Fabrication of a Hybrid Transition Edge Sensor Array for Lynx

Edward Wassell[1,2], Joseph S. Adams[1,4], Simon R. Bandler[1], Meng-Ping Chang[1,2], James A. Chervenak[1], Aaron M. Datesman[1,2], Megan E. Eckart[1], Audrey J. Ewin[1], Fred M. Finkbeiner[1,5], Jong Yoon Ha[1,3], R. Kelley[1], Caroline A. Kilbourne[1], Antoine R. Miniussi[1,4], F. Porter[1], John E. Sadleir[1], Kazuhiro Sakai[1,4], Stephen. J. Smith[1], Nicholas Wakehan[1,6]

1 NASA Goddard Space Flight Center, Greenbelt, MD, USA, 2 KBRWyle Inc., Lexington Park, MD, USA, 3 SB Microsystems Inc., Glen Burnie, MD, USA,
4 UMBC, Baltimore, MD, USA, 5 Sigma Space Corporation, Lanham, MD, USA, 6 USRA, Columbia, MD, USA

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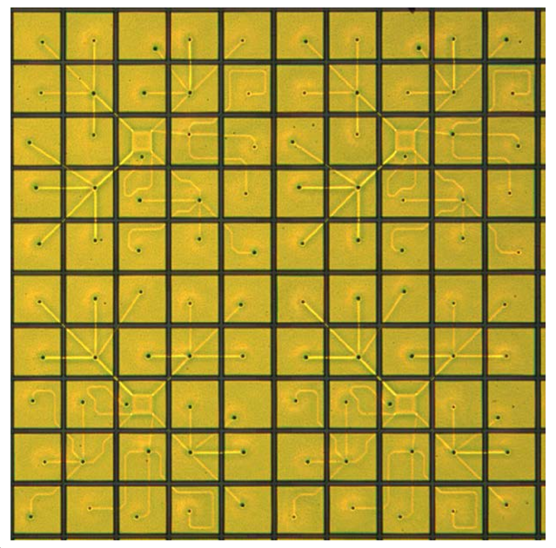
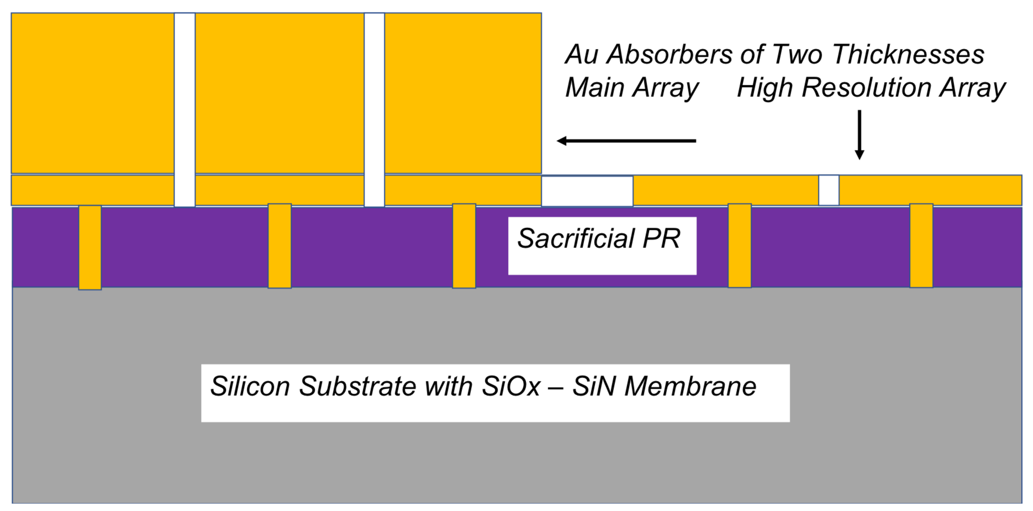
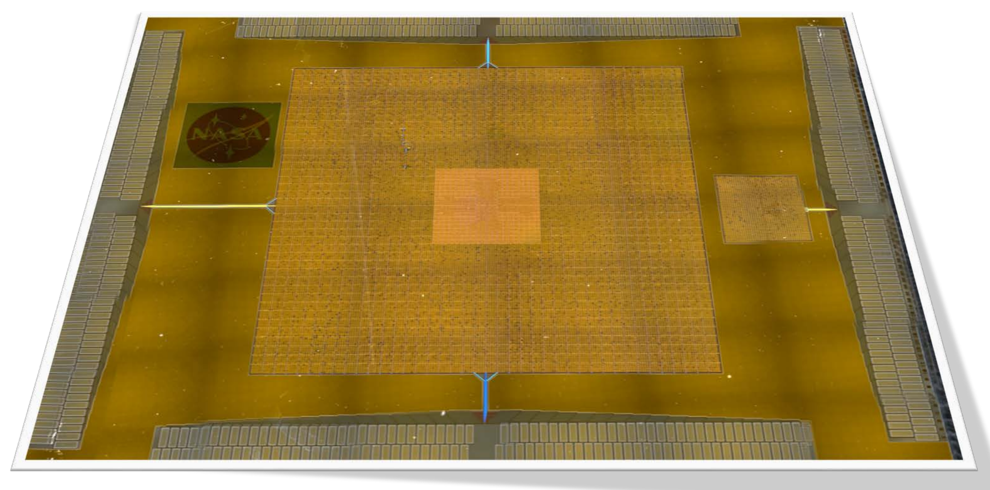
INTRODUCTION



