Appendix B. PolyMUMPs Run Data

The material properties of every PolyMUMPs™ fabrication run are measured and made available to users so that deviations from the nominal values can be accounted for during device testing. The following tables show the measured data for each fabrication run as provided by the MUMPs® foundry [1]. The "T" and "C" in the Residual Stress column represents tensile or compressive stress, respectively.

Table B-1. PolyMUMPs Run #66 measured fabrication data [1].

	Thickness (μm)	Standard Deviation (μm)	Sheet Resistance (Ω/□)	Resistivity (Ω-cm)	Residual Stress (MPa)
Nitride	0.6136	0.0115			78.5 T
Poly0	0.5010	0.0026	31.4	1.57×10^{-3}	33 C
Oxide1	2.0497	0.0477			
Poly1	1.9782	0.0141	24.3	4.81×10^{-3}	6.3 C
Oxide2	0.7521	0.0129			
Poly2	1.4960	0.0094	12.3	1.84×10^{-3}	7.3 C
Metal	0.5421		0.049	2.66×10^{-6}	25.7 T

Table B-2. PolyMUMPs Run #67 measured fabrication data [1].

	Thickness (μm)	Standard Deviation (μm)	Sheet Resistance (Ω/□)	Resistivity (Ω-cm)	Residual Stress (MPa)
Nitride	0.5805	0.0192			88 T
Poly0	0.5014	0.0033	29.8	1.49×10^{-3}	9 C
Oxide1	2.0191	0.0324			
Poly1	2.0044	0.0256	11.6	2.33×10^{-3}	8.5 C
Oxide2	0.7442	0.0100			
Poly2	1.4888	0.0104	21.8	3.25×10^{-3}	7.6 C
Metal	0.4971		0.058	2.88×10^{-6}	20.1 T

Table B-3. PolyMUMPs Run #68 measured fabrication data [1].

	Thickness (µm)	Standard Deviation (µm)	Sheet Resistance (Ω/□)	Resistivity (Ω-cm)	Residual Stress (MPa)
Nitride	0.6008	0.0292			95 T
Poly0	0.4999	0.0051	35.6	1.78×10^{-3}	16.33 C
Oxide1	1.9810	0.0316			
Poly1	1.9922	0.0220	13.9	2.77×10^{-3}	6.33 C
Oxide2	0.7582	0.0072			
Poly2	1.4605	0.0240	28	4.09×10^{-3}	6.00 C
Metal	0.5245		0.048	2.52×10^{-6}	17.13 T

