Supplementary Materials: Heated Assembly and Transfer of Van der Waals Heterostructures with Common Nail Polish

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S1. Heated heterostructure assembly with a nail polish microstamp

In addition to the pick up slide described in the main text (Figure 1), we have also tried to assemble van der Waals heterostructures with a single drop of nail polish (Revlon Nail Enamel, Clear 771). Figure S1(a) shows a picture of a glass slide with a drop of nail polish at the bottom used for pick up. After pick up of the first BN flake (Figure S1(b), a noticeable deformation of the nail polish is evident (white arrow). After baking on a hot plate at 90 °C for 1 min the deformation is absent and the surface smooth again (Figure S1). Figure S1(d–e) show subsequent optical images during the pick up of a graphite flake using the first BN. After this pick up, there is significant deformation of the nail polish (Figure S1(f)) that is again reduced after a hot plate bake at 90 °C for 1 min (Figure S1(g)). This deformation, while seemingly not detrimental to a two layer stack, would be a significant problem for many layers with required alignment between layers. In addition, the final transfer is slightly more problematic because of the amount of nail polish that is melted. Figure S1(h) shows a strand of nail polish that persists during the transfer of the stack. Care must be taken to slowly retract the slide even at significant distances as to not disturb the stack during transfer. Figures S1(i–j) show optical images after the transfer and after the chip cleaning, respectively.

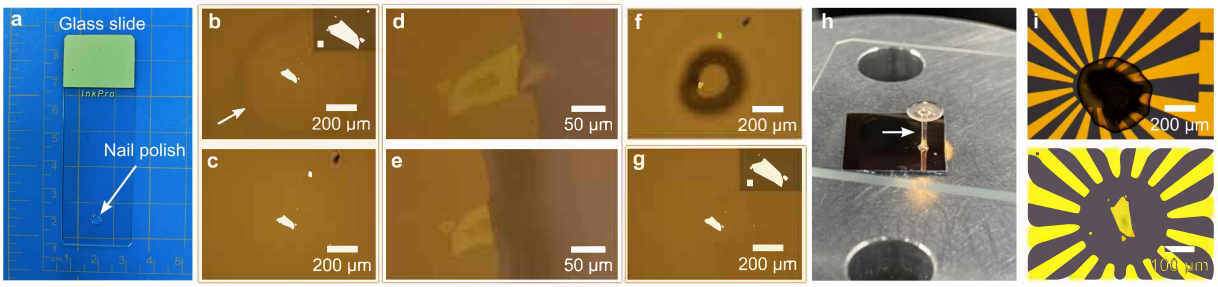

Figure S1. Heterostructure assembly with a single drop of nail polish. a) Picture of a glass slide with a drop of nail polish used for assembly. b) Optical image of a BN flake after pick up with the glass slide/nail polish. The inset shows a higher magnification image of the BN flake. The scale bar is 20 μm. The white arrow indicates the deformation of the nail polish after pick up. c) Optical image of the pick up slide after baking on a hot plate at 90 °C for 1 min. d) Optical image taken during the van der Waals pick up of a graphite flake using the BN flake. This image demonstrates full lamination of the graphite, but not of the BN during pick up. e) Optical image taken during pick up showing the separation of the BN and graphite flake from the surface. f) Optical image of the BN/graphite stack on the pick up slide. Considerable deformation of the polish is present. g) Optical image after baking the pick up slide on a hot plate at 90 °C for 1 min. h) Picture showing the long strand of melted nail polish during the high temperature transfer of the stack. i) Optical image of the stack on a substrate with prepatterned electrodes. The dark region shows the melted nail polish. j) Optical image of the stack and substrate after cleaning with acetone and isopropyl alcohol.

