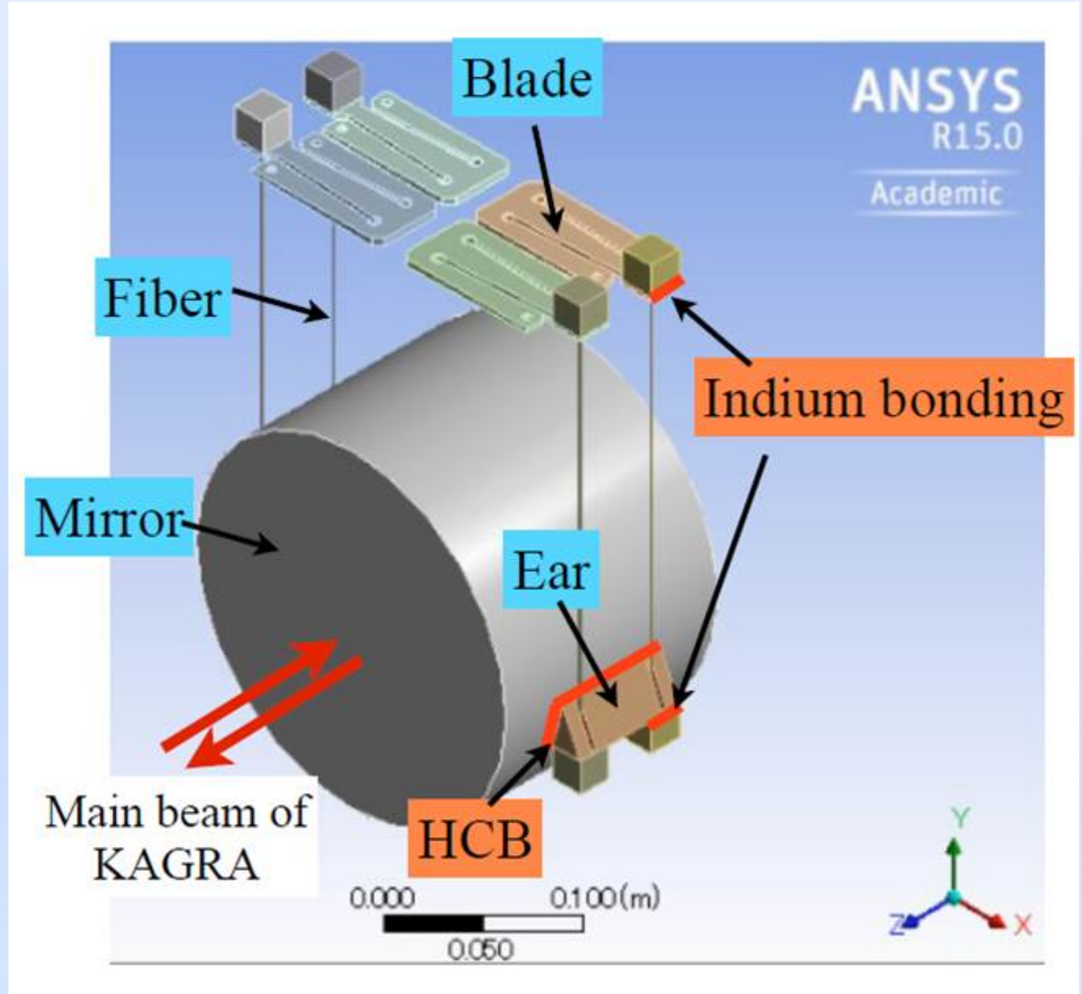
Indium bond research for crystalline cryogenic suspensions

Margot Phelps, Mariëlle van Veggel, Jim Hough, Sheila Rowan, Kieran Craig, Kazuhiro Yamamoto
Institute for Gravitational Research, SUPA, University of Glasgow, Glasgow, G12 8QQ, UK

1. Motivation

Pure indium bonds to itself and non-metallic substrates like fused silica with comparable ease. Its vacuum compatibility, thermal conductivity [1], malleability, low mechanical loss [2,3] and low melting point also make it a good candidate for use in cryogenic systems. Currently it is proposed for use in the sapphire KAGRA test mass suspensions [6] as well as a possibility for interfaces in silicon mirror suspensions of the future ET detector [5]. This poster explains two approaches to achieve strong, thin indium bonds. One method uses layers of 400nm thick indium evaporated onto silicon substrates and bonded at the Institute for Gravitational Research in Glasgow. A second approach uses inductive heating of indium foil between sapphire substrates with the aim of bonding suspensions in a detector in-situ, conducted in part at the IGR in Glasgow and in part at the ICRR in Tokyo.

