Edge Contacts to Atomically-Thin Superconductors

Sofia Cruz[1,2], Jesse Balgley[2], Xuanjing Chu[2], Ted Chung[2], Jinho Park[2], James C. Hone[2]

1. Paul M. Rady Department of Mechanical Engineering, University of Colorado Boulder
2. Department of Mechanical Engineering, Columbia University

Introduction: A qubit's unconventional quantum properties make them distinct from classical bits and enable them to possess exponentially greater computing power than a classical computer. The prospect of scaling quantum computers to contain a large number of qubits on a single processor chip is limited, with a single qubit typically occupying > 1 mm^2 area. We study a class of materials known as van der Waals (vdW) layered materials which show promise to host next-generation qubits with both long-coherence-time data storage and small areas for better scalability. Over the course of the summer, we explored different methods for isolating and making edge contact to single atomic layers of the vdW superconductor molybdenum telluride ($MoTe_2$), encapsulated by the vdW insulator hexagonal boron nitride (hBN), which will serve as a platform for next-generation quantum devices.

Methods: Using techniques pioneered at Columbia University, we can *stack* hBN and $MoTe_2$ to protect $MoTe_2$ from the environment and oxidation. We begin with *exfoliation* to extract thin sheets of hBN and $MoTe_2$. Once we encapsulate the $MoTe_2$ within a stack, we need to make high-quality electrical contact to it, which is usually done by *etching* holes into the stack and *depositing* metal along the exposed edge of the conductive material, a technique known as *edge contact*. This is done using *Argon (Ar) milling* to etch and deposit onto $MoTe_2$ "in-situ", at ultra-high-vacuum (UHV).

Reference	Milling rate	Parameters			Material
		Beam V	Accel V	Emission Cur	
Phillip Kim Group (Harvard)	~0.6 nm/min (soft milling)	200 V	40 V	8.0 mA	TMDC
Gil-Ho Lee Group (POSTECH)	~1.0 nm/ min	400 V		10 mA	h-BN
Raytheon BBN	15 nm/min	400 V	80 V	23 mA	MoTe2
Photonics Labratory[3]	~14.7 nm/min	250 V	50 V	10 mA	MoOx (for contact)

Figure 4. Future conditions

Results:

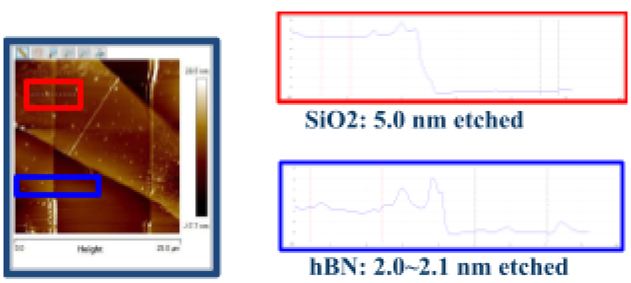

Figure 1. hBN on SiO_2 chip, "soft milled" for 5 minutes

Figure 2. hBN, $MoTe_2$ stack

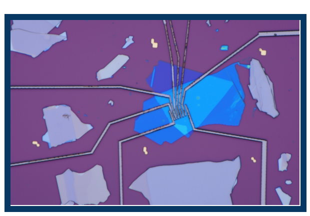

Figure 3. Post etch/deposition

Conclusions: While we were able to effectively test Ar milling on the hBN as shown in Figure 1, it did not translate to the stack (Figure 2 and 3). With the Ar milling conditions highlighted in Figure 4, 5 minutes was not long enough to etch through the top layer of hBN. Therefore, we could not make edge contact with the $MoTe_2$. In the future, with more time, we can test longer milling with various other conditions shown in this table. Ultimately, this development can contribute to future possibilities of $MoTe_2$, as well as the improvement to future quantum devices.

References:

1. L. Wang et al. *Science* 342, 614-617 (2013).
2. A. Antony et al. *J. Phys.: Condens. Matter* 34, (2022).
3. A. Jain et al. *Nano Letters* 19 (10), 6914-6923, (2019).

Acknowledgements: This work was supported by the Columbia Amazon Summer Undergraduate Research Experience (SURE) Fellowship and the Hone Lab.