**Bismuth Tri-Iodide Polycrystalline Films For X-ray Direct And Digital Imagers**

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**ANTECEDENTS**

- **X-RAY AND DIGITAL IMAGERS**
  - Deposition of a suitable material for radiation detection onto a charge collection device useful for image processing, usually a readout matrix.

**WHY BiI₃ AS PHOTODETECTOR?**

- **BiI₃ PROPERTY**
  - High absorption (85% absorbance at 20 keV)
- **DETECTOR PROPERTY**
  - High sensitivity

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**FILM REQUIREMENTS**

- **REQUIRED PHYSICAL PROPERTIES OF THE FILM**
  - Area: up to 40 cm x 40 cm for medical applications and larger for others such as cargo inspection or astronomy
  - Thickness: 30 to 500 µm, depending on the X-ray energy
  - Grain size: less than 50 µm, matching readout matrix pixelation and required imaging spatial resolution
  - Orientation: the best with the (0 0 1) planes parallel to the substrate
  - Texture: more oriented or better still, epitaxial films give better electrical and transport properties
    - Surface: The smoother the surface the better the front electrode
    - Resistivity: about 10²Ω·cm (dark current density lower than 10 pA/mm² biased at about 1 Vµm for readout matrix requirements)
    - Sensitivity and signal to dark relation: as high as possible
    - Uniformity: Every film property must be uniform for the complete film active area

**FILM GROWTH METHOD REQUIREMENTS**

- The material must not decompose (stoichiometry)
- The growth temperature must be below 200 – 250°C (readout matrix stability)
- The growth time must be less than 1 – 2 days (readout matrix stability)
- The film thickness and uniformity must be amenable to control
- The method must be easy to scale-up to large areas
- The production cost must be competitive

**EXPERIMENTAL**

- **STARTING MATERIAL**
  - Synthesized from Bi₂O₂CO₃·H₂O and KI:
    - Bi₂O₂CO₃·H₂O + 6 KNO₃ + 6 KI → 2 BiI₃ + CO₂ + 4 H₂O + 6 KNO₃
  - Treated with HI to turn the following equilibrium to the left:
    - BiI₃ + H₂O → BiI₂ + HI
  - Purified by:
    - Zone refining (100 passes, 3 cm/hr)
    - Three sublimations (6 x 10⁻⁶ Pa, 350°C)

- **GROWTH METHOD**
  - Physical Vapor Deposition (PVD), with possibility of controlling source, wall and substrate temperatures

- **GROWTH PARAMETERS**
  - Initial pressure: 6 x 10⁻¹ Pa
  - Source temperature: 350°C
  - Growth temperature: 175°C
  - Growth time: 48 hours

**RESULTS**

- **POLYCRYSTALLINE FILMS**
  - Film thickness: 5 to 60 µm (±10%), appropriate for absorption of radiation of 20 keV.
  - Film grain size: (0.5 ± 5) and (5 ± 10) µm, appropriate for the readout matrix pixelation and for X-ray imaging spatial resolution.

- **ELECTRICAL PROPERTIES**
  - Detector thickness: 59 µm, electrode area: 0.25 cm²
  - Elecdroles are ohmic contacts: the dark current density is identical for negative electric fields
  - Resistivity: 1.4 x 10¹⁰ Ω·cm (Higher than the ones reported for single crystals, and for previous polycrystalline films of the material, and lower than the one obtained for oriented films)
  - Dark current density is lower than 10 pA/mm² for electric fields below 6 V/µm, which agrees with the readout matrix requirements (10 pA/mm² maximum).
  - This very low dark current permits to apply a high electric field to the detector, sufficient to optimize the charge collection

- **SENSITIVITY TO X-RAYS**
  - Linear response
  - Sensitivity: 0.11 nC/R.cm²
  - A signal to dark relation [Iₐ(t)/Iₐ] of 9.5 was calculated at 2.7 R/min and 40 KVP, with an electric field of 0.4 V/µm applied to the film.

- **ELECTRON CHARGE COLLECTION**
  - Fitting to the Hecht relation, n² = σE²d² (1 + 1/2μ²d²) H(d, E)
  - n: current density at complete charge collection
  - σ: current density related to the electric field applied to the film
  - μ: electron mobility
  - E: applied electric field
  - Mobility-lifetime value for electrons (µe): 3 x 10⁻¹⁵ cm²/V·s (in the order of previously reported data for bismuth tri-iodide films and lower than for other heavy metal halide films)

**CONCLUSIONS**

- Layers of bismuth tri-iodide have been grown by PVD and characterized in their thickness, grain size and orientation. The values of these properties are appropriate for X-ray direct and digital imaging.
- Detectors made with these films give dark current densities which permit to apply electric fields appropriate for good electron collection, a linear response, and a good sensitivity as well as a high signal to dark response to an X-ray beam.
- Although with not so good properties than oriented films of the same material, the films reported here have acceptable performance for direct and digital X-ray imaging, with better electrical and response to radiation properties than previously reported for polycrystalline bismuth tri-iodide films.
- Time requirements and yield are better than for the previously reported oriented films, which makes our procedure an interesting and cheaper alternative for producing photodetectors of this material.