Lynx is a proposed NASA X-Ray telescope flight mission aimed at achieving state-of-the-art angular and energy resolution with a 100 kilopixel array to probe the hot energetic young universe in unprecedented detail. To achieve these goals, our team plans on leveraging our current work in development of the focal plane for the Athena X-Ray Integral Field Unit (XIFU) while advancing the state-of-the-art in transition edge sensor (TES) X-ray detector technology. To the left is an image of the 5x5 hydras, 25 pixels all connected by different thermal links to a single TES. Our team is able to identify the pixel location of an x-ray event by the shape of the current pulse. The hydra concept helps achieve a 100 kilopixel detector array, by reducing to 4000 the number of TES pixels that need to be wired and read out.

LYNX HYBRID ARRAY DEVELOPMENT

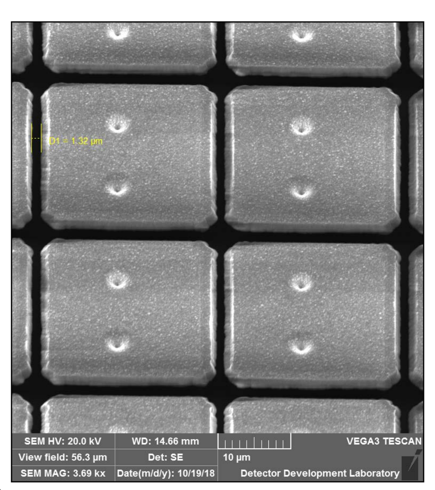


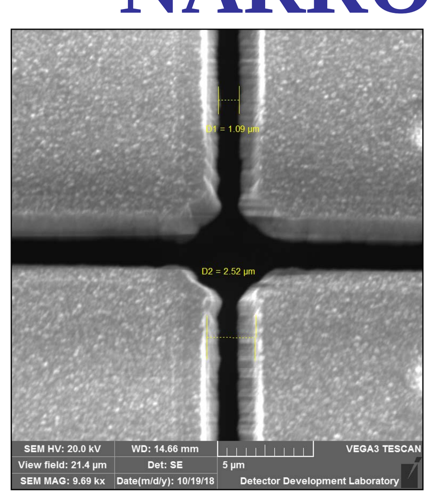


- Coat TES and circuit with sacrificial resist
- Pattern stems to cantilever absorbers to TES and evaporate Ti/Au as a seed layer.
- Electroplate 1.0 um Au over entire wafer
- Electroplate 3.0 um additional Au through a mold on main array.
- Coat entire wafer with Ti/Al_2O_3 or Ti/TiO_2 as a hard mask
- Pattern hardmask and etch with CF_4 plasma in RIE
- Add resist and ion mill streets separating 4 micron absorbers to 3.5 micron depth
- Strip photoresist in O_2 plasma
- Continue Ion mill with hard mask to yield main and high resolution array
- Remove residual Ti hardmask with CF_4 and O_2 plasma