S2. Surface roughness of a transferred flake

To determine the cleanliness of the stacks after cleaning, we have measure the surface roughness of a BN flake after pick up, transfer, and cleaning. Figure S2(a) shows a BN flake that has been exfoliated onto a Si/SiO_2 substrate. Figure S2(b) shows an optical image of the flake after pick up with a nail polish slide and transfer to a substrate with prepatterned electrodes (not explicitly used). Figure S2(c–d) show optical images after cleaning the flake and substrate in acetone for 10 mins, rinsing with isopropyl alcohol, and drying with

nitrogen. An atomic force microscopy scan of the same flake after cleaning is shown in Figure S2(e). A line cut shows at the white dotted line in Figure S2 shows that the flake is 59 nm (Figure S2(f)), a typical thickness utilized for our heterostructures. A 1 um by 0.7 um scan at the center of the flake is shown in Figure S2(g). From this data set, we calculate (using Gwyddion data analysis software) an RMS surface roughness of 0.57 nm. This is slightly better than the RMS surface roughness of the SiO_2 surface (0.68 nm in Figure S2(h)) several millimeters away from the flake and far from any region which had direct contact with the nail polish. This shows that while the the surface roughness does not compare with a pristine exfoliated BN surface (typically 100 pm, Ref. 4 of the main text), the BN flake surface is not any worse than the SiO_2 surface around it. A high temperature vacuum anneal may improve the surface roughness if this is an important design consideration.

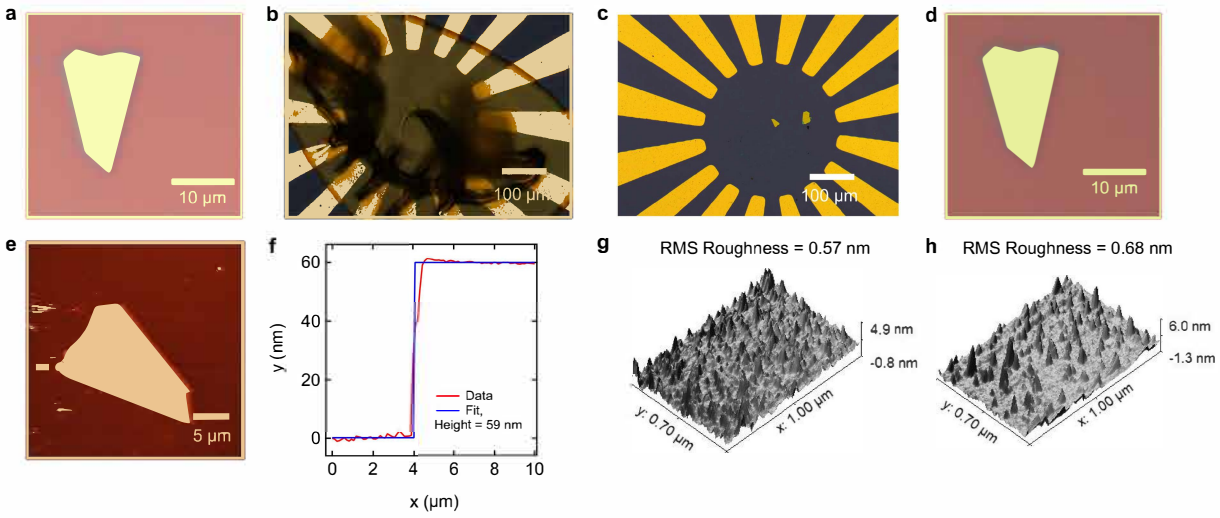

Figure S2. Surface roughness analysis of a transfer flake. a) Optical image of an exfoliated BN flake before pick up. b) Optical image of the flake after transfer to a substrate with prepatterned electrodes. Note the electrodes are not used here. c) Optical image after cleaning the substrate in an acetone bath for 10 mins followed by a rinse with isopropyl alcohol, and drying with nitrogen. d) 100x magnification optical image of the same BN flake after cleaning. e) AFM scan of the BN flake after cleaning. f) Line cut from the AFM scan in panel (e) showing the height of the flake as 59 nm. g) A measurement of the surface roughness of the BN flake, taken near the center of the flake. The surface roughness is 0.57 nm. h) A measurement of the surface roughness of the SiO_2 substrate, several millimeters away from the BN flake and any region that was in contact with the nail polish. The surface roughness here is 0.68 nm.