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The Materials Science Foundation Supporting the Microfabrication of Reliable Polyimide–Metal Neuroelectronic Interfaces

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S1 Metal Resistivity Measurements

Each four-point probe metal resistivity test-structure consists of a 400 nm thick, 10-cm-long metal trace fit to a small (~1250 µm x 1650 µm) footprint using forty 180˚ switchbacks spaced 15 µm apart (edge–to–edge) (**Figure S1**). Two rectangular contact pads (200 µm in diameter) at each end of the trace were designed for micropositioner probe tips, and the top polyimide, a-SiC, and titanium were dry etched at the contact sites to reveal bare metal (platinum, gold, or platinum silicide). Seven different test-structures were designed for each metal stack cohort with metal trace widths ranging from 4 to 10 µm. Average (standard deviation) resistivity was determined between the seven different test-structure designs on at least two different wafers ($N = 2$, $n = 14$).

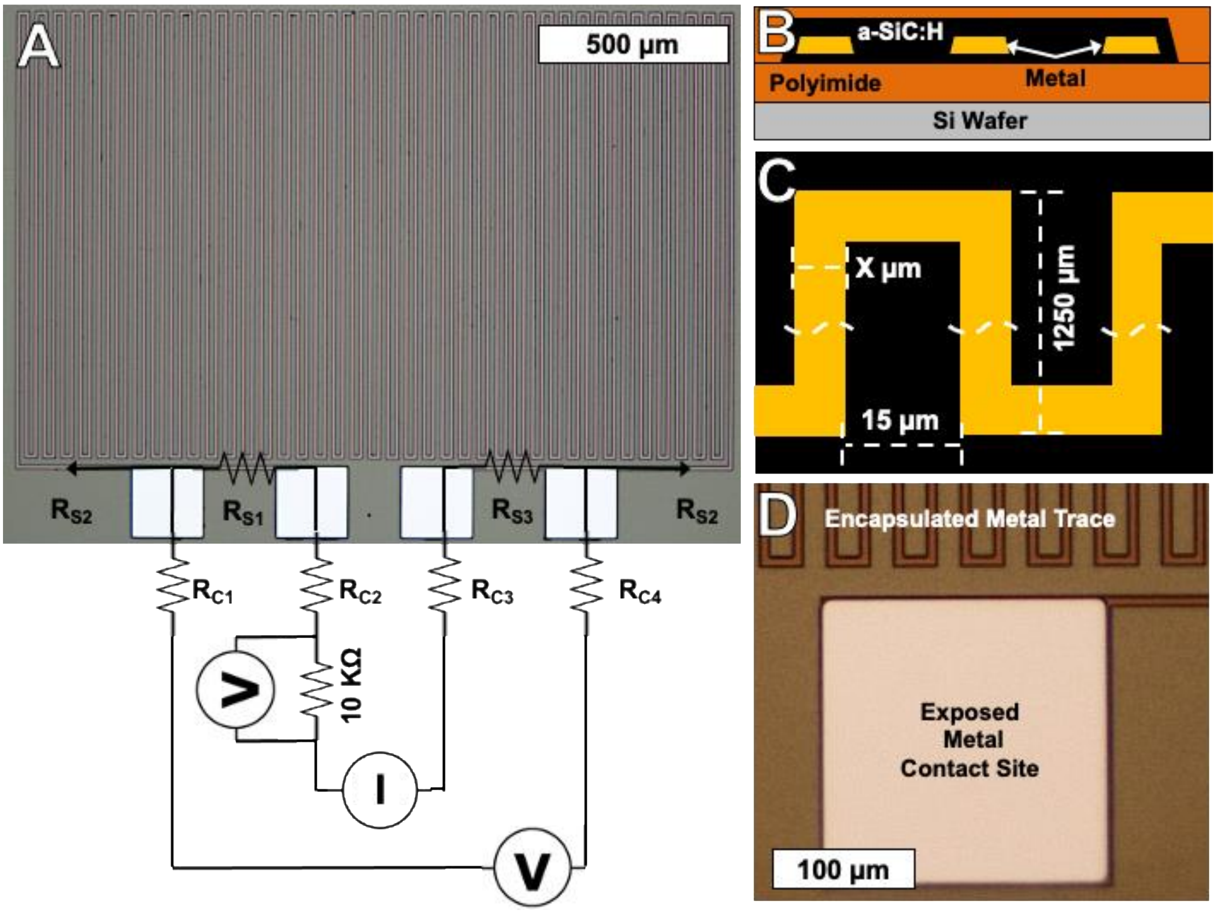

Figure S1. 4-point probe test-structures used for resistivity calculations (Figure 9). (A) Top-down optical image of test-structure showing the switchback metal path starting/ending at two contact pads each. The circuit schematic used to calculate the resistivity is overlaid. (B) Cross-sectional schematic showing the polyimide and a-SiC:H encapsulation around each metal trace. Each polyimide layer is 5 µm thick, and the a-SiC:H film is approximately 500 nm thick with 250 nm above and below the metal stack (C) Top-down schematic showing the metallic trace switchback geometry with X varying from 4 to 10 µm. (D) Top-down optical image showing a exposed metal contact site used to electrically connect with the metal traces using the micropositioner probe tips.