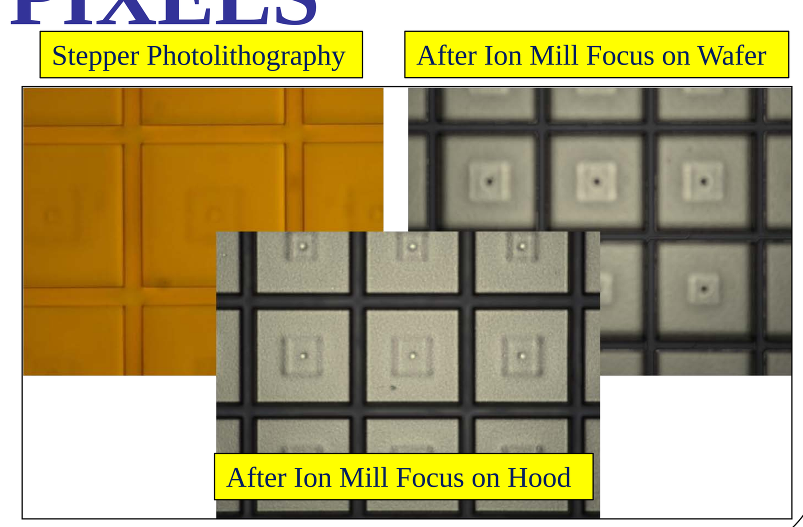
A hybrid array detector is proposed for the Lynx mission. Specifically, three different arrays will be fabricated in the same planar process in one focal plane and optimized for different science goals. The main array consists of 5x5 hydras, 25 pixels with 4 micron thick Au absorbers each with its own unique thermal link to a common TES. The outer array has absorbers on a 50-micron pitch for most of the 5 arc-minute field of view, and the inner array has 25-micron pitch pixels covering the central 1 arc-minute region. A high resolution array consisting of single pixel 1 micron thick Au absorbers on 50-micron pitch will lie off to the side.

NARROW GAPS BETWEEN PIXELS





- **We have achieved narrow gaps of < 2um by ion mill on 1.1um thick Au absorbers**
- **With nxn arrays of 25um square TES pixels, this yields an areal fill factor of 92% when pixels are defined by contact lithography and ion mill.**
- **Future Plan is to use direct write or stepper to prevent clipping of corners of pixels**



