



Fabrication of the SCUBA-2 Detector Arrays



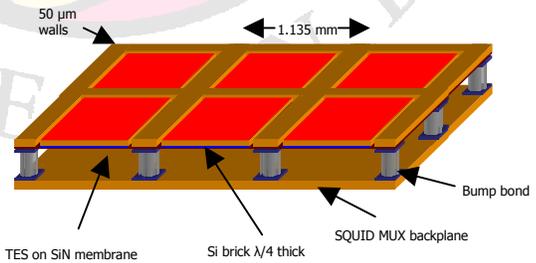
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Introduction

SCUBA-2, initiated by the Astronomy Technology Centre (ATC) at the Royal Observatory in Edinburgh is the second generation sub-millimetre detector array for the James Clark Maxwell Telescope. The new instrument will form images 100 times faster than its predecessor with improved image fidelity and an increase of more than 15 times in the field of view. See poster Y25 for more details. The detailed design and fabrication of the detectors is largely shared by the Scottish Microelectronics Centre (SMC) and the National Institute of Standards and Technology (NIST) at Boulder. Production of the SCUBA-2 prototype subarrays is now underway.

Fabrication steps



Representation of a group of detector pixels within a 40×32 subarray. Each subarray is fabricated from $3''$ Si wafers. The detector wafer is thinned to $70 \mu\text{m}$ or $100 \mu\text{m}$, depending on the detection wavelength and masked so that deep etching of the pixel well leaves a silicon "brick" on a silicon nitride membrane. The surface of the brick is ion-implanted to $377 \Omega/\text{sq}$ to match free space and to dissipate incident radiation as heat. Underneath each brick is a TES thermometer which also acts as a backshort. Bump bonds connect each TES to a corresponding SQUID which detects the change in conduction current due to the incident radiation and amplifies the signal. A second stage of SQUIDs provides further amplification and multiplexing for readout.

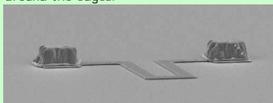
Microfabrication technology

SCUBA-2 uses a unique combination of advanced techniques:

- Thermal bonding and thinning of wafers (SMC and outside contractors)
- Ion implantation to match detector to impedance of free space (SMC, University of Wales, Cardiff and outside contractor)
- Deep etch micromachining to $100 \mu\text{m}$ by the Bosch process to isolate each pixel (SMC)
- Deposition of 500 nm silicon nitride membrane with low tensile stress (SMC)
- Transition Edge Sensor (TES) as the detector on each pixel (NIST)
- Superconducting Quantum Interference Device (SQUID) for multiplexed readout (NIST)
- Flip-chip bonding to the multiplexer chip by indium bumps (NIST, SMC and Raytheon)

Indium bump bonds

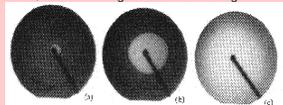
Each subarray is held together with $\sim 160,000$ bump bonds. There are ~ 80 bumps per pixel plus a forest of bumps around the edges.



Indium bumps $20 \mu\text{m}$ square are used to hybridize the detector and MUX wafers. (Photo: Raytheon Vision Systems)

Wafer bonding

When two clean, flat wafers from the same batch are brought together they stick. The bond is strengthened by having activated oxide surfaces before, and annealing after the bonding.

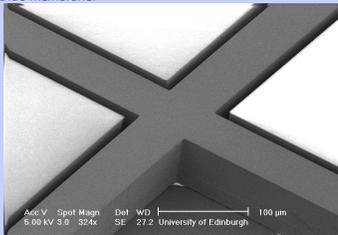


(a) bonding wave starts at centre of $3''$ wafer; (b) propagates in seconds; (c) bonding complete (Figure courtesy of Karl Hobart)

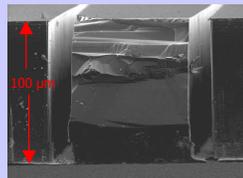
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Deep-etched Structures

Deep-etch silicon micro-machining by the Bosch process is used to thermally isolate each pixel. The thermal link between the pixel and the bath is a $0.5 \mu\text{m}$ silicon nitride membrane.

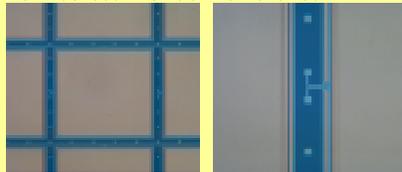


SEM image showing deep-etched silicon quarter-wave bricks and walls. The lighter colour of the bricks is caused by charge buildup. The bricks are suspended on silicon nitride membranes and are thus less well grounded than the walls.



$10 \mu\text{m}$ trench. Etch stopped on nitride membrane.

Low-stress nitride membranes



Dummy TES and heaters on the nitride membrane fabricated to test the layout of bumps and tracks. The TES is approximately 1 mm square.

