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Van Zuijlen et al.

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[54] **FILAMENT-CURRENT CONTROL UNIT IN ELECTRON-BEAM APPARATUS**

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[52] **U.S. Cl.** **315/94**

[51] **Int. Cl.** **H01j 3/08**

[58] **Field of Search** .... 315/94, 106, 107, 111, 315/30, 31, 307; 219/121 EB, 121 EBM; 178/DIG. 29

[56] **References Cited**

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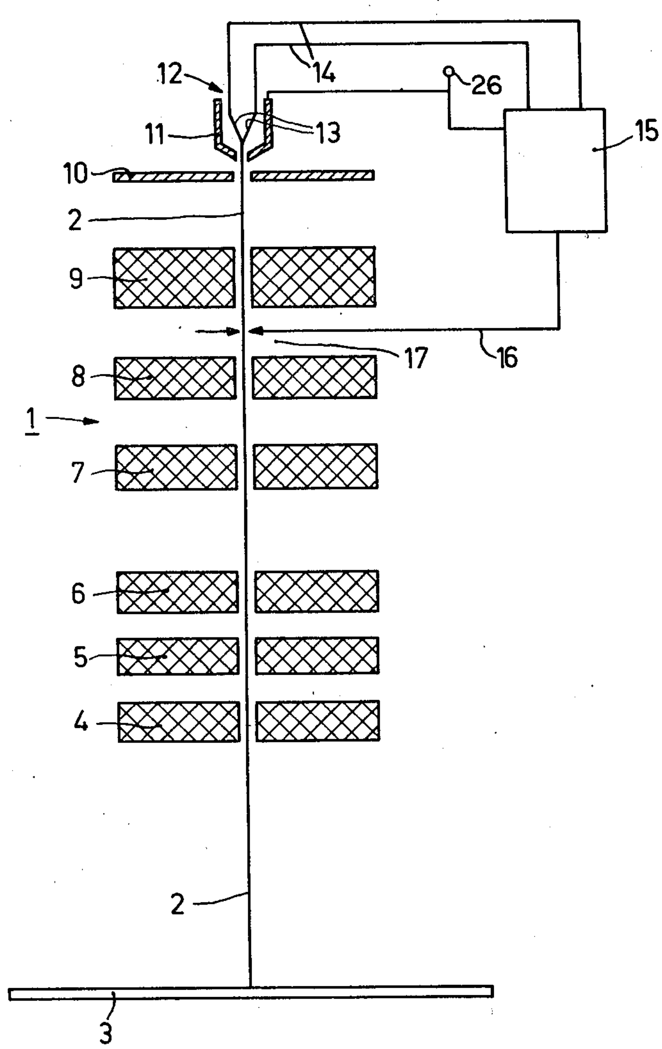
[57] **ABSTRACT**

An electron-beam apparatus is provided with an electrode for intercepting a portion of the electron beam so as to achieve automatio cathode temperature control. The filament current is controlled by means of a signal derived from this interception electrode.