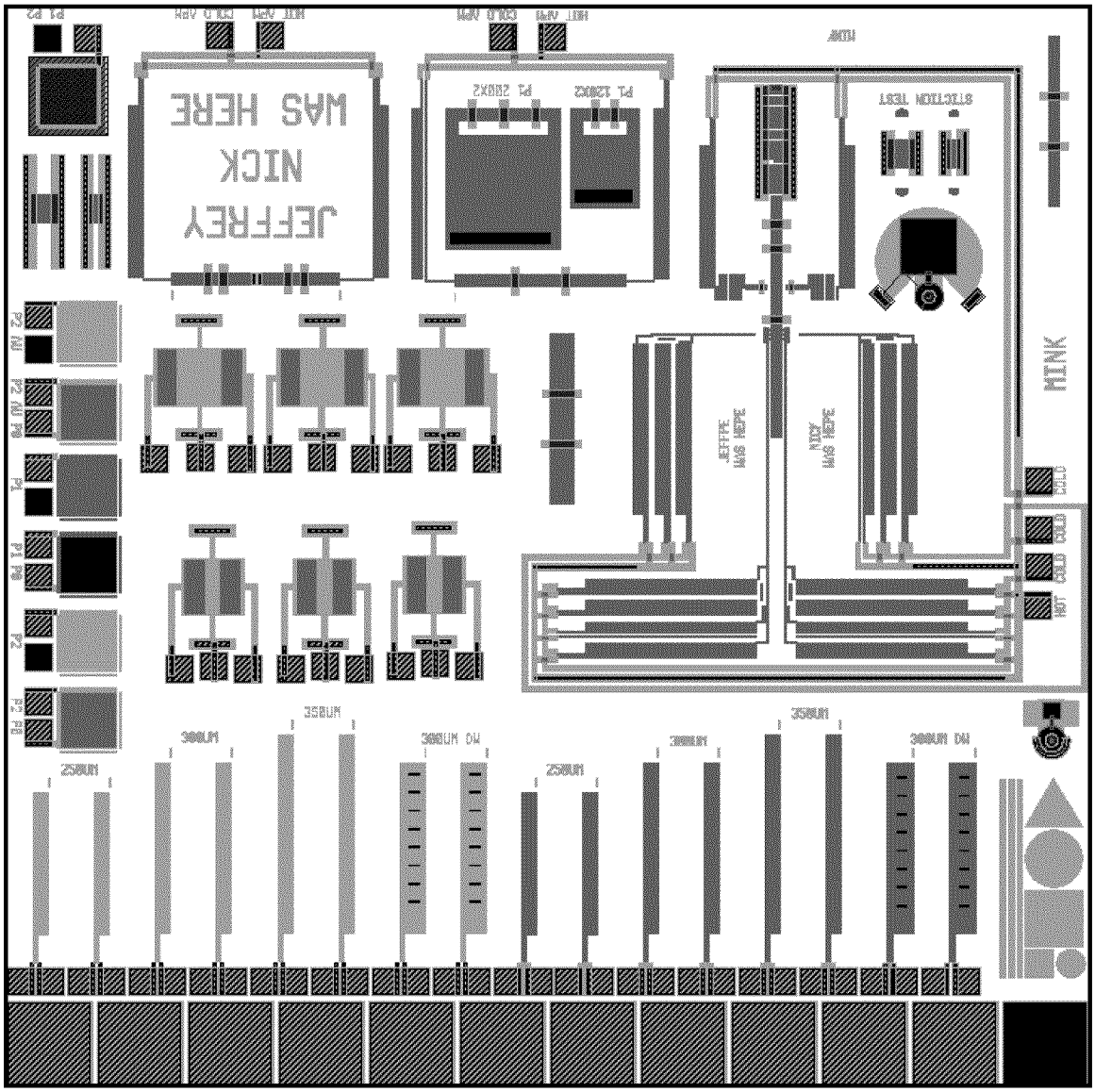
Table B-4. PolyMUMPs Run #69 measured fabrication data [1].

	Thickness (µm)	Standard Deviation (µm)	Sheet Resistance (Ω/□)	Resistivity (Ω-cm)	Residual Stress (MPa)
Nitride	0.5968	0.0506			95 T
Poly0	0.5011	0.0077	28.1	1.41×10^{-3}	24.3 C
Oxide1	1.8884	0.0405			
Poly1	2.0132	0.0116	10.5	2.11×10^{-3}	8.00 C
Oxide2	0.6915	0.0026			
Poly2	1.4966	0.0087	20.9	3.13×10^{-3}	7.66 C
Metal	0.5117		0.055	2.81×10^{-6}	15.76 T

