this from occurring, but we have made no further attempts in this direction.

3. Evaporation of Boron: Powdered boron in a carbon boat was evaporated by resistance heating of the boat. This method was satisfactory for our laboratory tests, resulting in uniform layers of boron. However, boron melts at 2300°C, and is not simple to evaporate. The boron does not make good thermal contact with the boat, and probably reacts with the carbon at elevated temperatures to form boron carbide, rendering the life of the boats quite short. No attempts were made to heat the boat by electron bombardment or by r-f heating. Most of the results quoted in the following section were obtained using evaporated layers of boron. It is not certain that these layers are pure boron. Carbon from the boats may be present, and also B_2O_3, since the targets were exposed to air while being transferred from the evaporator to the measuring tube. Both carbon and oxygen are low atomic number elements, and so their presence is not considered harmful to the backscattering properties of the layer.

4. Evaporation of Carbon: Carbon was evaporated by resistance heating of a thin (1/4 inch) rod of carbon. Carbon sublimes at the very high temperature of 3650°C. This method produced suitable layers for testing.

5. Electrostatic Spraying of Carbon: Powdered graphite was deposited on an aluminized screen by electrostatic spraying. The graphite powder was held in a flask at ground potential, with a 150-mesh screen also at ground potential over the mouth of the flask. A small jet of air was used to stir the graphite, making a cloud of graphite dust above the bottle. Fifteen kv potential was applied to the aluminized phosphor held a few inches from the mouth of the flask. The graphite dust is attracted to the aluminized phosphor, and adheres to it, forming a fairly uniform coating of carbon.

6. Evaporation of Lithium Borate: When evaporated onto the aluminized phosphor in a vacuum, the lithium borate forms a glassy layer that tears the aluminum from the phosphor. By evaporating lithium borate through argon, uniform powdery coatings that do not tear the aluminum have been obtained.

7. Evaporation of B_2O_3: Boric anhydride or boric acid was evaporated in a vacuum. A glassy coating is obtained, but the coating is an insulator. A very thin aluminum layer (less than 10 micrograms/cm^2) was evaporated onto the boric oxide so that the composite target is conducting, but so that the outer aluminum scarcely affects the backscattering from the target.

EXPERIMENTAL RESULTS

Figure 5 presents the backscattered fraction, η, from an aluminized phosphor with varying amounts of evaporated boron. The backscattered fraction is presented as a function of the primary electron energy. Since these are composite targets, the curves are not flat. As the primary energy is increased, the higher backscattered fraction of the aluminum and phosphor contribute increasingly and cause the curves to rise. Figure 6 demonstrates the reduction in backscattered fraction with increasing boron thicknesses. These data are for a primary electron energy of 20 kev. The backscattered fraction of pure boron was determined to be 0.06 and independent of primary energy from 1 - 25 kev. This was determined with sprayed boron layers that were considerably thicker (1/16 inch) than the penetration depth of the primary beam. It is apparent that the application of the boron layer reduces the backscattered fraction from the aluminized phosphor, and that the extent of the reduction is determined by the amount of boron applied.

As the boron thickness is increased, the energy lost by the primary beam while traversing the boron layer must be increased, with consequent reduction in the primary light output. It is highly pertinent to know the corresponding reduction in primary light output on application of various layers of boron. Light output measurements were made on these targets by H. D. Coghill and L. R. Koller. These data are presented in Table I. The relative light output is given in arbitrary units at 10 and 25 kev primary energy for several thicknesses of boron on the aluminized phosphor. The reduction in the light output is seen to be severe with 10 kev primary electrons, but is small (within the scatter of the experimental points) for the 25 kev primary electrons.

