Časopis pro pěstování matematiky a fysiky

Václav Dolejšek; B. Janíček

Conditions for discharge in the ionic tube

Časopis pro pěstování matematiky a fysiky, Vol. 66 (1937), No. 3, 218--223

Persistent URL: http://dml.cz/dmlcz/122523

ČÁST FYSIKÁLNÍ.

Conditions for discharge in the ionic tube.

V. Dolejšek and **B. Janíček**, Praha.

(Received December 21, 1936.)

Influence of cathode-sputtering on discharge. Use of Copper and Iron cathodes at high current-densities. Influence of impurities in the material of the cathode. Study of the distribution of load on the cathode surface with the Copper cathode employed. Conditions for normal discharge with Copper and Iron cathodes. Disadvantages of pure Aluminium.

In the neighbourhood of the longer wavelengths, round about 100 Å slight traces of impurities always begin to appear in the spectrum, which greatly increase the difficulty of classifying new lines. On the other hand it is well known that all materials that may be used as electrodes will distill off more or less in a vacuum when affected by heat. A certain heating effect on at least part of the electrodes during the discharge cannot be avoided, hence it follows that, without considering here the effects of cathode-sputtering, a layer of the material of the cathode will always be formed on the anticathode.

On the average, we found that the contamination of this region of the spectrum by impurities was least, in our work on absorption edges with the ionic tube[1]) when using a directly-cooled aluminium cathode and a tungsten anticathode.

It is important to mention here that, even with these electrodes, and under the optimum working conditions, as found by Dráb[2]) and Kunzl,[3]) the lines of aluminium from the cathode always appeared, though with a relatively weak intensity.

[1]) V. Dolejšek-B. Janíček, Nature **132** (1933), 443; J. Bačkovský-V. Dolejšek, Zs. f. Phys. **99** (1936), 48; V. Dolejšek-V. Kunzl, Zs. f. Phys. **74** (1932), 565, Časopis **61** (1932), 242.

[2]) K. Dráb, Časopis 2 (1933), 31; V. Dolejšek-K. Dráb, C. R. **196** (1933), 334.

[3]) V. Kunzl, Acta physica polonica 2 (1934), 447, Zs. f. Phys. **99** (1936), 42.

We attempted to remove the above-mentioned traces of aluminium from the cathode by a method analogous to that employed by Dauvillier when working with an electronic tube. This method consists in using an incandescent cathode made of the material whose spectrum we wish to obtain, so that, during the discharge, the anticathode is continuously covered, by sputtering, with fresh layers of material from the cathode. Therefore to obtain the Copper or Iron lines we substituted for the Aluminium cathode in our ionic tube a cathode of Copper or Iron respectively. The Aluminium cathode having been replaced by one of Copper or Iron, all other conditions for obtaining the discharge with normal cathode potential were left the same as when the Aluminium cathode was used. We found, however, that in this case the character of the discharge in the ionic tube is changed, and becomes anomalous, which form is not effective for the generation of X-rays. In order to secure the normal discharge, as obtained with the Aluminium cathode, we tried altering the above-mentioned conditions, such as the pressure, distance between electrodes, etc.

We also investigated how the discharge in the tube depended upon the purity of the material of the cathode. We found that at high current-densities, such as were employed in our ionic tube, it was quite impossible to use cathodes of e. g. pure Copper, as will be mentioned later. The most resistant material found for the cathode was Copper, cast in vacuo and containing a certain percentage of Silicon, the presence of the latter element being determined from the appearance of the Si K_α-doublet in the spectrum. With this material, as also with certain varieties of Iron (pure Iron was not examined), and with certain distances apart of the electrodes, we were able to obtain the normal discharge, and the normal L-series spectrum of Copper and Iron. The photographs however were no better than those obtained with the Aluminium cathode, and brought to light no new spectral data.

It is important to state here that, while with 1200 Volts and 250 MA. on the Aluminium cathode the optimum pressure was about 0,2 mm of mercury, when using the Iron cathode it was necessary to increase the pressure to over 1 mm of mercury to obtain the same conditions of discharge. Unless unexpected difficulties turn up, it should be possible to apply these results to the method of obtaining the emission spectra of gases with the ionic tube, as put forward by J. Bačkovský.[4])

[4]) J. Bačkovský-V. Dolejšek, Nature **136** (1933), 643; J. Bačkovský, C. R. **202** (1936), 1671.

The use of Copper as a cathode also enabled us to learn how regularly different parts of the cathode surface are loaded. It was shown that copper was sputtered more from those parts of the cathode that were bombarded by positive ions. It appears that the intensity of the surface loading, for a given curvature, varies with the distance from the centre, which is in accordance with the results of Dráb (loc. cit.), while it further appears that with lessening curvature the loading of points farther from the centre is increased. This was particularly apparent when using a cathode that had different curvature in two dimensions mutually at right angles. The parts furthest from the centre in the direction of least curvature, forming an annular space about 2 mm wide close to the edge of the cathode, were so heavily bombarded by positive ions that after a few hours use the cathode in these regions appeared carved into sharp edges, so that the discharge became completely irregular. On the other hand in the direction of the greater curvature the edges were far less affected. The distribution of load over the whole surface of the cathode could be determined by the amount of Copper removed at any point.

In the case of the Copper cathode its surface remains very pure, even throughout a prolonged discharge, and it is obvious that it is well possible to use such a surface bombarded by positive ions as a source of radiation in any method where it is not necessary to screen the rays, but an extended source may be employed. This is the case in e. g. certain focussing methods, in which the source may be of considerable area, and may have much the same size as our cathode. It is scarcely possible to decrease the surface of the cathode, since this is to increase the specific loading of the cathode surface, which the material will not stand.