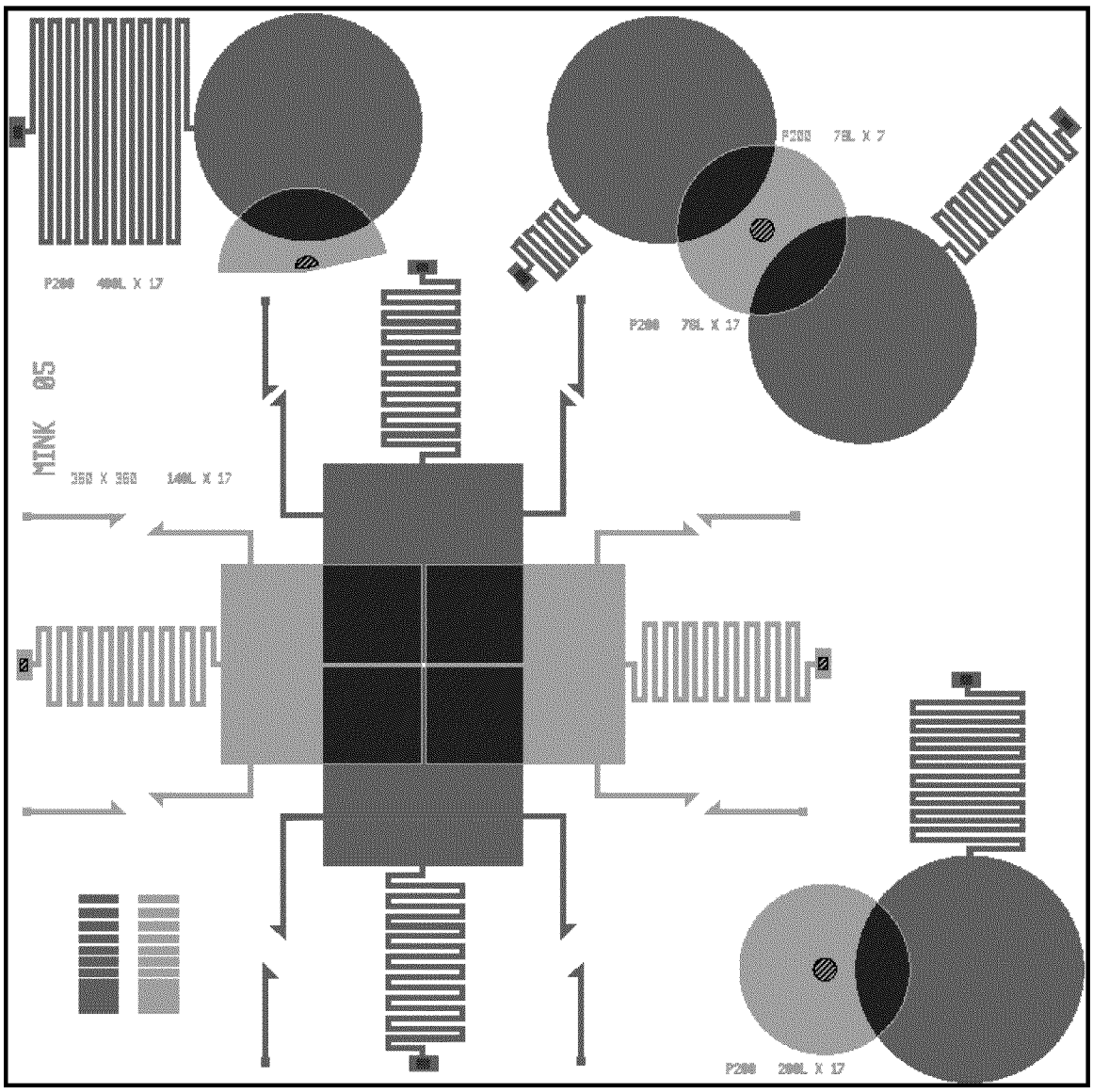
[1] "PolyMUMPs.rundata.xls." *PolyMUMPs Run Data.* <http://www.memsrus.com/nc-pmumps.refs.html>.