2. Indium bonds in a cryogenic suspension-KAGRA



- New hybrid suspension design utilizing both indium and hydroxide catalysis bonding.
- Indium used in compression between the fibres and ears, and the fibres and blade springs.
- Hydroxide catalysis bonds in shear joints.
- Indium in compression for easier repair scenarios.
- Hydroxide catalysis bonds for strength.

Figure1: Example of indium bonds in KAGRA's cryogenic suspension. [6]

3. Induction heating of indium foils

Motivation for this approach: Compression and direct contact heat that is the most straightforward way of making an indium bond. However, the geometry of real detector suspensions (KAGRA example above) includes a variety of delicate parts of different shapes and sizes. Designing an in-situ contact heat and compression system would be difficult and fairly risky given the interface geometry and the larger sapphire parts acting as heatsinks. Induction heating of the indium itself is proposed as a contact-less method of heating the indium in a suspension interface with minimal impact on the optic and suspension components.

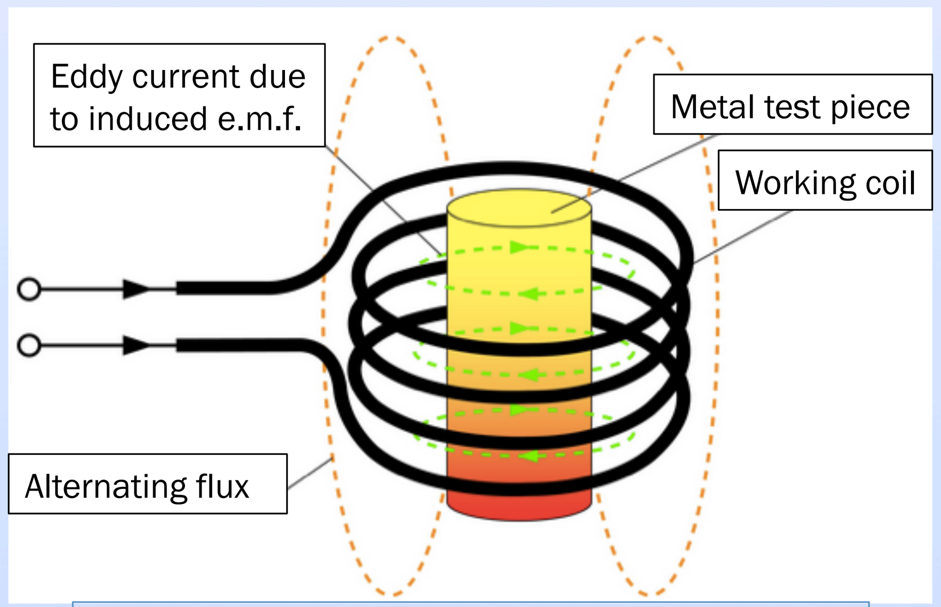


Figure 2: How induction heating works, Here the working coil heats a metal test cylinder by induced eddy currents.

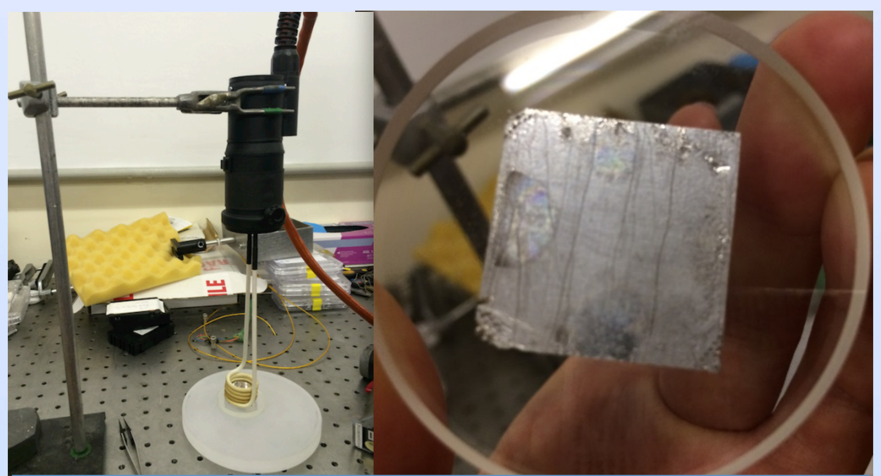


Figure 3: Indium bonded sapphire using a 1750W/50Hz commercial Draper induction heater at IGR.