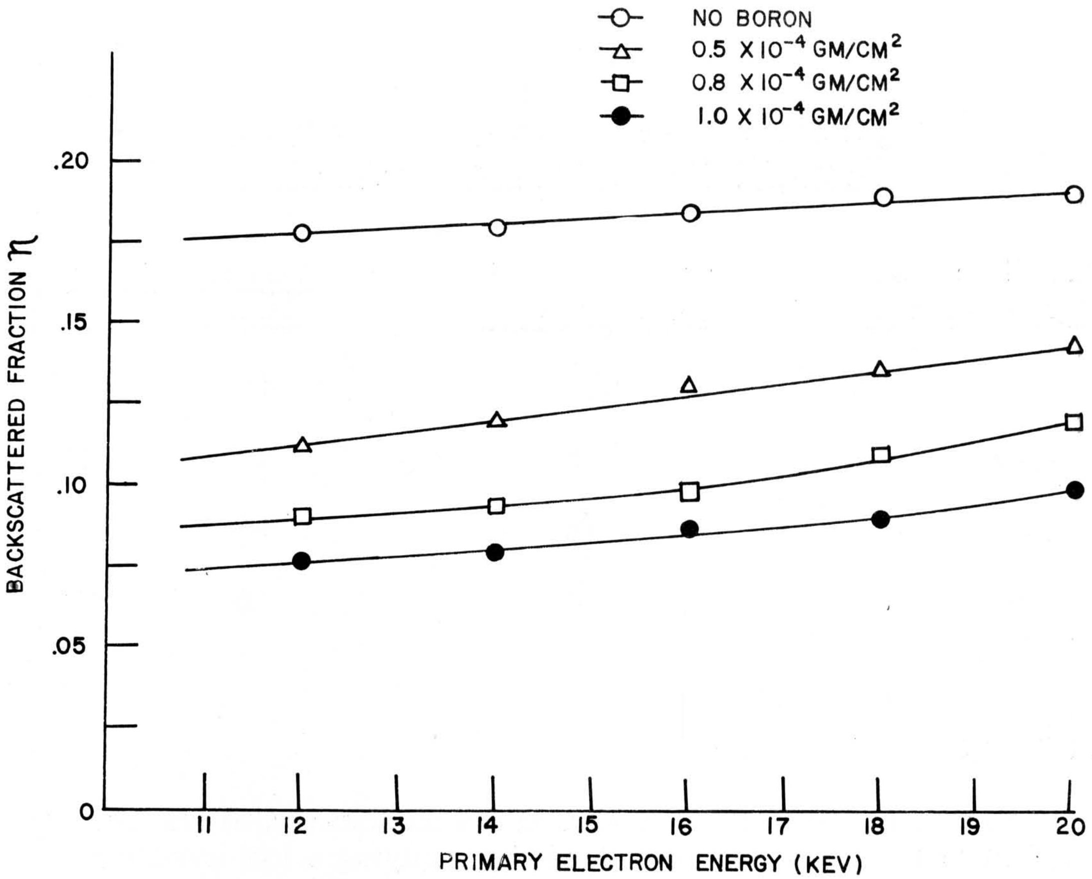

Fig. 5 Dependence of the backscattered fraction, η, on the primary electron energy.

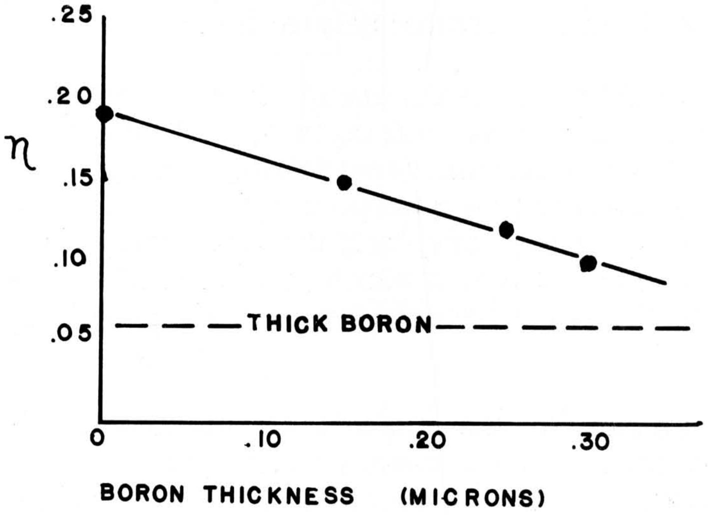

Fig. 6 The dependence of the backscattered fraction, η, on the thickness of the boron coating.

