Preparation for New Dispenser Cathode's Active Substance Using Freeze-Drying Method

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Introduction

The fast development of vacuum electron devices especially terahertz wave devices put forward a ascending demand for cathode's emission capacity. Previously, we introduced a new kind of dispenser cathode whose active substance combines scandate-doped barium aluminate with SrO, and it reached a pulse emission current density of 171.6±2.8A/cm^2 at 1100℃$_B$ in test [1].

However, due to the inhomogeneity existing in solid-phase mechanical grinding and mixing processes of ingredients, these cathodes performed inconsistently at times.

Thus, we bring out a liquid-phase way of synthesis, namely freeze sublimation method, to improve the material's homogeneity and cathodes' performance as well as its consistency.

Deployment

The raw materials are soluble acetates or nitrates of Ba, Sr, Al and Sc. They are made into water solution at specific ratios. After adequate stirring, the solution was instantly frozen by liquid nitrogen and then put into a vacuum freeze-drying machine to let water sublimate sufficiently. Dry precursor powder was calcined and then impregnated into porous tungsten matrix at 1750℃, both in hydrogen atmosphere.

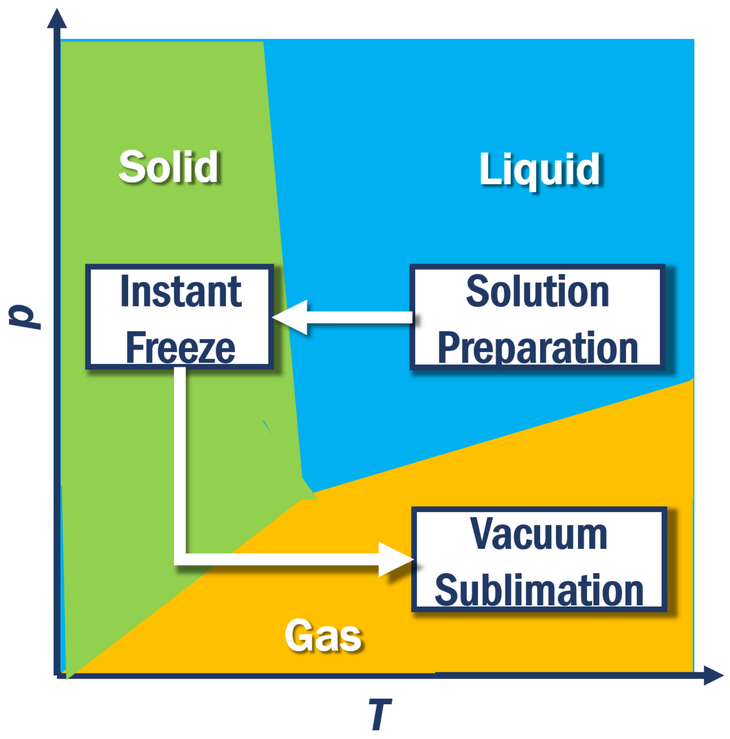
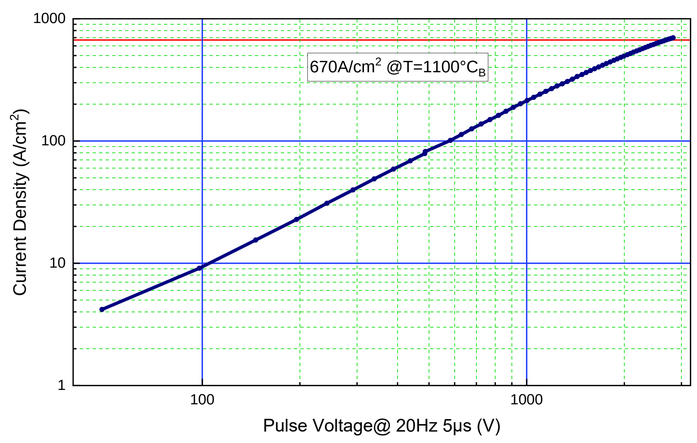


Fig.1 Sketch for precursor preparation with water's phase diagram

Tests & Characterizations

Emission tests were carried out using the same close-spaced diode configuration as that of [1]. The cathodes were machined into Φ1mm and mounted into an ultra-high vacuum chamber with a water-cooled anode, the distance to which is typically 0.20mm. After activation at 1150 ℃$_B$ for 2 hours, the cathodes reached a pulse emission current density of 670A/cm^2, about approximately 4 times of that of [1], with good consistency between 2 mounted samples in the meantime. Pulse emission curve is shown in Fig.2.