Appendix C.Fabricated Design Layouts

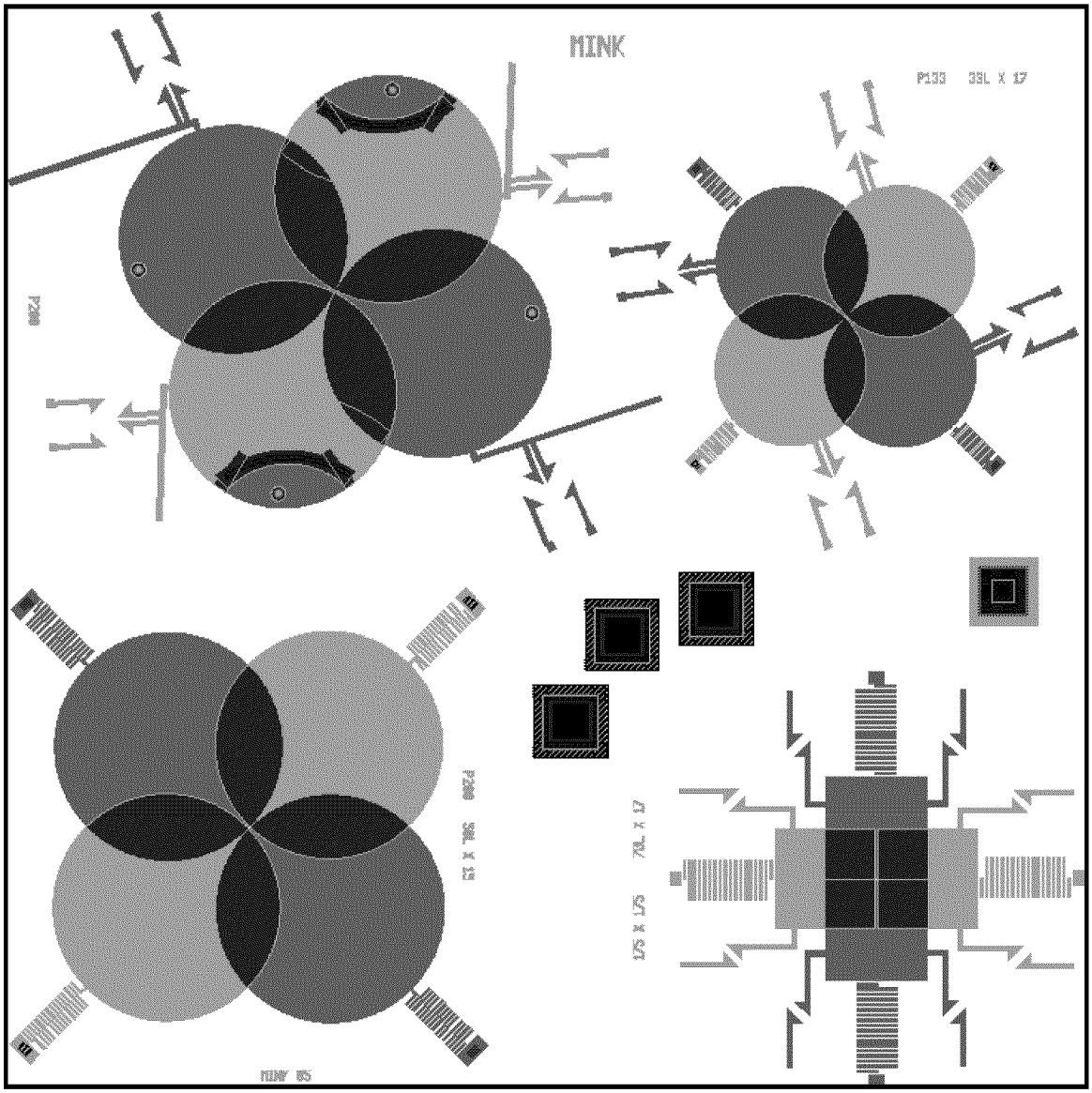
Each layout on the following pages is designed to a 1.9 mm × 1.9 mm die.



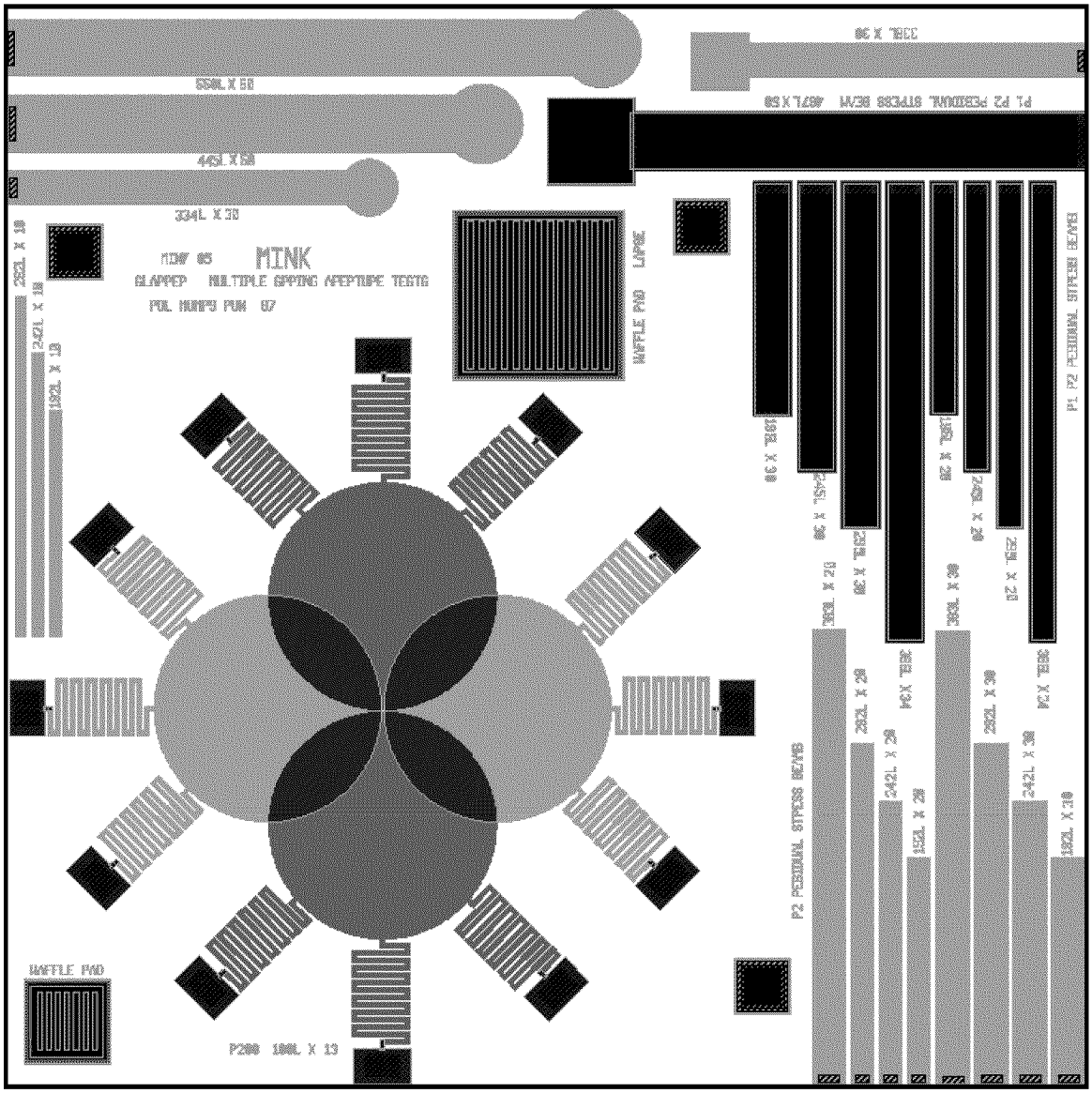
PolyMUMPs™ Run No.:	66
Working Nomenclature	Die#1
Fabricated Devices:	Poly1/Poly2 Electrothermal Actuators Electrostatic Actuators/Micromirrors Poly2/Metal Residual Stress Beams/Structures Hinge Structures (Rotating/Non-Rotating) Fabrication Process Test Structures
Main Uses:	Test/Compare Various Actuators Observe/Measure Residual Stress Investigate Fabricated Mechanical Structures