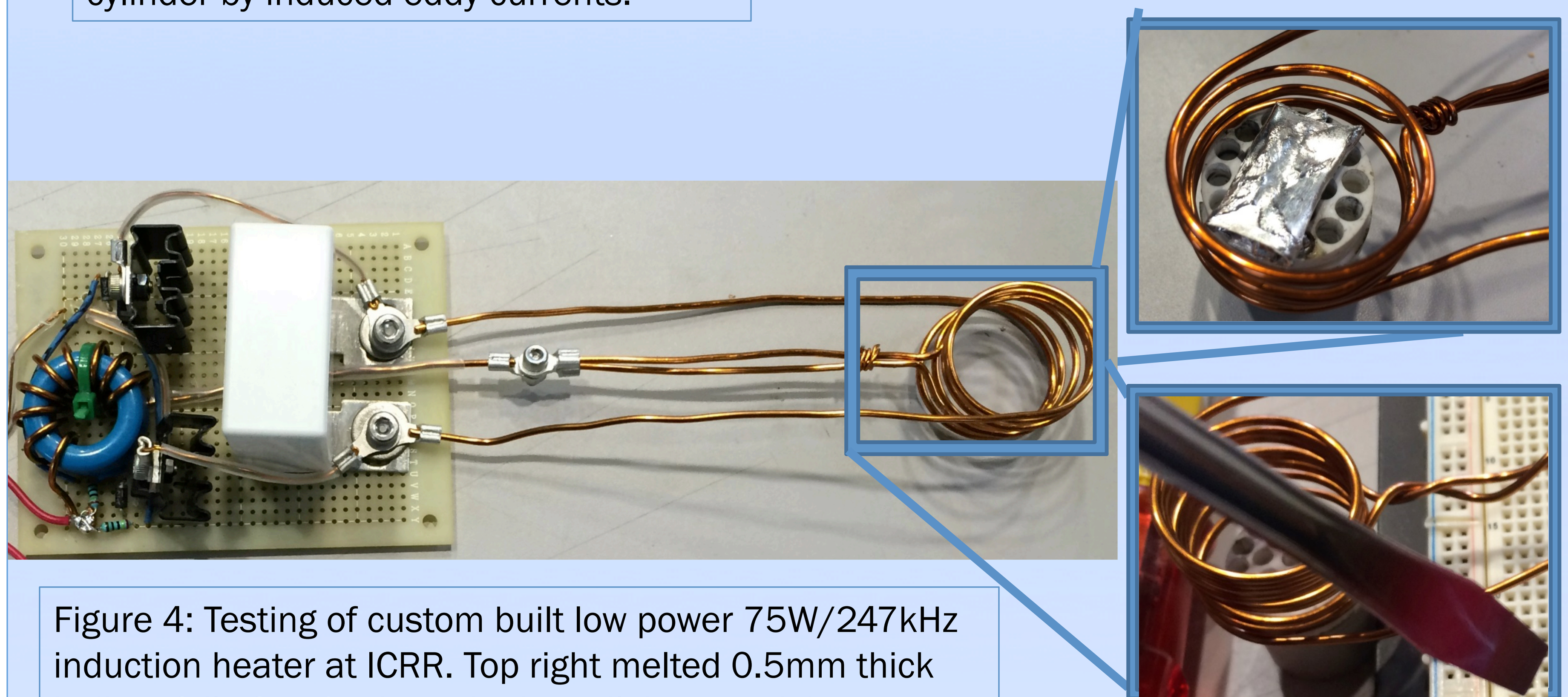


Figure 4: Testing of custom built low power 75W/247kHz induction heater at ICRR. Top right melted 0.5mm thick indium foil after 1 minute in the coil, bottom right a screwdriver tip red hot after 30 seconds in working coil.