5 Claims, 3 Drawing Figures



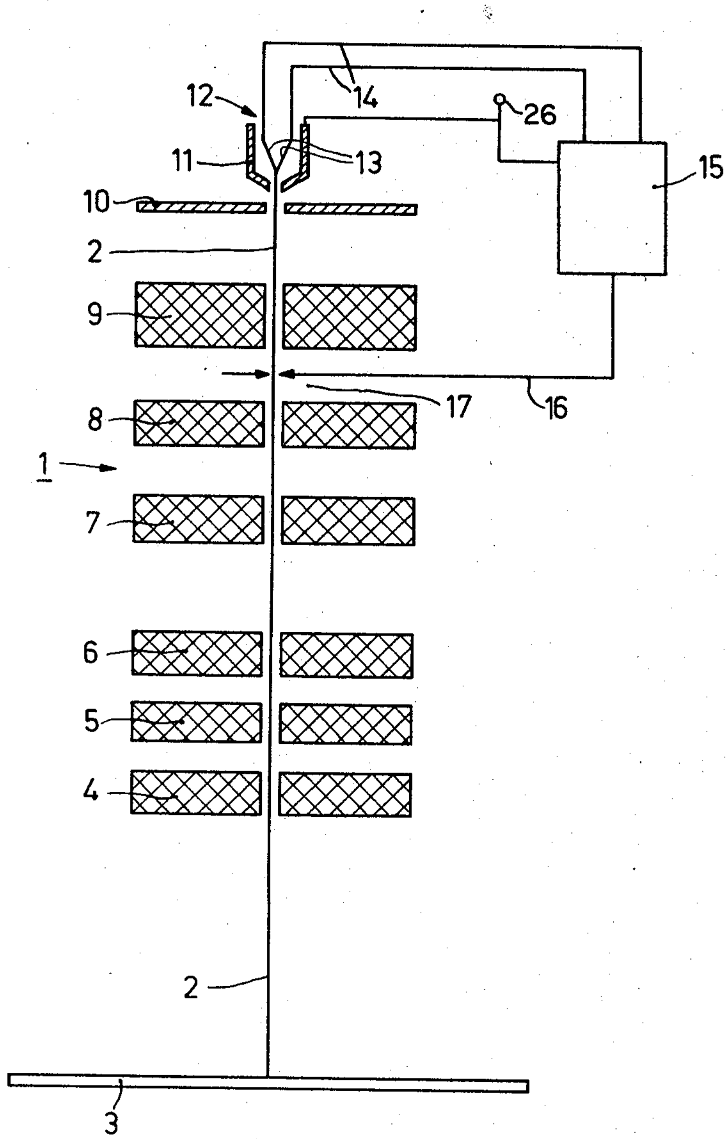


Fig.1

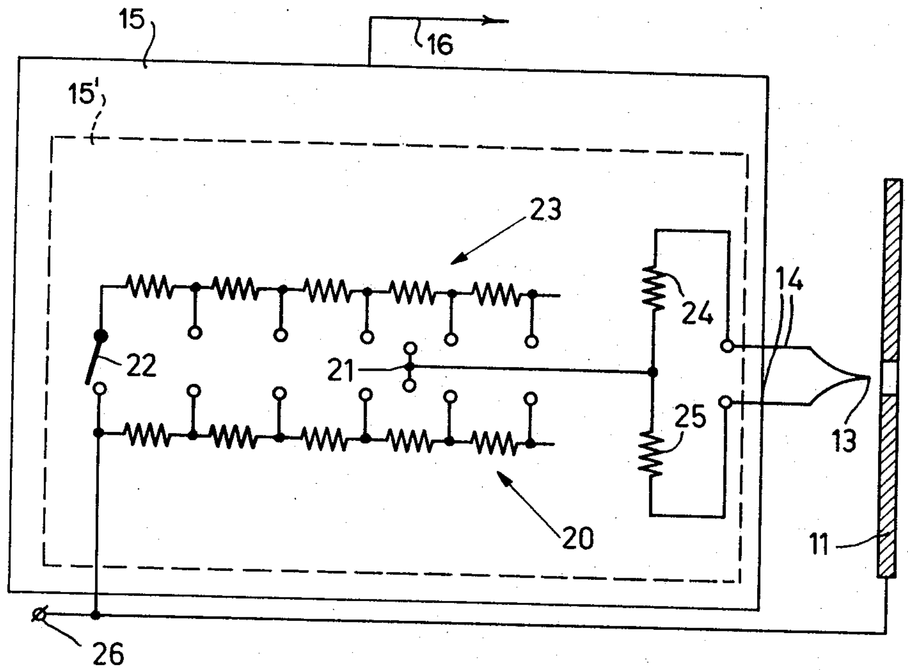


Fig.2

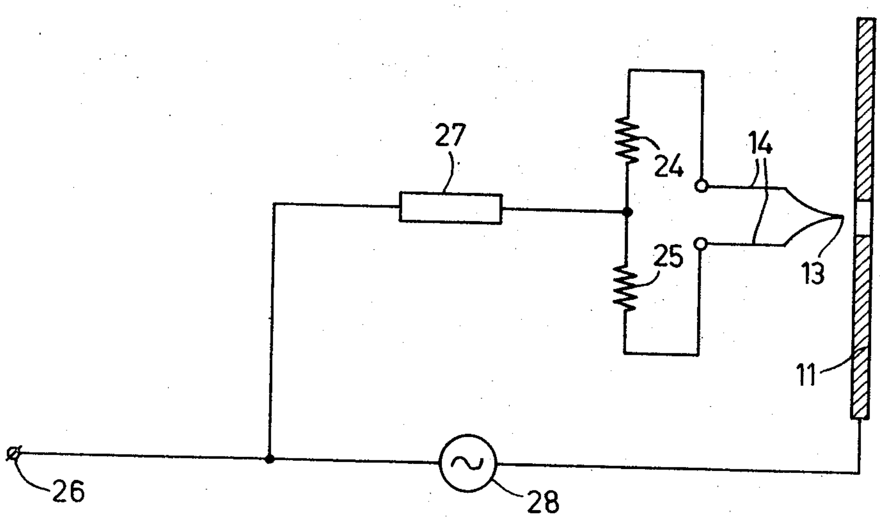


Fig.3

FILAMENT-CURRENT CONTROL UNIT IN ELECTRON-BEAM APPARATUS

The invention relates to an electron-beam apparatus comprising a cathode for thermal emission of an electron beam, a Wehnelt electrode, and a filament-current control unit.