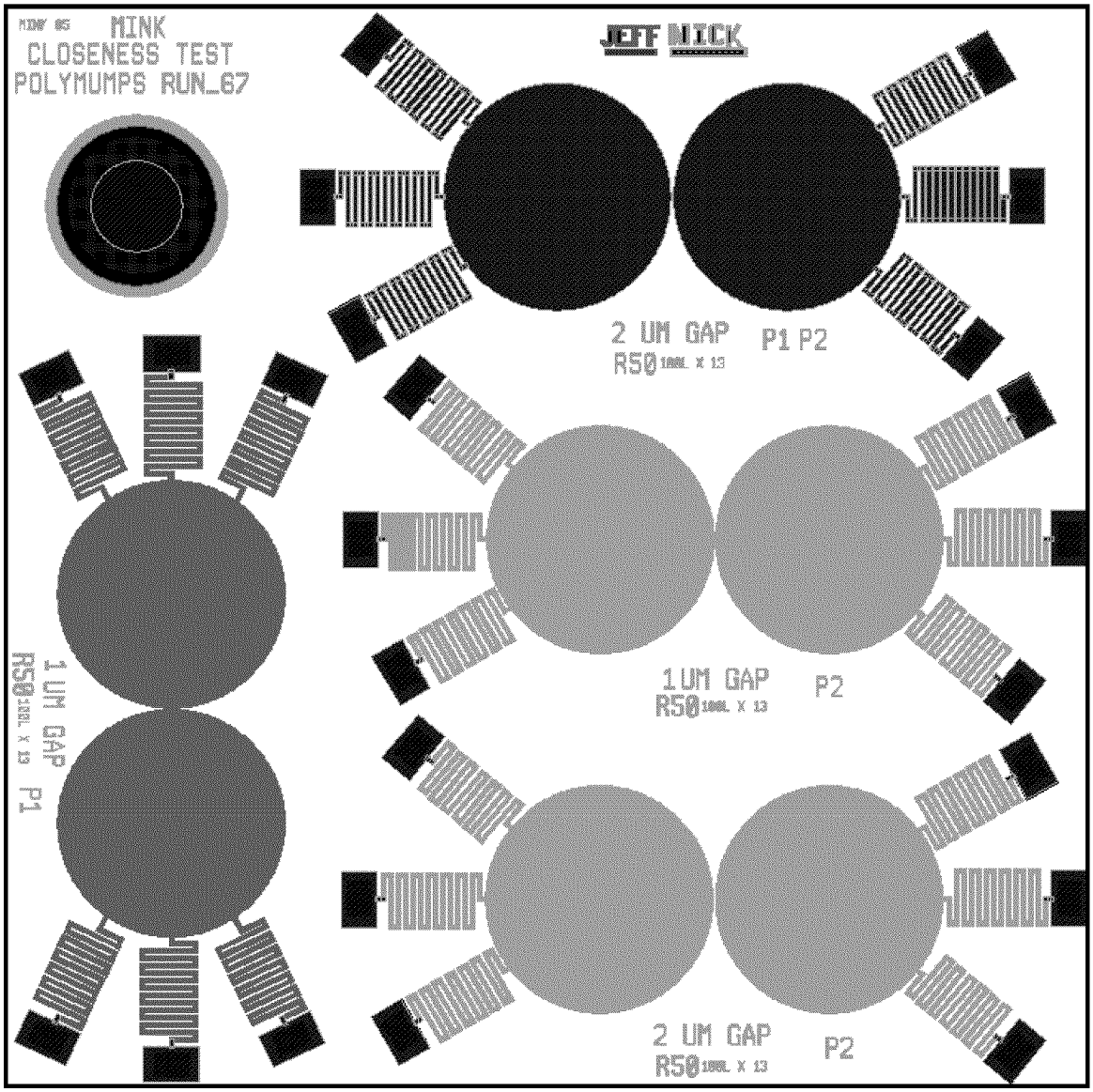
PolyMUMPs Run No.:	66
Working Nomenclature	Die#2
Fabricated Devices:	350 μm x 350 μm Square Plates, Rotating Aperture 200 μm Radius, Spring-Based, Poly1 Disk with Anchored Poly2 – Test Structures Poly1/Poly2 Minimum Spacing Test Structures
Main Uses:	Test Feasibility of Spring-Based Rotating Design Test/Observe Various Springs Designs Test/Observe, Single Layer, Fabricated Latches Test/Observe Conformal Deposition Observe/Measure Poly1/Poly2 Minimum Spacing Limitations in Fabrication Process



