Fabrication of Flexible Superconducting Wiring with High Current Carrying Capacity Indium Interconnects

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ABSTRACT

The X-ray Integral Field Unit (X-IFU) is a cryogenic spectrometer for the Advanced Telescope for High Energy Astrophysics (ATHENA). ATHENA is a planned next-generation space-based X-ray observatory with capabilities that surpass the spectral resolution of prior missions. Proposed device designs contain up to 3840 transition edge sensors (TES), each acting as an individual pixel on the detector, presenting a unique challenge for wiring superconducting leads in the focal plane assembly. In prototypes that require direct wiring, the edges of the focal plane on the instrument have hosted aluminum wire bonding pads; however, indium ‘bumps’ deposited on an interface layer such as molybdenum nitride (MoN) can instead be used as an array of superconducting interconnects. We investigated bumped MoN:In structures with different process clean and layer thicknesses. Measurements of the resistive transitions showed variation of transition temperature $T_c$, as a function of bias and generally differed from the expected bulk $T_c$ of In (3.4 K). Observed resistance of the In bump structures at temperatures below the MoN transition (at 8.0 K) also depended on the varied parameters. For our proposed X-IFU geometry (10 microns of In) and a 2 micron In pad, we measured a $T_c$ of 3.1 K at a bias current of 3 mA and a normal resistance of 0.55 mΩ per interconnect. The design and fabrication of superconducting niobium (Nb) microstrip atop flexible polyimide was also investigated. We present a process for combining In bumps with Nb on polyimide to enable high density wiring for the X-IFU focal plane.

FABRICATION OF INDIUM PLUS FLEX

Polyimide flex successfully integrated with superconducting Nb microstrip and 10 micron indium lift-off. Left side shows completed chip. Right side is a detail of the array of indium bumps fully wired out across “flex” region (1260 bumps to 630 wire pairs)

FABRICATION OVERVIEW: FLEX CHIP

Polyimide spun onto oxidized silicon and cured (~6 micron thick) Poly is etched with CF4/02 to slop sidewall ~45 degrees Deposit and Pattern wiring (To/Ni/Ti) including MoN capping layer Top layer of polyimide (~6 microns) is cured and patterned 10 microns indium deposited through image reversed lift-off mask Wax mounting of indium (120 C wax press) followed by deep etch

HEX CHIP FABRICATION

Detector fab is routine and Indium adds two steps for MoN dep and Pattern followed by Indium lift-off (to 1 micron thickness) Absorber deposition follows the indium lift-off - restricting In height So 3 micron photosist will cover them during electroplating If Bi is used in absorber, heat restriction (120 for short time) and gentle clean prior to bumps (such as ONTOS downstream plasma) is indicated / preferred.

CAD design for bump-bonded “flex-to-flex” testbed. Prototype silicon parts are in fabrication

Hex chip will have 90 mm diameter - 6 regions with indium bump fields with ~1260 bumps per region (plus support bumps to increase joint strength)

Flex chip is 1.5 cm sq with fanout to 4.5 cm chip for initial wirebond tests of circuit. Second side of chip will eventually be bumped to readout card in full assembly.

Flex chip bumpbonder (4 inch top plate / 6 inch base plate)

Vac interface plate uses to lift flex chip

INDIUM BUMP RESULTS

Resistance versus temperature of bumped 10:1 micron indium coupons at different excitation. The R(T) at the highest excitation (3 mA) exhibited $T_c$ above 3 K.

CURRENT CARRYING CAPACITY

Te drops linearly with bias current in R(T) curves and indicates a high low-temperature critical current for Mo/Ni 10:1 indium bendl cold pressed with no post bump aneal process applied

REFERENCES