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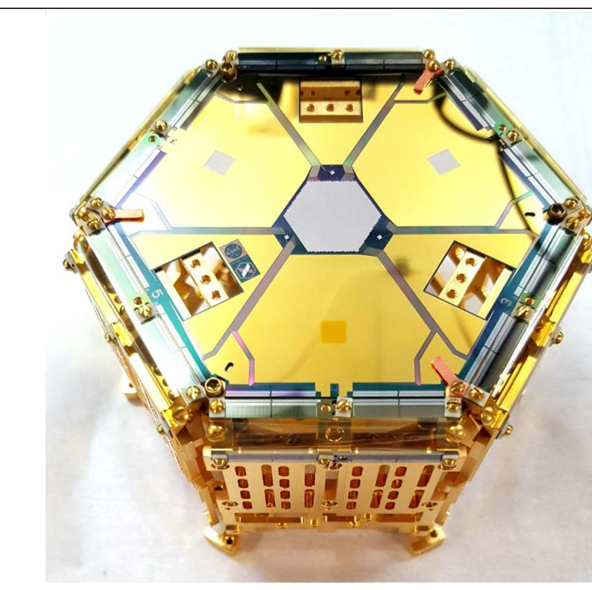
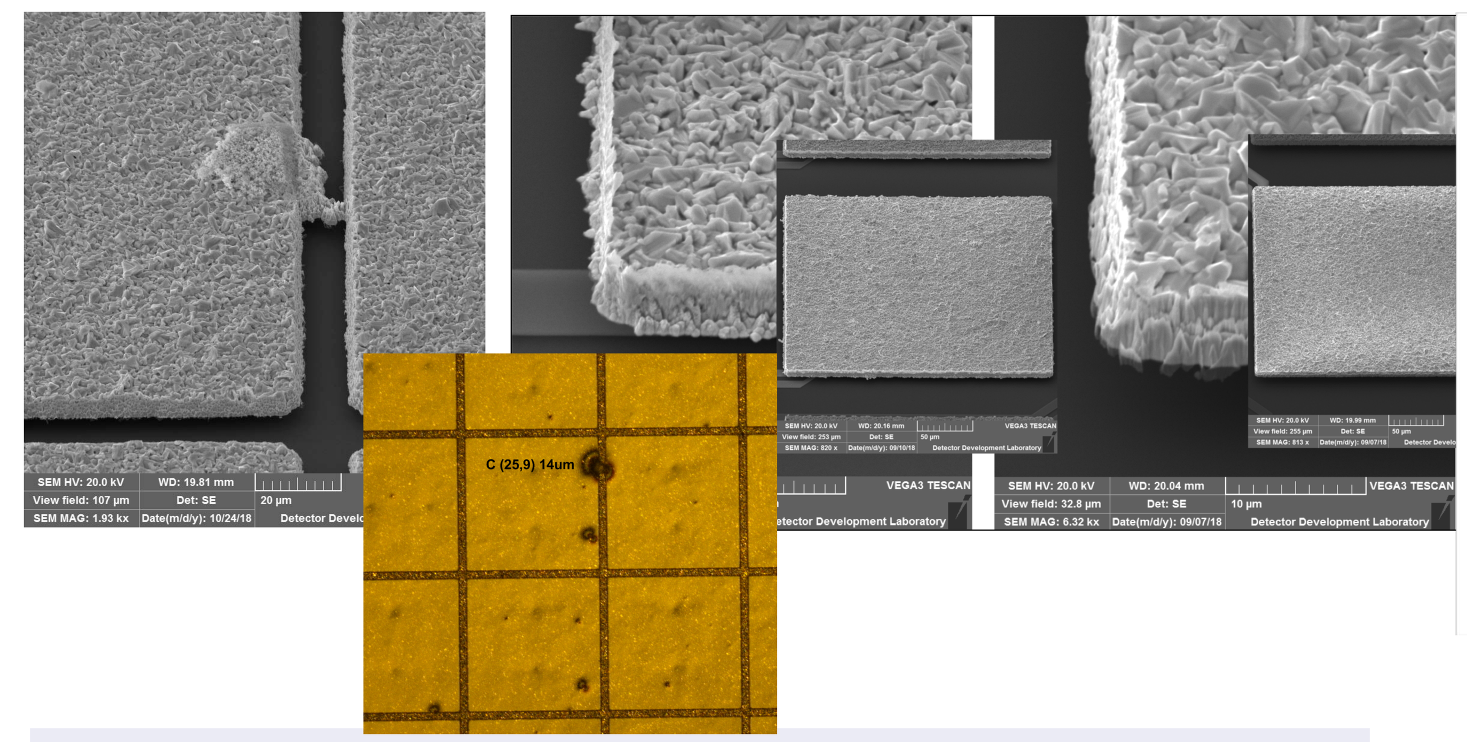
We would like to acknowledge the significant contributions of two interns, Sebastian Chen and Issac Mastalski for their work on bismuth recipe development.