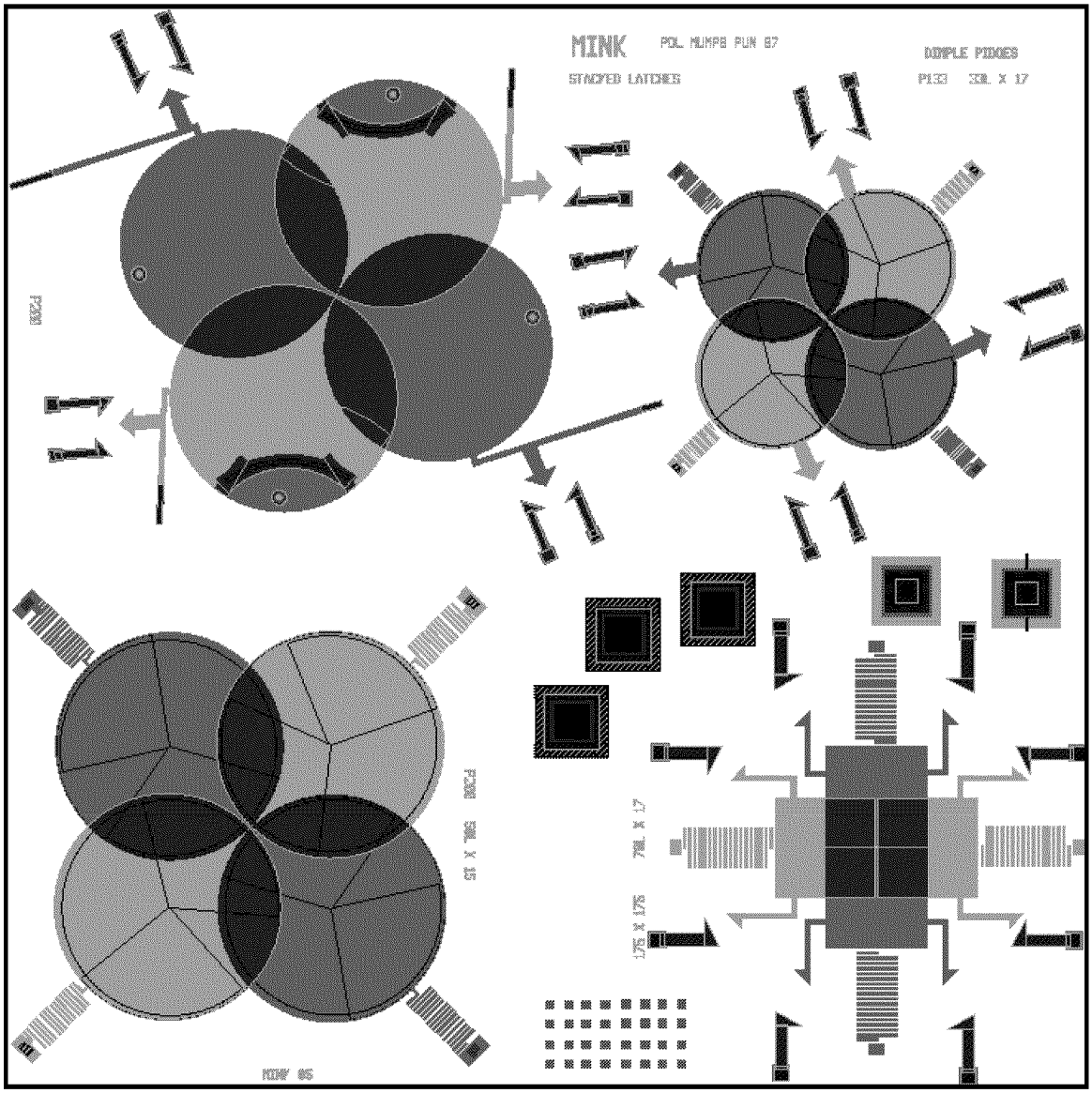
PolyMUMPs Run No.:	66
Working Nomenclature	Die #3
Fabricated Devices:	200 µm Radius, Hinge-Based Rotating Aperture 200 µm Radius, Spring-Based Rotating Aperture 135 µm Radius, Spring-Based Rotating Aperture 175 µm x 175 µm Square Plates, Rotating Aperture Layer Deposition Test Structures
Main Uses:	Test Feasibility of Hinge-Based Rotating Design Test Feasibility of Spring-Based Rotating Design Test/Observe, Single Layer, Fabricated Latches Observe/Measure Fabricated Layer Thicknesses and Etch Depths