4. Thermally evaporated films bond set up

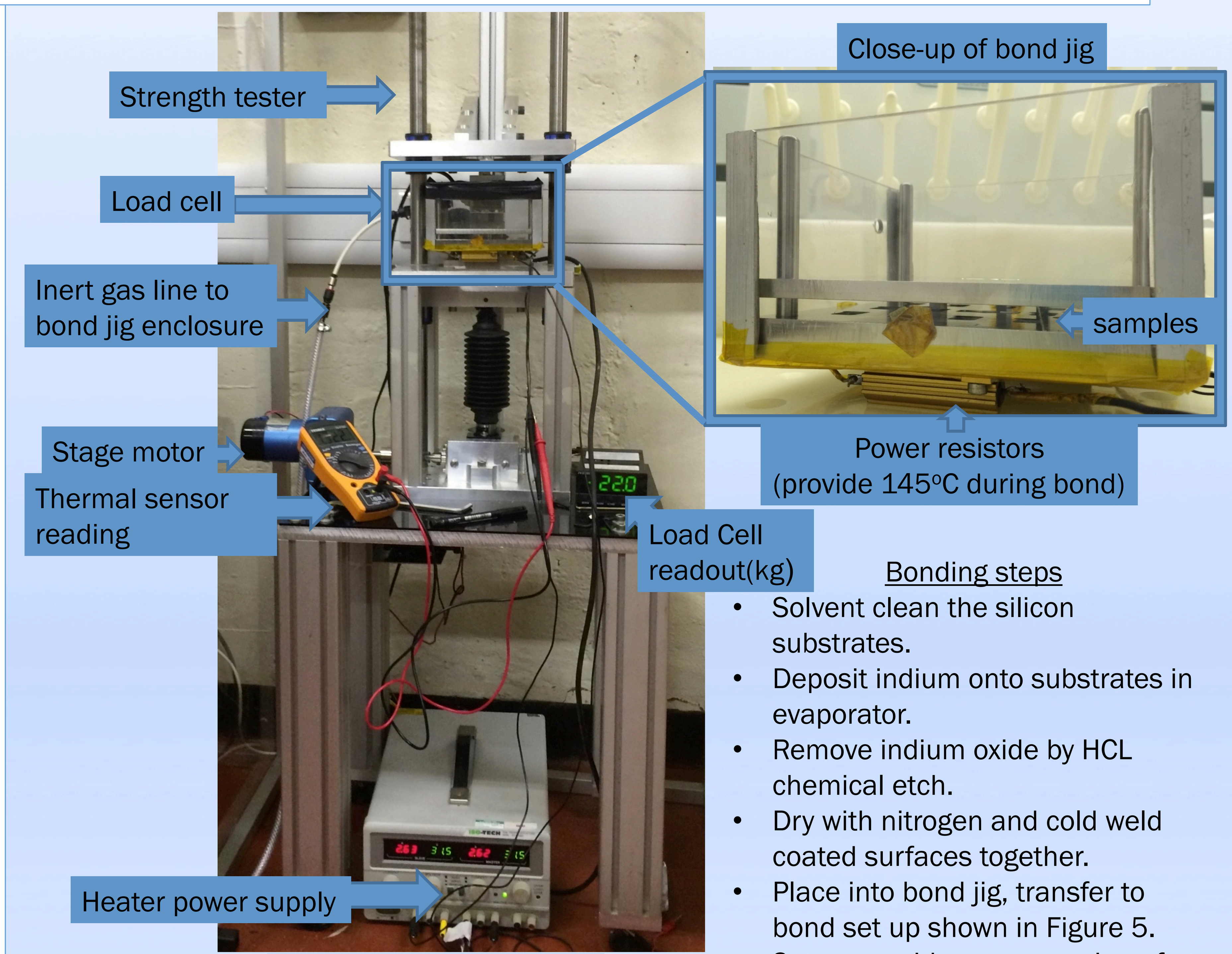


Figure 5: Bonding setup.

Bonding steps

- Solvent clean the silicon substrates.
- Deposit indium onto substrates in evaporator.
- Remove indium oxide by HCL chemical etch.
- Dry with nitrogen and cold weld coated surfaces together.
- Place into bond jig, transfer to bond set up shown in Figure 5.
- Set up provides compression of at least 1MPa/145°C per bond.

5. Evaporated film bond strength results

Motivation for this approach:

- Thermally evaporated indium layers made very thin with the aim of being low noise, must also be strong bonds between silicon substrates. Measured thicknesses of deposited layers in figure 6.
- Left side of Figure 7 compares success of two different oxide mitigation approaches:
  - Oxide prevention w/inert gas.
  - Oxide removal with chemical etch.
- Right side of Figure 7 shows the strength test results for all chemical etch bonds.