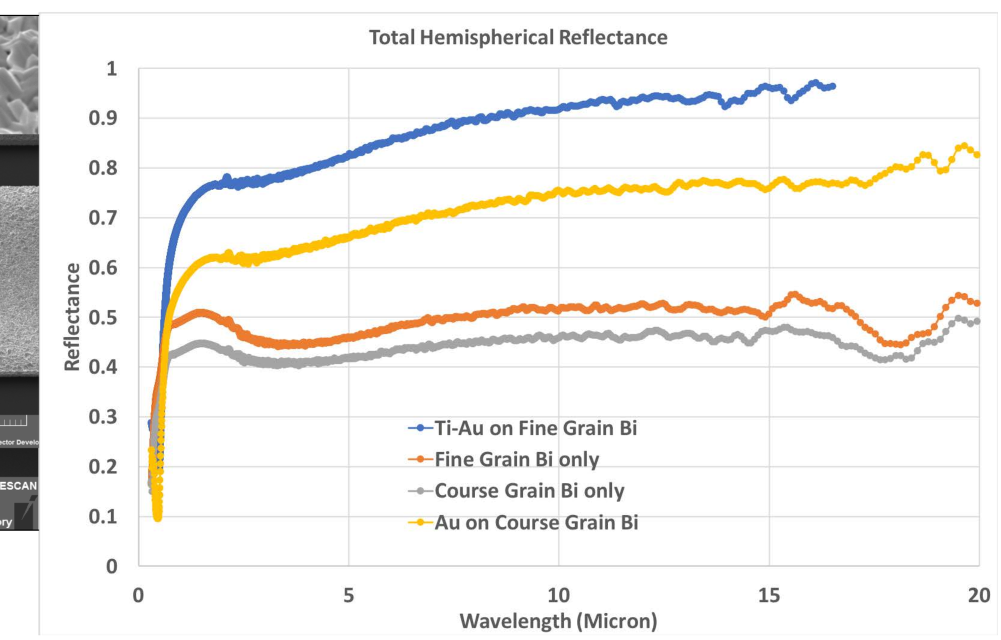
ATHENA FOCAL PLANE DEVELOPMENT

The Lynx focal plane will leverage the technology development in support of the ESA Athena X-Ray Integral Field Unit (XIFU). Our group is actively engaged in improving detector yield by reducing shorts between pixels and improving the quality of the x-ray absorbers. We are also developing flexible superconducting wiring which bends around a 90 degree corner connecting pixels on the detector array to a three stage series SQUID readout array. Our path includes indium bump bonding pads on the detector array to pads on a symmetrical structure terminating the flexible wiring. We report on our progress in these technology developments for the Athena focal plane below.



