Direct observation of flat bands in near-magic-angle twisted bilayer CVD graphene

Gianluigi Baiardi[1,2], Alex Boschi[1], Giulia Piccinini[1,2], Vaidotas Mišeikis[1], Lorenzo Cavicchi[3], Aaron Bostwick[4], Chris Jozwiak[4], Eli Rotenberg[4], Kenji Watanabe[5], Takashi Taniguchi[6], Marco Polini[7], Fabio Beltram[2], Antonio Rossi[1], **Stiven Forti**[1], Sergio Pezzini[8], Camilla Coletti[1]

1 Center for Nanotechnology Innovation @NEST, Istituto Italiano di Tecnologia, P.zza San Silvestro 12, 56127 Pisa, Italy.

2 NEST laboratory, Scuola Normale Superiore, Pisa, Italy.

3 Scuola Normale Superiore, Pisa, Italy.

4 Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA.

5 Research Center for Electronic and Optical Materials, National Institute for Materials Science, Tsukuba, Japan.

6 Research Center for Materials Nanoarchitectonics, National Institute for Materials Science, Tsukuba, Japan.

7 Physics department, Università di Pisa, Pisa, Italy.

8 NEST laboratory, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy.

Abstract: Chemical-vapor-deposition of graphene on copper, followed by pick-and-flip assembly, can synthetize ultra-high-quality stacks with fine angle-control, that allows the observation of quantum collective phenomena, such as flat-bands at the Fermi level in magic-angle-twisted bilayer graphene.

Advances in chemical vapor deposition (CVD) growth have driven graphene crystal quality to unprecedented levels [1], yet it is still unknown whether this route can realize the fragile flat-band and correlated states of magic-angle (MA) twisted bilayer graphene (TBG). Here, we report on the experimental observation by room-temperature nano angle-resolved photoemission spectroscopy (nano-ARPES) of flat bands in a TBG sample close to the MA, assembled via a grow-and-stack protocol based on low-pressure CVD of graphene on copper and the PVA-mediated pick-and-flip technique [2]. Our study indicates electronic bands fully comparable to those measured in exfoliation-based samples and determines the size of the largest near-MA domain to be compatible with electronic transport experiments, motivating further experiments on flat band physics in CVD-graphene.

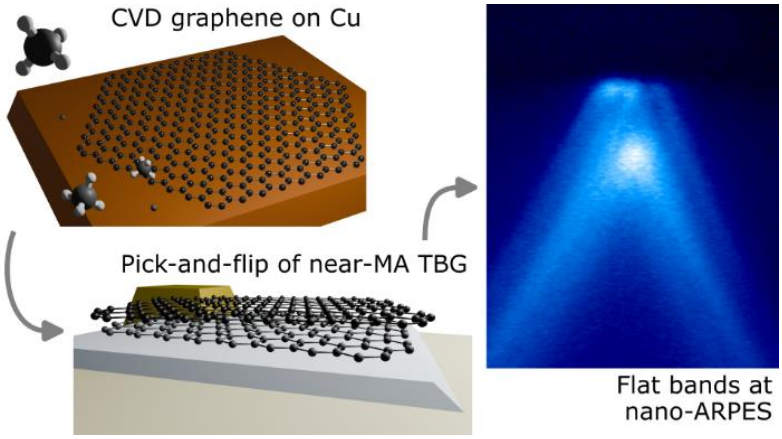

Fig. 1 Sketch of graphene on copper and the transferred twisted homo-structure. On the right, experimental nano-ARPES data, centred at the graphene K-point.

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References

[1] Piccinini G; Mišeikis V.; Novelli P.; Watanabe K.; Taniguchi T.; Polini M.; Coletti C.; Pezzini S. Moiré-Induced Transport in CVD-Based Small-Angle Twisted Bilayer Graphene. *Nano Lett.* **22**, 5252 (2022)

[2] Wong, D.; Nuckolls, K. P.; Oh, M.; Lian, B.; Xie, Y.; Jeon, S.; Watanabe, K.; Taniguchi, T.; Bernevig, B. A.; Yazdani, A. Cascade of Electronic Transitions in Magic-Angle Twisted Bilayer Graphene. *Nature* **582** 7811 (2020).