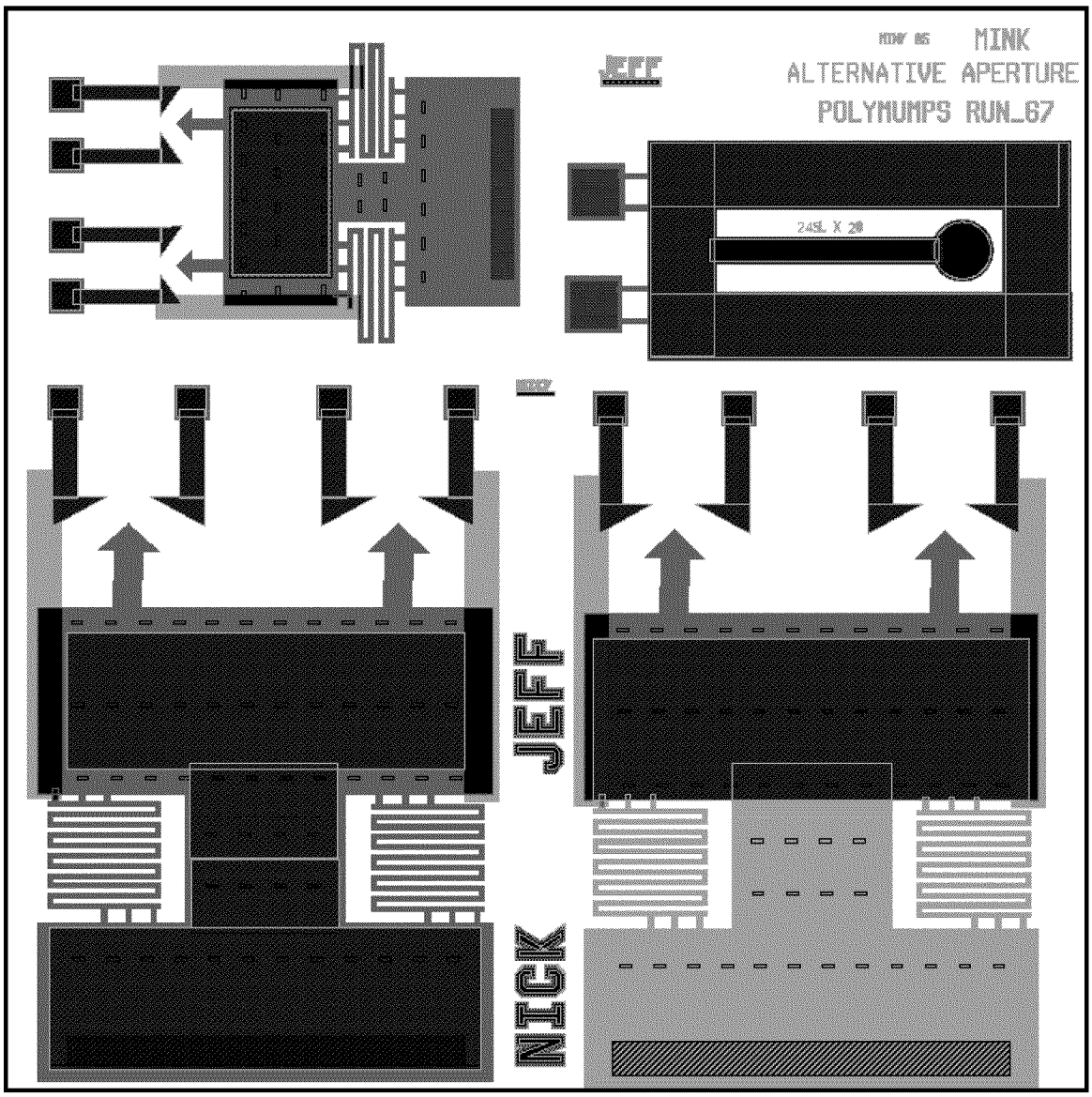
PolyMUMPs Run No.:	67
Working Nomenclature	Die #4
Fabricated Devices:	200 µm Radius, Multiple Spring, Rotating Aperture Poly2/Metal Residual Stress Beams Poly1/Poly2/Metal Residual Stress Beams Layer Deposition Test Structures Electrical Contact Pad to Substrate – Test Structures
Main Uses:	Test Feasibility of Multiple Spring Rotating Design Observe/Measure Residual Stress Beams of Varying Thicknesses Observe/Measure Fabricated Layer Thicknesses and Etch Depths