S2 Polyimide Curing and Surface Modification

ATR-FTIR analysis was used to track changes in the polyimide film after thermal curing (**Figure S2**). Films cured to 120 ˚C do not show any significant imide peaks because no widespread imidization has occurred after the low temperature soft-bake. However at 250 ˚C, there are numerous examples of imide peaks, and comparing to the 450 ˚C peaks, there is no significant change in the peak shape or height indicating that imidization is almost fully completed between 120 to 250 ˚C.

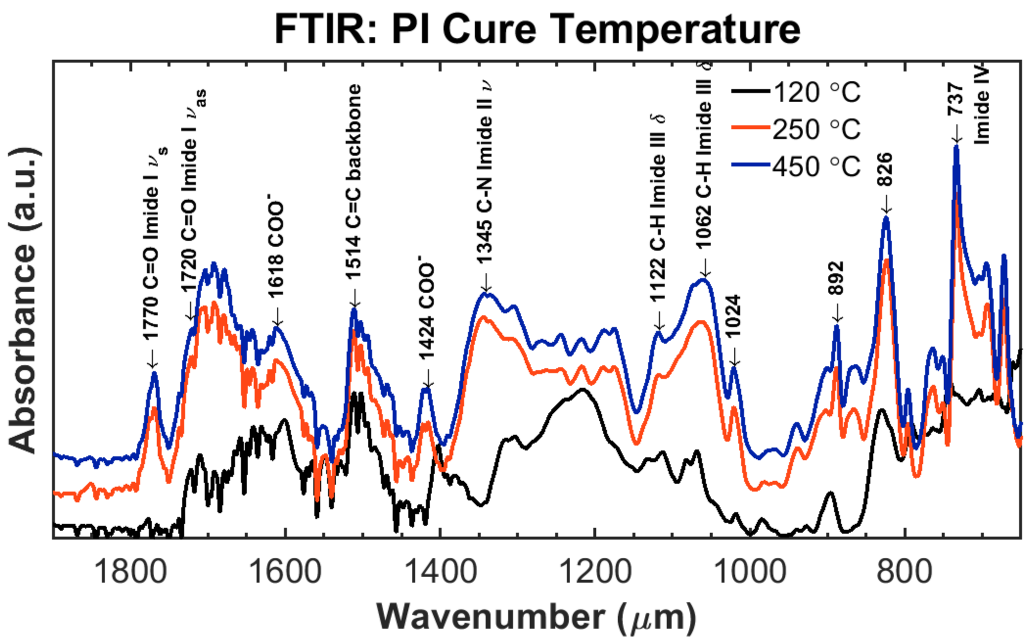

Figure S2. FTIR spectra of polyimide films after thermally curing to the indicated maximum temperatures. Spectra are shifted along the Y-axis slightly to allow for easy comparison between each. Peak identifications are included to highlight the appearance of several imide peaks after curing to 250 ˚C that do not appreciably change when curing to 450 ˚C indicating that the film is fully imidized at 250 ˚C.

S3 a-SiC:H Deposition and Surface Modification

Depth profiling through 250nm-thick a-SiC:H films on Si wafers was used to confirm the absence of any significant oxygen and the film stoichiometry (50% Si, 50% C) (**Figure S3** A). The thin native oxide layer is only detectable within the top few nm of the film. Transmission FTIR spectroscopy was used to confirm that the a-SiC:H films were indeed SiC without the formation of other significant polytypes likely to arise from the precursor gases used (Figure S3 B).

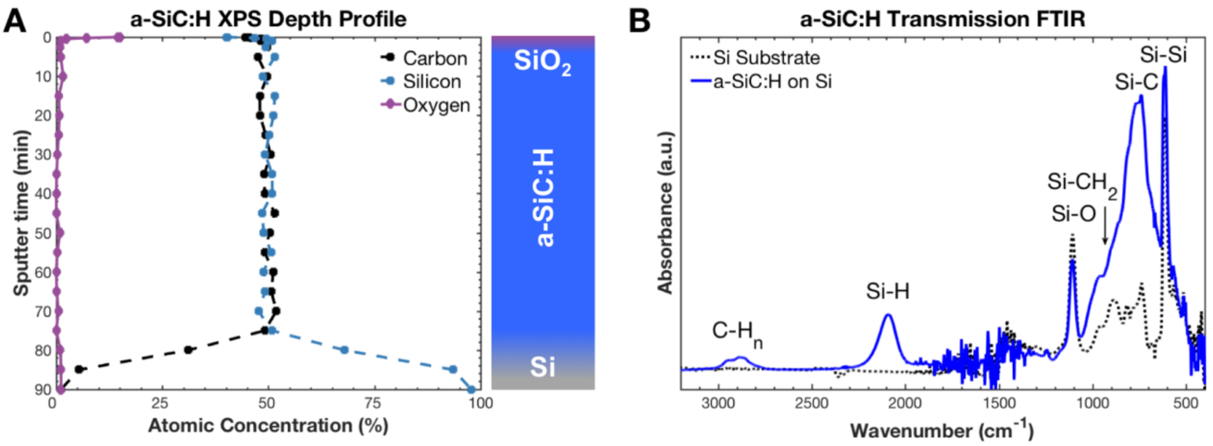

Figure S3. (A) XPS depth profiling of 250 nm thick stoichiometric a-SiC:H film on Si wafer, and (B) transmission FTIR spectra of stoichiometric a-SiC:H film with included peak IDs. Si–Si and Si–O peaks are primarily from the Si wafer substrate.