TABLE I

Light Output and Backscattered Ratio from Boron Coated Aluminized Phosphors

Boron Thickness in microns (est.)	Backscattered Ratio (20 kev)	Relative Light Output 10 kev	Relative Light Output 25 kev
0	0.19	65	81, 84
0.15	.15	59	82
0.25	.12	38	80, 81
0.30	.10	38	81

DISCUSSION

It appears from these data that the backscattered fraction from an aluminized phosphor can be reduced by applying a low atomic number material to the aluminized phosphor with only a slight corresponding decrease in the light produced by the primary beam. The thickness of low atomic number material is critical. If the layer is too thick, the light produced by the primary beam will be decreased; if the layer is too thin, the backscattered fraction will not be substantially reduced.

Some of the low atomic number materials used in this experiment might prove to be difficult to apply in a commercial color tube. Others such as lithium borate and boric oxide-aluminum (see "Experimental Procedure" section, No. 6 and 7) appear to be good possibilities. They evaporate relatively easily and form satisfactory, uniform coatings. All of the seven types of low atomic number coatings which have been discussed were found to substantially reduce the backscattered fraction of an aluminized phosphor.

In addition to reducing the number of backscattered electrons, a layer of a low atomic number material may improve the color purity by a second mechanism. The backscattered electrons have on the average less energy than the primary electrons. They consequently lose more energy in traversing the added layer than do the primary electrons (the Bethe-Bloch relationship). By adding a low atomic number layer to the aluminized phosphor the stray light should be reduced more rapidly than the light from the primary beam by this mechanism. It seems desirable to reduce the aluminum thickness to the minimum required for reflectivity and conductivity, and to increase the thickness of the low atomic number layer until the light from the primary beam begins to decrease substantially.

We have made no measurements of the energy distribution of the backscattered electrons. It may be possible that a low Z coating would unfavorably shift the energy distribution to higher energies. However, Sternglass(2) reports that the mean energy of the backscattered electrons from a low Z element (carbon) is about half the primary electron energy. This would indicate a shift toward lower energies with the low Z coating, which should improve the color purity in the post-acceleration tube.

CONCLUSIONS

1. A coating of a low atomic number material (boron) was found to reduce the backscattered fraction from an aluminized phosphor by a factor of two while reducing the light output from the primary beam by less than 10 per cent.

2. The resulting improvement in color purity in the post-acceleration tube on application of a low atomic number coating is difficult to estimate, and may be more than the factor of two improvement in backscattered fraction.

3. Lithium borate and boric oxide-aluminum coatings evaporate relatively easily, and may be useful for the color tube application.

4. The backscattered fraction of boron was found to be 0.06.

Recently W. D. Rublack of the Cathode Ray Tube Sub-Department has examined aluminized phosphors in a post-acceleration tube. The aluminized phosphors were covered with layers of (1) evaporated carbon, (2) boric oxide-aluminum, and (3) lithium borate. Preliminary results indicate that a singnificant improvement in contrast in the post-acceleration tube can be obtained by this method.

ACKNOWLEDGMENTS

Contributions to this work have been made by a great number of people. The post-acceleration color tube is under development at the Cathode Ray Tube Sub-Department and the Electronics Laboratory in Syracuse. Valuable discussions were held with a number of people from these departments.

We wish to thank P. E. Pashler for suggesting the problem to us and for numerous contributions, C. R. Bunting for measurements and evaporations of boron and boric oxide, H. E. Tanis and R. J. Bondley for numerous evaporations of lithium borate and boric oxide, H. D. Coghill and L. R. Koller for light measurements, and J. W. Havens of the General Engineering Laboratory for preparing boron-coated targets by pyrolysis of B_2H_6.

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Backscattered Electrons in the Post-acceleration Color Television Tube 45-504

ABSTRACT

A possible method to improve the color purity and constrast in the post-acceleration color television tube is discussed. Color impurity and lack of contrast are caused by high-energy backscattered electrons from the aluminized phosphor screen. It was found that a thin layer of low atomic number material applied to the back of the screen reduces considerably the number of back-scattered electrons. The corresponding reduction in light produced by the primary beam is less than 10 per cent.

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