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Kelvin probe studies of cesium telluride photocathode for AWA photoinjector

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ABSTRACT

Cesium telluride is an important photocathode as an electron source for particle accelerators. It has a relatively high quantum efficiency (> 1%), is sufficiently robust in a photoinjector, and has a long lifetime. This photocathode is grown in-house for a new Argonne Wakefield Accelerator (AWA) beamline to produce high charge per bunch (≈ 50 nC) in a long bunch train. Here, we present a study of the work function of cesium telluride photocathode using the Kelvin probe technique. The study includes an investigation of the correlation between the quantum efficiency and the work function, the effect of photocathode aging, the effect of UV exposure on the work function, and the evolution of the work function during and after photocathode rejuvenation via heating.

1. Introduction

Cesium telluride (Cs_2Te) photocathodes are a proven electron source for particle accelerators and photodetectors. They have a high quantum efficiency (10% at 4.9 eV photon energy), a long lifetime (months) and are robust in a high gradient environment [1]. The new RF photocathode drive gun being commissioned at the Argonne Wakefield Accelerator (AWA) is a high peak-current electron beam source for the new 75 MeV linear electron accelerator to be used to excite wakefields in dielectric-loaded accelerating (DLA) structures and other novel high-gradient structures [2]. A unique requirement of the AWA experimental program is the ability to produce long trains of high-charge bunches, hence the need for a high quantum efficiency (QE) photocathode such as Cs_2Te. The AWA is producing Cs_2Te photocathodes for use in the new high-charge 1.3 GHz photoinjector [3]. In particular, an electron bunch train of 30 bunches with up to 50 nC per bunch is expected to be produced. The substantial demands on the photocathode necessitate a thorough understanding of the photocathode and its parameters. The QE at a particular photon energy and the work function (ϕ) are two important parameters of electron emission. Here, we present the results of Kelvin probe measurements of the work function on Cs_2Te photocathodes. We examined (i) the correlation between the QE and the work function, (ii) how QE and the work function evolved with photocathode aging, (iii) effects of rejuvenation of the photocathode via heating, and (iv) the effects on the work function upon exposure to UV light. This study may also shed some light into the properties of other high-QE photocathodes, such as the Cs-based multialkali antimonide, which are used in photomultiplier tubes.

2. Photocathode fabrication

The photocathodes studied were fabricated in the AWA photocathode laboratory using a standard recipe and procedure [4,5]. AWA photocathodes are deposited on a molybdenum plug designed to fit into the back wall of the gun. In preparation for deposition, the plug is polished and cleaned, placed under vacuum, then heated to 120 °C. A 22 nm layer of tellurium is deposited via thermal evaporation. When tellurium deposition is complete, cesium deposition commences and the photocurrent is monitored. Deposition continues for several minutes after maximum photocurrent is achieved. The result of this process is a Cs_2Te thin film photocathode on a molybdenum substrate with an effective photocathode diameter of 31 mm and a typical initial QE of 15%. QE is measured at 4.9 eV photon energy to closely match the photoinjector laser. The anode voltage is 450 V and the cathode is grounded. The separation between anode and cathode

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