In devices comprising a thermal cathode for generating an electron beam for electron-optical applications it is of essential importance that the cathode temperature during operation is always optimum for the emission of an electron beam of this kind. An operating temperature which is lower than the optimum temperature results in a comparatively small emissive power of the cathode. As a result, an electron beam to be emitted by the cathode has, at least on the cathode surface, a comparatively small current density. This has an adverse effect on the optical properties of the apparatus. Too high an operating temperature of the cathode reduces the service life of the cathode, particularly in the case of directly-heated filament cathodes.

A known method of adjusting the cathode temperature is based on the visual evaluation of an image of the emissive cathode to be formed on a phosphor screen. The temperature is then adjusted such that a reasonably uniform image is formed on the phosphor screen. This adjusting method has the drawback that the adjustment criterion is formed by subjective observations and that a cathode image must be formed for any readjustment. It was found that the use of this criterion usually gives rise to an excessively high cathode temperature.

An automatically-operating filament-current adjustment for an electron-beam apparatus comprising a thermal cathode is described in U.S. Pat. No. 3,413,517. Therein, a variation of the cathode output current, caused by an impressed filament-current variation, is compared with a preset reference value. The reference value is derived from an emission curve which is assumed to be the standard emission curve. Mutual differences in the emission curves for different cathodes and temperature-dependent leakage currents from the cathode can then result in deviations from the optimum temperature adjustment.

The invention has for its object to eliminate these drawbacks and to provide reliable and, if desired automatically-operating, filament-temperature control. To this end, an electron-beam apparatus of the kind set forth according to the invention is characterized in that the electron-beam apparatus is provided with an interception electrode for local interception of part of the electron beam, said interception electrode forming part of the filament-current control unit.

In an electron-beam apparatus according to the invention the subjective criterion is replaced by an objective measuring value which is to be generated in the electron-beam apparatus, it no longer being necessary to use a reference value. In a preferred embodiment according to the invention, a periodic variation is associated with the Wehnelt resistance or the Wehnelt voltage, a resultant signal from the interception screen being used for adjusting the optimum cathode temperature.

A preferred embodiment of an electron-beam apparatus according to the invention will be described hereinafter with reference to the drawing. In the drawing:

FIG. 1 is a diagrammatic view of an electron microscope provided with a filament-current control unit according to the invention,

FIG. 2 shows a cathode Wehnelt circuit for using a filament-current control unit with a varying Wehnelt resistance, and

FIG. 3 shows a cathode Wehnelt circuit for using a filament-current control unit with a varying Wehnelt voltage.

An electron microscope **1** as shown in FIG. **1** comprises, moving against the direction of movement of an electron beam **2** to be generated therein, a phosphor screen **3** for intercepting the electron beam, a projection lens **4**, an intermediate lens **5**, a diffraction lens **6**, an objective lens **7**, a second condensor lens **8**, a first condensor lens **9**, an acceleration anode **10**, a Wehnelt electrode **11**, and a cathode **12**. In this case the cathode is formed by two interconnected filaments **13**. The filaments are connected, via filament-supply conductors **14**, to a current-control unit **15** which is connected to an interception electrode **17** via a coupling **16**. During operation the interception electrode **17** intercepts, for example, at least 5% of the electron beam **2**. The interception electrode preferably consists of a plate having a round aperture with a diameter of approximately 300 microns. The interception electrode can also be arranged elsewhere in the electron microscope, the diameter of the aperture being adaptable to the location. The interception electrode is preferably made of an electrically conductive material, in which case it must be electrically insulated from the electron microscope so as to be capable of supplying an electrical output signal. The coupling **16** is then formed by an electrical conductor. The interception electrode in another embodiment comprises a phosphor which is to be activated by the electron beam. Via an optical coupling **16** which is to used in conjunction therewith, a signal is obtained which is dependent of the beam-current intensity, it being possible for said signal to be intercepted, for example, by a light-sensitive element of the filament-current control unit **15**. Provided that the entire emitted electron beam does not reach the display screen **3**, the device can also be constructed such that the display screen **3** or if the entire emitted electron beam impinges upon the display screen, a portion of the display screen, acts as the interception electrode. An electrical or optical signal which is dependent of the beam-current density is then derived from the display screen. The detected signal is applied to the current-control unit **15** which controls the filament current in accordance with the received signal.

