Investigating the Impact of an External Electric Field on Thermal Behavior

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Primary CNF Tools Used: ABM Contact Aligner, SUSS MA6-BA6 Contact Aligner, SC4500 Odd-Hour Evaporator, Glen 1000 Resist Strip, Everbeing EB-6 DC Probe Station

Abstract:

As electronics continue to scale to smaller dimensions and increased power densities, understanding how electric fields impact the thermal properties of materials becomes important for accurate thermal budgeting. In this work, we fabricate structures to study how thermal properties of hexagonal boron nitride (hBN) change when a cross-plane electric field is applied to the material. Microscale capacitors with Ti/Au contacts were fabricated using dry transfer, contact photolithography, electron-beam evaporation, and liftoff processing. Thermal measurements of the devices under applied external fields are ongoing.

Summary of Research:

To perform thermal measurements, a lateral hBN flake dimension of at least 80 µm is desirable, and thicker flakes are selected to help limit the influence of the interfaces on thermal measurements. (Bulk samples are not used since a single-crystal domain is necessary to eliminate the effect of grain boundaries.) Compared to typical 2D material flakes used for device fabrication, these flakes have much larger lateral dimensions (~100 µm x ~100 µm) and are thicker (~100 nm or thicker). This, combined with the electrode dimensions, allows us to utilize contact photolithography to pattern our electrodes, a technique not typically used for 2D flakes.

Mask design, mask writing, and photolithography dose testing were all performed as initial steps in the device development process. To make a wafer of devices, the bottom electrodes are patterned, metal is deposited, and liftoff is performed. After the bottom electrode is set, dry transfer is used to precisely place hBN flakes. Then, the top electrode is patterned on top of the flake, and deposition and liftoff are repeated. Sonication cannot be used at any step once the flakes are placed, as it can lead to delamination. An example of a fully fabricated device is shown in Fig. 1.

Some iteration on this general process was necessary to ensure repeatable and high quality results. The initial wafer of devices run showed contaminants on the flake that affected the top electrode, and atypical aging of the gold used for both the top and bottom electrodes was observed. An oxygen plasma resist strip and a more aggressive substrate clean prior to processing resolved these two issues, respectively. A comparison of a device from the first wafer and one from the second wafer, after these changes have been implemented, is shown in Fig. 2.

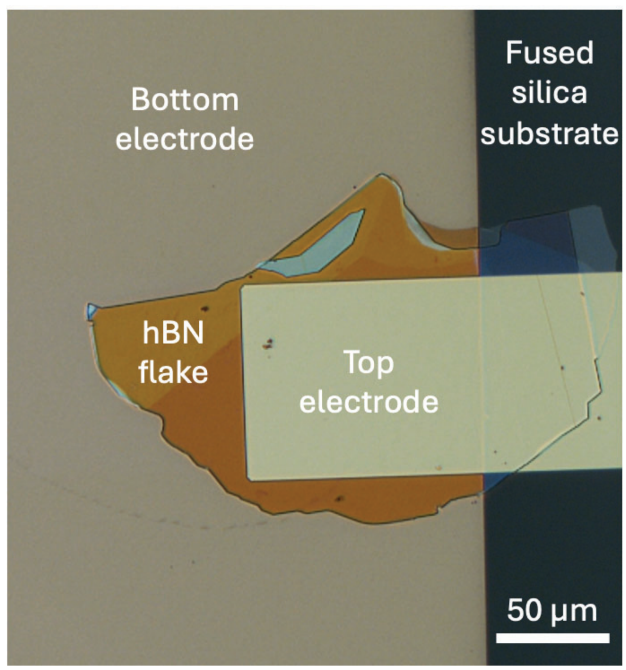

Figure 1: An optical microscope image of a fully-fabricated device with structures labelled for clarity. Both the top and bottom electrodes are Au with a Ti adhesion layer, but the difference in appearance is due to different thicknesses of Au.

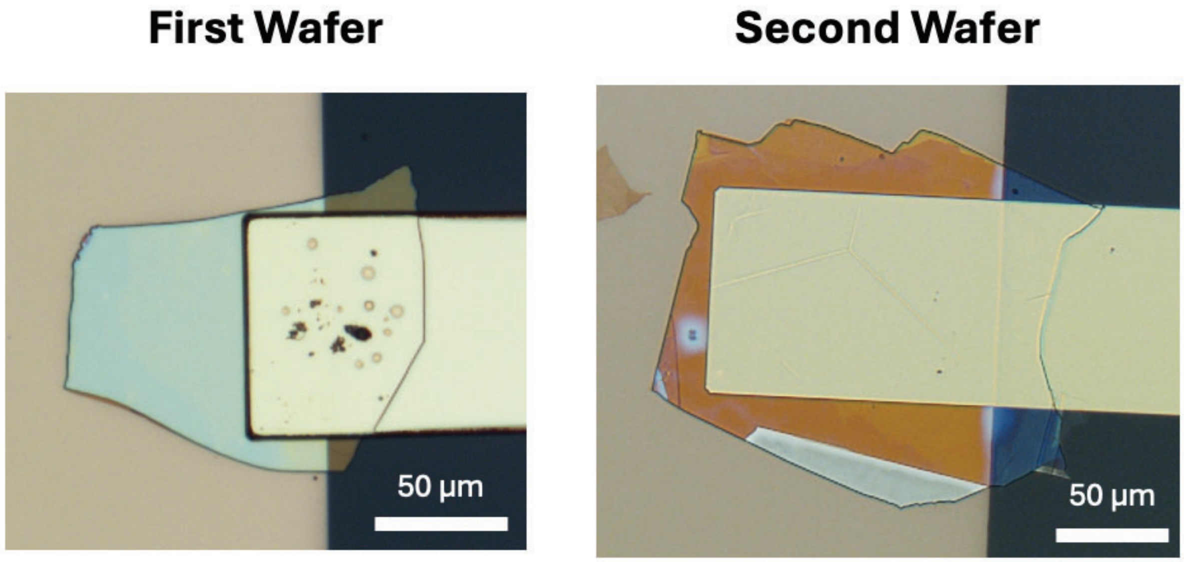

Figure 2: Two optical microscope images showing a device on the first wafer fabricated without additional cleaning steps and a device on the second wafer where more robust substrate cleaning and an oxygen plasma clean immediately prior to top electrode deposition helped to eliminate residues present on the first wafer.

Conclusions and Future Steps:

A repeatable and effective fabrication method has been developed for these devices that ensures well-defined contacts and clean surfaces. These devices are now undergoing thermal measurements while fields are applied, and future steps will be informed by the experimental results obtained from these measurements.