ABSORBER DEVELOPMENT

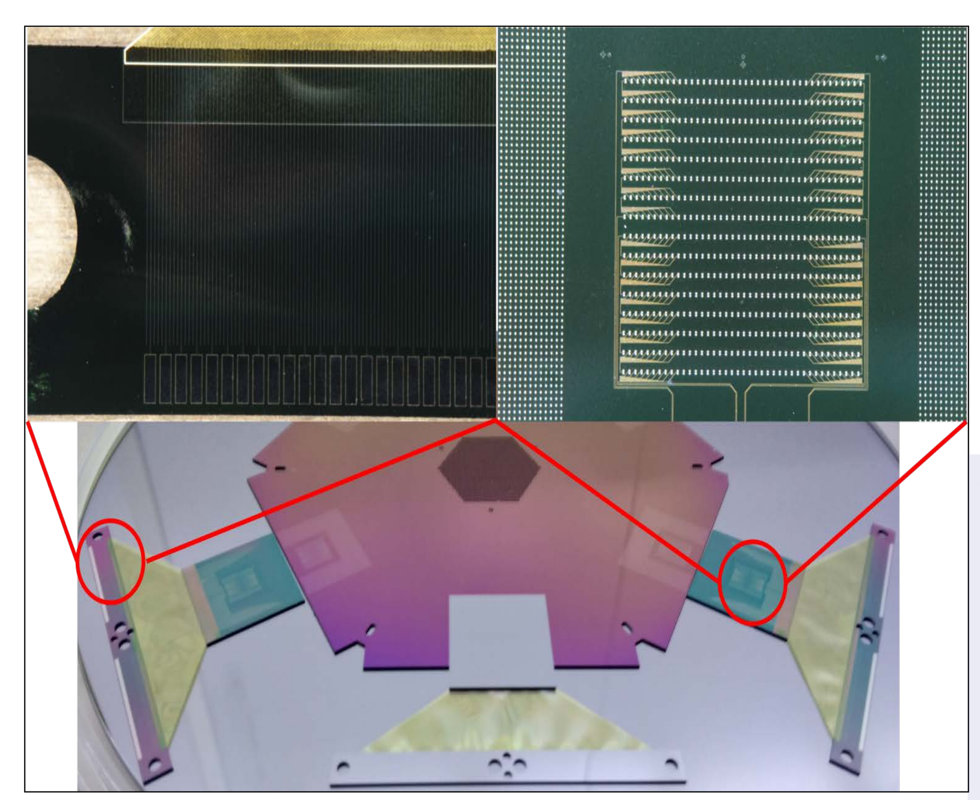


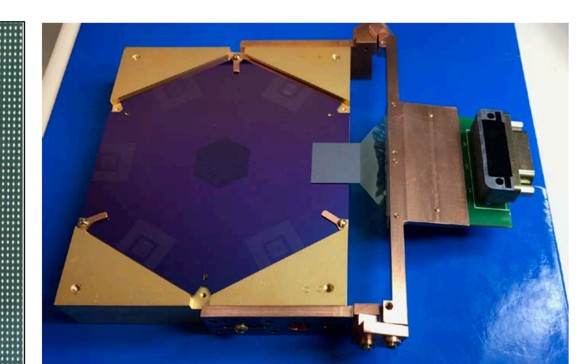


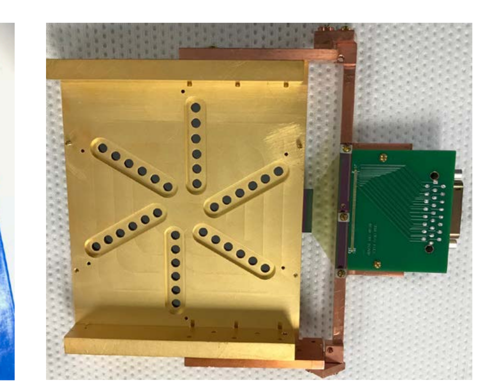
We have observed that the electroplated Au/Bi films can grow rough for a variety of reasons resulting in high spots in the bismuth film and lead to absorber shorts. We find the peaks in photolithography (yellow light image), and if they happen to land in a street, do not come clear after our normal ion mill (top left). Careful monitoring of the chemistry during Au plating followed by appropriate additives to our Bismuth plating solution (Rajamani 2016) can suppress the growth of unwanted large bismuth grains that lead to potential absorber shorts. These bismuth additives have been observed to have fewer voids, less trapped precipitate, high reflectivity and a visibly smoother surface.

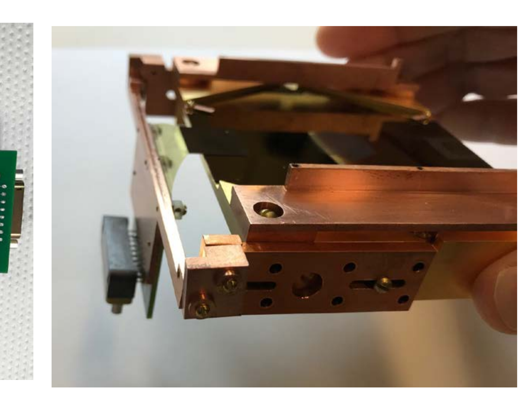
Absorption of infrared photons can lead to unwanted phonon noise and degrade the energy resolution achievable in our detectors. By adding a thin coating of Ti/Au to our Au/Bi absorbers, we found a pronounced increase in IR reflectivity. The graph above illustrates that the Ti/Au coating and the improved Bismuth film recipe both contributed to increases in detector reflectivity of out-of-band phtons.

INDIUM BUMP BONDING TO FLEXIBLE WIRING









- In preparation for the Athena flight focal plane, our Goddard team successfully demonstrated bump bonding of flexible fan out wiring to the prototype Athena hexagonal array. Indium bumps are placed on the hexagonal array pads and an identical set of pads terminating Nb wiring on a flexible polyimide film that can bend 90 degrees around a corner. Left image depicts how the flex connector fan out bonds to the wafer. Top left is the fan out of the flex connector. Next is an image of the indium bumps on the silicon backed portion of the flex connector which mate to bumps with an identical layout on the wafer. Above images show an assembly for testing the critical current of the indium bumps highlighting the flex connection and bend around the 90 degree angle.