S4 Metal Deposition and Lift-Off

During microfabrication of thin-film polyimide-metal devices, sporadic delamination of metal structures was evidenced during the lift-off process when only titanium was used as the tie-layer between the metal structures and the underlying polyimide substrate (**Figure S4**). This problem was eliminated when using tie-layers (e.g., chromium, a-SiC:H) that had significantly higher adhesion with the underlying polyimide.

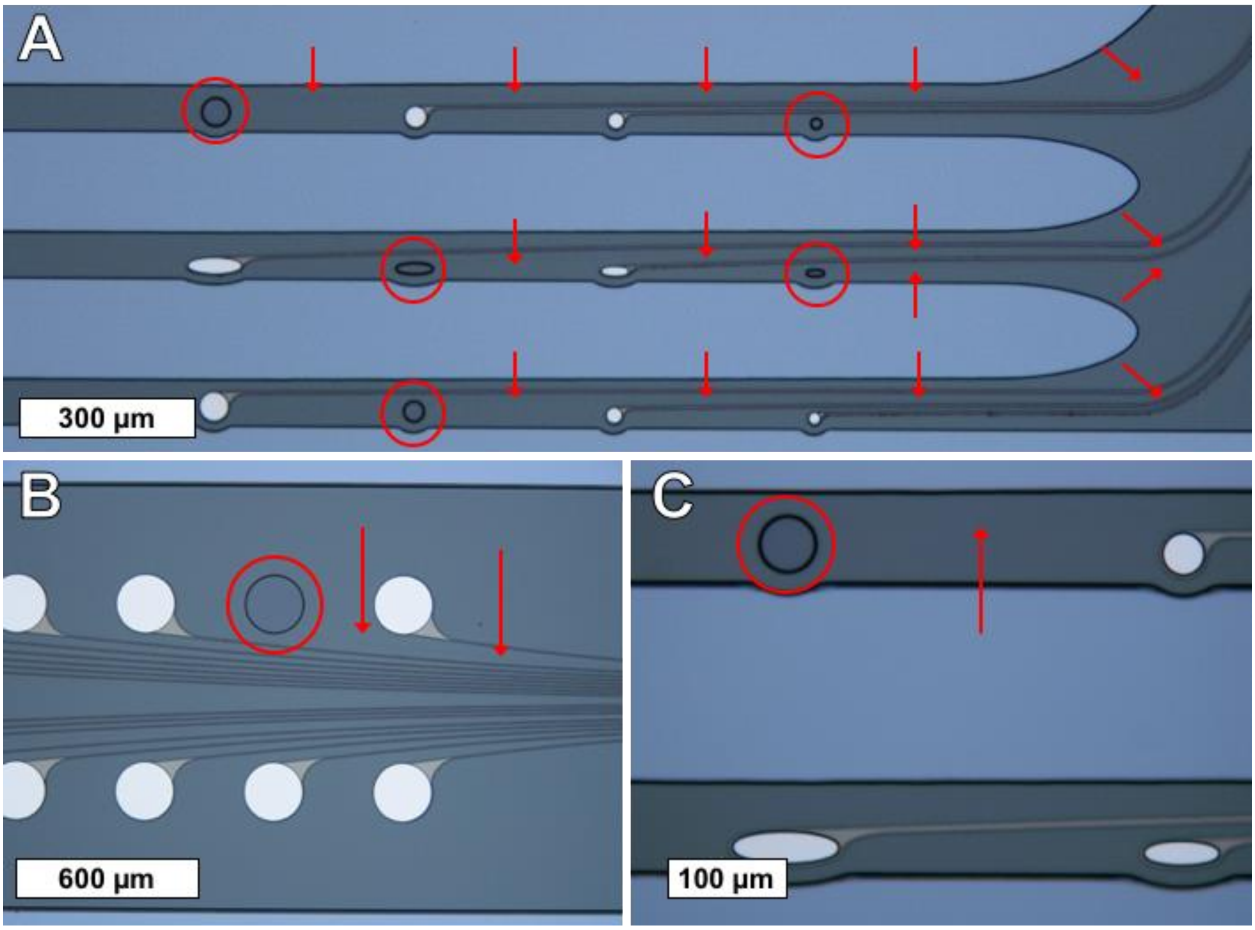

Figure S4. Metal delamination from devices that used only titanium as a tie-layer between noble metals and the underlying polyimide substrate. Each delamination point is highlighted in red to indicate where either a microelectrode/contact site (circle) or metallic trace (arrow) delaminated.