Lithography for Topological Nanowires

CNF Project Number: 3032-22
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Primary Source(s) of Research Funding: The Gordon and Betty Moore Foundation's EPiQS Initiative, Grant GBMF9062; Semiconductor Research Corporations (SRC) JUMP 2.0 SUPREME; The National Science Foundation, Division of Materials Research #2240956

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Primary CNF Tools Used: Nabity System for Supra SEM, Zeiss Ultra SEM, SC4500 Odd-Hour Evaporator

Abstract:

Topological materials in nanowire forms can transform future computing technologies by enabling fault-tolerant quantum computing using topological superconductor nanowires or energy-efficient interconnects using topological semimetal nanowires. The major challenge remains synthesis of these materials in nanowires. We employ the recently developed thermomechanical nanomolding [1] to fabricate nanowires of topological materials. In this project, we fabricate nanodevices using the molded nanowires to measure their transport properties.

Summary of Research:

We have successfully molded various topological semimetals [2] and layered materials into nanowires using thermomechanical nanomolding. We have further extended the nanomolding method to two-dimensions (2D) and demonstrated wafer-scale fabrication of 2D nanostructures [3]. We are fabricated nanodevices on these molded nanostructures to test if some of the topological semimetals may be promising interconnect materials that can replace the state-of-the-art copper interconnects and to measure topological protected surfaces states in transport in these molded nanowires.

Conclusions and Future Steps:

Thermomechanical nanomolding is a promising synthesis technique that can rapidly and with scale fabricate nanowires of topological materials. We have produced several classes of topological materials into nanowires using this method. Future steps include fabrication of nanodevices using standard e-beam lithography on these molded nanowires to measure their transport properties.

References:

[1] M. T. Kiani, J. J. Cha, Nanomolding of topological nanowires, APL Mater. 10, 080904 (2022).

[2] M. T. Kiani, Q. P. Sam, G. Jin, B. Pamuk, H. J. Han, J. L. Hart, J. R. Stauff, J. J. Cha, Nanomolding of metastable Mo_4P_3, Matter doi:10.1016/j.matt.2023.03.023 (2023).

[3] M. T. Kiani, Q. P. Sam, Y. S. Jung, H. J. Han, J. J. Cha, Wafer-scale fabrication of 2D nanostructures via thermomechanical nanomolding, arXiv: 2306.10167 (2023).

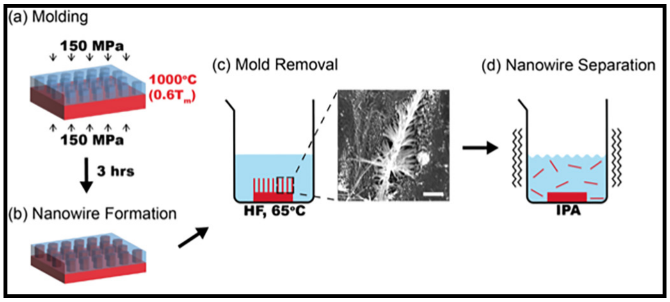

Figure 1: Schematic of thermomechanical molding. (a) Bulk feedstock of topological material (red) is pressed onto the nanostructured mold, in this case anodized aluminum oxide (blue). (b) After molding, nanowires form. (c) The molded nanowires are extracted from the mold by etching the mold. (d) the molded nanowires are separated from the bulk feedstock by sonication.

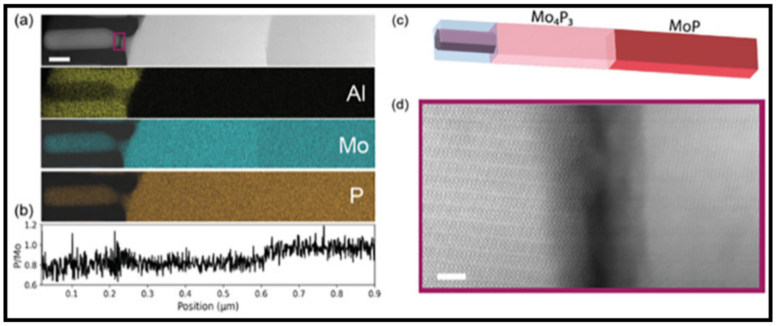

Figure 2: Thermomechanically molded Mo_4P_3 nanowires. (a) Cross-section scanning transmission electron microscopy (STEM) and chemical mapping images of the Mo_4P_3 nanowire molded into the aluminum oxide mold, with the bulk feedstock also intact. (b) The P/Mo composition changes at the mold entrance as phosphorus vapor leaves the apparatus during molding. (c) Schematic of the molding process for Mo_4P_3 nanowire. (d) Atomic-resolution high-angle annular dark field STEM image of the molded nanowire.

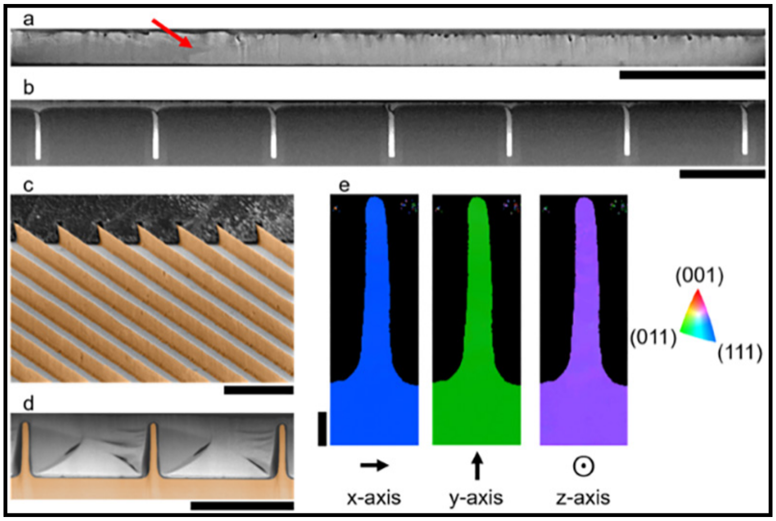

Figure 3: Nanomolded 2D Cu-filled trenches and free-standing 2D Cu fins. (a, b) Scanning electron microscopy (SEM) images of the Cu-filled trenches at the wafer scale, using Si mold. (c, d) Free-standing 2D Cu fins, after etching away the Si mold. (e) Single-crystalline Cu-filled trench at the nanoscale.