It should be stated here that, as we have already mentioned in connection with Copper, extremely pure materials are not at all suitable for electrodes under heavy surface loading, or, at least, they may greatly change the conditions for optimum discharge. Thus for example we used Copper from various sources, among them also Copper from the firm of Haereus, and from the Bureau of Standards, which last was kindly presented to us by Professor A. Šimek of Brno. Cathodes made from this extraordinarily pure copper gave a completely different character to the discharge, since they produced extraordinarily strong sputtering, and it was quite impossible to concentrate electrons on the anticathode or to obtain a clear focus. The whole anticathode became covered with a black film. Under these circumstances the spectrum lines either did not appear at all, or else were very feeble. As we have stated, when we used as cathode material

Copper containing certain impurities (e. g. traces of Silicon) such as is used in the manufacture of electrodes for Röntgen tubes, the cathode sputtering greatly decreased, and the black film on the anticathode did not appear. In the same way we also used chemically pure Aluminium from the Bureau of Standards, again provided by the kindness of Prof. A. Šimek, and compared the discharge from a cathode of this Aluminium with that from ordinary commercial Aluminium. In this case the difference was not so marked, nevertheless it was easily seen that pure Aluminium is not such a suitable cathode material as commercial Aluminium.

It was not possible to determine precisely and quantitatively the optimum conditions for discharge, especially the pressure for a given intensity, given voltage, or given distance or size of electrodes, since this involves the simultaneous variation of a number of other factors, which cannot be evaluated.

The difference in the character of the discharge obtained with Aluminium and Copper cathodes is not surprising, since Copper suffers enormously greater cathode sputtering than Aluminium. It is thus quite understandable that with high current densities, as in our case, even with good cathode cooling, there should be considerable differences in the character and conditions of the discharge. On the other hand, the great difference between the character of the discharge from a Copper cathode and an Iron cathode must be explained by the great difference in the thermal conductivity of the cathode material, Iron, as a far worse heat-conductor, permitting the existence of a very large temperature difference between the cooled interior of the cathode and the layer immediately beneath the surface. As has been shown by the work of previous authors, in order to maintain a normal potential fall across an X-ray tube, the cathode must be maintained below a certain critical temperature, above which the discharge becomes anomalous. From this it may be judged that, in order to get a normal discharge it is necessary to increase the surface of the Iron cathode so as to decrease the specific loading. Thus it should only be possible to use Iron cathodes for those methods which allow of the use of an extended source of radiation.

When examining the connection between the size of the focus and the distance of the electrodes, it was found alike with Aluminium, Copper, and Iron cathodes that if the distance of the electrodes was increased above a certain minimum value the size of the focal spot increased, at another given distance a maximum was obtained, and a further increase of the distance between the electrodes again caused the size of the focus to decrease. For example, with the Aluminium cathode and electrodes of the normal size, the size of the focal spot was a minimum at distances of 22,5 and 25,0 mm. and a maximum at a distance of 23,0 mm. We did not examine whether with still smaller or greater distances the size of the focal spot again increased, since at these distances the surface of the anticathode becomes fouled. At the maximum size of focus between the two minima the focus is clearest, i. e. the discharge is most suitable, the focus produces the least layer of impurities on the anticathode, and it is under these conditions that one may best obtain the true spectrum of the anticathode.

The results obtained inder these conditions of absorption were published in Nature (loc. cit.) and continued therein by J. Bačkovský (loc. cit.). Besides the absorption edges we have obtained some new lines in the emission spectrum. Since we had not a precision spectrograph at hand with a plane grating, and since in certain positions of the grating it was necessary to determine the angles of deviation entirely from dispersion curves, it has not been possible mutually to compare the wave-lengths of all the lines photographed; for this reason we prefer not to give them here.

Spectroscopical Institute of the Charles' University of Prague.

*

Podmínky pro výboj v iontové trubici.

(Obsah předchozího článku.)

Tepelné namáhání elektrod, zvláště katody, při výboji ve vakuu způsobuje, že se vždy vypaří něco materiálu elektrod. Toto vypařování nedá se nikdy při větších hustotách proudových zcela odstraniti a působí rušivě zvláště v oboru vlnových délek v okolí 100 Å.

Autoři zkoušeli, zda lze použíti v iontové trubici tohoto fakta k získání X-spekter způsobem, jakého použil Dauvillier v trubici elektronové. Konali měření s katodami Cu a Fe. Při tom se ukázalo, že na př. čisté mědi (pocházející z Bureau of Standards, nebo od firmy Haeraeus) nelze vůbec při větších intensitách v iontové trubici použíti. Obecně lze říci, že čisté kovy jako Cu, Fe a Al jsou pro výboj méně vhodné než kovy s určitými přísadami, i když lze některých takových kovů čistých (na př. čistého aluminia) použíti.

Měděná katoda s přimíšeninou silicia se neukázala výhodnou k získání dlouhovlnného X-spektra Cu, naopak intensivnějších spekter bylo dosaženo s aluminiovou katodou, jak ukázáno v již publikovaných pracích autorů.

Užití Cu jako katody ukázalo však rozdělení zatížení tepelného na povrchu katody. Z nastalých změn destilací na povrchu bylo zřejmo, že při určité křivosti, při níž jsou elektrony nejlépe fokusovány, jsou positivními ionty nejvíce atakována místa těsně u okraje katody na ploše mezikruží povrchu katody o rozdílu poloměrů asi 2 mm. Celkové rozdělení zatížení povrchu katody je v souhlasu s výsledky Drábovými získanými na aluminiové katodě cestou fotografickou.