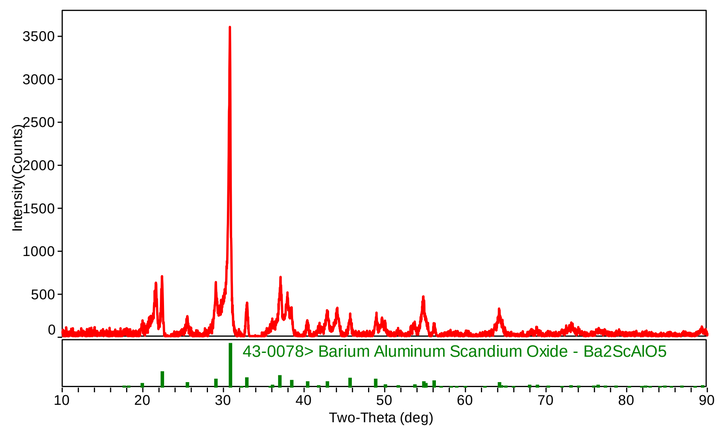
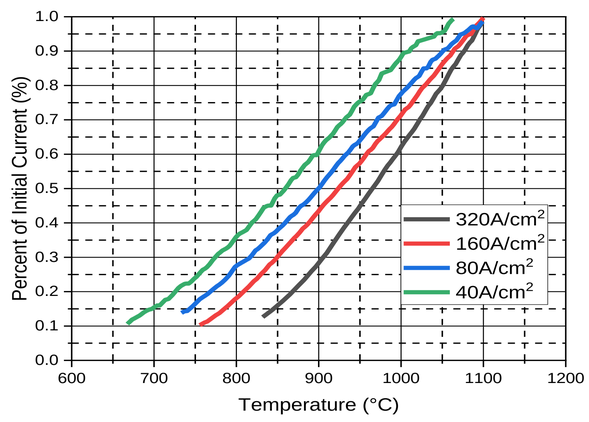


Fig.2 (left) Cathode's pulse emission of one of the recipes at 1100 ℃$_B$
Fig.3 (right) XRD pattern of the major phase of precursor after calcination

EDAX results demonstrate that the elementary compositions keep uniform in random areas of the powder of the active substance. XRD patterns (Fig.3) demonstrate that the main phase of calcined precursor is mainly Ba_2ScAlO_5 with 3at% SrO, which is a novel component in scandate cathodes [2]. Miram curves of 320-, 160-, 80- and 40A/cm^2 have been measures and Practical Work Function Distribution (PWFD) curves have also been calculated, respectively. Peak work function of 320- and 160A/cm^2 is around 1.50eV while that of 80- and 40A/cm^2 is 1.55eV. Anomalous Schottky effect enhanced as emission current amplified. DC duration test is undergoing and there is no apparent emission drop after 2700 hours of normal operation by now.



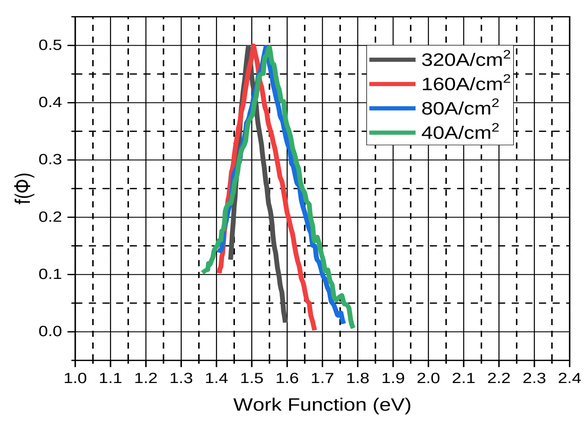


Fig.4 (left) Miram curves of the new cathode
Fig.5 (right) PWFD curves of the new cathode

Conclusions & Prospects

Liquid-phase reaction and freeze-drying sublimation technology has seen a wide use in the syntheses of nano functional powders. However, it is the first time that this technology is used in the synthesis of emission active substance. The material's elementary homogeneity has been improved, so as the cathode's emission performance and its consistency. Our research may provide a promising electron source option for future terahertz devices, and furthermore lay a foundation for revealing the emitting mechanism of scandate as well as other kinds of thermionic cathodes. Further investigations and characterizations like LEEM/PEEM and Auger Electron Spectroscopy (AES) are to be done. More mechanisms and properties of this substance are to be studied.

[1] Shengyi Yin, Zhaochuan Zhang, et al., IEEE Transactions on Electron Devices, (2013) 4258.
[2] Wei Liu, Ke Zhang, et al., Applied Surface Science, 251.80-88.

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