PolyMUMPs Run No.:	67
Working Nomenclature	Die #5
Fabricated Devices:	200 µm Radius, Poly1 Multiple Spring Aperture, 200 µm Radius, Poly2 Multiple Spring Aperture, 200 µm Radius, Poly1/Poly2 Multiple Spring Aperture Layer Deposition Test Structure
Main Uses:	Test Separation Distance Between Aperture Designs Observe Variations in Apertures due to Fabricated Layer Thicknesses Observe/Measure Stacked Layer Thicknesses and Etch Depths



PolyMUMPs Run No.:	67
Working Nomenclature	Die #6 (Modified Die #3)
Fabricated Devices:	200 µm Radius, Hinge-Based Rotating Aperture 200 µm Radius, Spring-Based Rotating Aperture 135 µm Radius, Spring-Based Rotating Aperture 175 µm x 175 µm Square Plates, Rotating Aperture, Layer Deposition Test Structures
Main Uses:	Test/Observe, Double Layer (3.5 µm) Latches on the Hinge-Based and Spring-Based Rotating Designs Observe/Measure Fabricated Layer Thicknesses and Etch Depths



PolyMUMPs Run No.:	67
Working Nomenclature	Die #7
Fabricated Devices:	Rotating Apertures: 140 μm Poly1/Poly2 Single-Sided Sliding Plate 140 μm Poly2 Single-Sided Sliding Plate 50 μm Poly1 Single-Sided Sliding Plate 240 μm Poly1/Poly2/Metal Releasable Residual Stress Beam
Main Uses:	Test Alternative Rotating Aperture Designs Observe Variations Based on Different Sliding Masses Observe Effects of Poly0 Runners for Sliding Plate Observe/Measure Effects of Residual Stress on a Long Releasable Structure