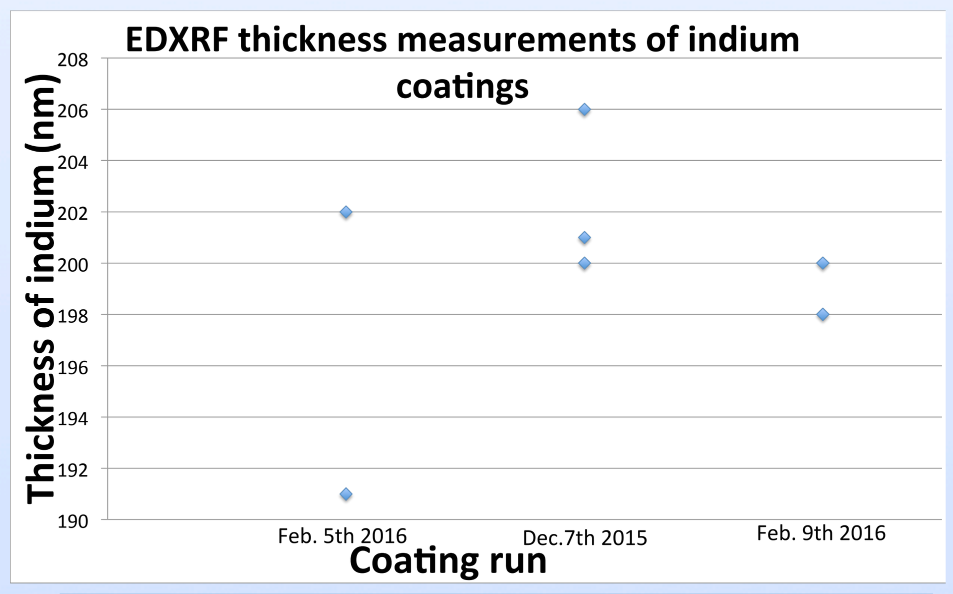


Figure 6: Deposition layer thickness of witness samples measured in an EDXRF.

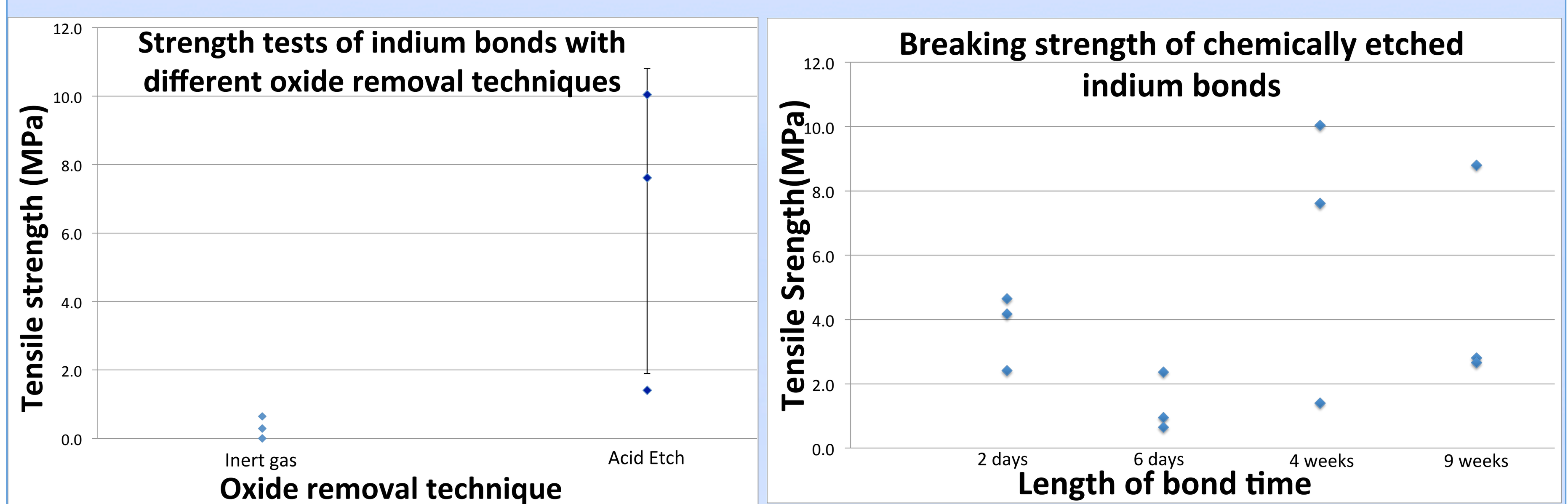


Figure 7: Results of strength testing indium bonds.
Plot on left compares two different oxide removal approaches. Plot on right compares the strength of chemically etched bonds from two days old to 9 weeks old. No degradation in strength is apparent.

6. Results and next steps

A procedure and set up that provides uniform and repeatable heat and compression of thermally evaporated indium films was designed, built and optimized. Repeatable strong indium bonds have been produced for the first time using this procedure, and will be utilised to produce samples for thermal conductivity testing. Sapphire substrates were successfully bonded by inductively heating 50μm indium foil. An inductive heater was then built and tested at the Institute for Cosmic Ray Research in Tokyo, Japan with the aim of bonding cryogenic sapphire suspensions at the KAGRA detector in-situ. Small indium foils were successfully melted with this heater, its coil design and overall bond procedure will now be optimised for use in cryogenic sapphire suspensions.

References
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