In a preferred embodiment of a filament-current control unit as shown in FIG. **2**, an adjustment signal is obtained on the interception electrode by variation of the Wehnelt resistance. To this end, the cathode Wehnelt circuit **15'**, forming a part of the current control unit **15**, comprises a series of resistors **20** and a selector switch **21** for adjusting an operating value for the Wehnelt resistance. Using a switch **22**, a variation of, for example, 10 to 20% of the operating value of the Wehnelt resistance is effected by inserting or not inserting resistors of a series of resistors **23** in the circuit arrangement. FIG. **2** also shows the two interconnected filaments **13**, provided with two equal resistors **24** and **25**, the Wehnelt electrode **11** and a switching point **26** which is to be connected to cathode potential.

During generation of a signal on the interception electrode by periodic variation of the Wehnelt resistance between the operating value and a value which is slightly there below, the signal intensity will decrease if the cathode temperature is adjusted too low, and will increase if the cathode temperature is adjusted too high. In both situations the filament current can be re-adjusted such that the signal again obtains the initial intensity, i.e. the intensity associated with the operating value of the Wehnelt resistance. This process can subsequently be repeated until a Wehnelt resistance variation no longer influences the signal. The optimum cathode temperature is thus reached. The readjustment of the filament current can be readily effected automatically by providing the filament-current control unit with a circuit for generating a difference signal between the signal at the operating value of the Wehnelt resistance and the signal at the decreased Wehnelt resistance. The filament current is then controlled by this difference signal, for example, via a servomechanism (not shown).

A cathode Wehnelt circuit for more practical filament-current control according to the invention is shown in FIG. **3.** This Figure shows the Wehnelt electrode **11,** the cathode **13** with the cathode resistors **24** and **25,** a Wehnelt circuit **27** and a voltage source **28.** The Wehnelt circuit **27** generates the Wehnelt voltage, the value of which is dependent of the geometry of the electron-beam apparatus. On the generated Wehnelt voltage a periodic, preferably sinusoidal, voltage variation is superimposed by the voltage source **28.** For example, an alternating voltage having a peak-to-peak value of 10 V can be superimposed on a nominal cathode Wehnelt voltage of 200 V.

Because the current density of the electron beam as a function of the Wehnelt voltage is maximum exactly at the optimum cathode temperature, an alternating voltage superimposed on the Wehnelt voltage will cause a signal having a double frequency, with respect to the frequency of the impressed alternating voltage, only at the optimum temperature setting. This is utilized in a preferred embodiment by using this frequency doubling, after addition of a frequency-sensitive detector, as an indication for the optimum

temperature. An oscilloscope can be used as the detector so that the frequency-doubling can be visually observed. In given cases such as, for example, in the case of an electron-beam machining apparatus where a large portion of the electron beam to be emitted by the cathode is effectively used, a phase sensitive element can be advantageously used for controlling the filament current. This is because in these cases the measuring on the edge of the electron beam produces an insufficiently accurate impression of the brightness variations at the centre of the electron beam.

What is claimed is:

1. An electron-beam apparatus comprising a cathode for the thermal emission of an electron beam, A Wehnelt electrode in proximity to said cathode for controlling said electron beam, a filament current control unit including a variable resistance coupled between said Wehnelt electrode and said cathode for maintaining a desired emission of said electron beam, and an interception electrode for intercepting a portion of the electron beam said filament-current control unit being operable for adjusting the temperature of said cathode to a value at which minimum signals resulting from variation of said variable resistance are generated at said interception electrode.

2. An electron-beam apparatus as claimed in claim **1** wherein said variable resistance is a Wehnelt resistance and means for varying the Wehnelt resistance.

3. An electron-beam apparatus as claimed in claim **2** wherein the filament-current control unit comprises a circuit for forming a difference signal from the signals at the extreme values of the Wehnelt resistance.

4. An electron-beam apparatus as claimed in claim **1** wherein the filament-current control unit comprises a voltage generator for superimposing a voltage variation on a cathode-grid voltage.

5. An electron-beam apparatus as claimed in claim **4** wherein the filament-current control unit further comprises a phase-sensitive detector for controlling the filament-current and thereby maintaining the temperature of said cathode, a preset phase shift with respect to the applied signal establishing the criterion for adjustment.

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