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Supplementary information

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Emma C. Regan, Danqing Wang, Chenhao Jin, M. Iqbal Bakti Utama, Beini Gao, Xin Wei, Sihan Zhao, Wenyu Zhao, Zuocheng Zhang, Kentaro Yumigeta, Mark Blei, Johan D. Carlström, Kenji Watanabe, Takashi Taniguchi, Sefaattin Tongay, Michael Crommie, Alex Zettl & Feng Wang ✉

Supplementary Information for

Mott and generalized Wigner crystal states in WSe_2/WS_2 moiré superlattices

Emma C. Regan†, Danqing Wang†, Chenhao Jin†, M. Iqbal Bakti Utama, Beini Gao, Xin Wei, Sihan Zhao, Wenyu Zhao, Zuocheng Zhang, Kentaro Yumigeta, Mark Blei, Johan D. Carlström, Kenji Watanabe, Takashi Taniguchi, Sefaattin Tongay, Michael Crommie, Alex Zettl, Feng Wang*

† These authors contributed equally to this work

* Correspondence to: fengwang76@berkeley.edu

S1. Effective AC circuit model

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We use an effective AC RC circuit, shown in Figure 1c, to model the AC electrical transport in the TMD heterostructure. C_1 and C_B are the geometric capacitances between the TMD and the top and bottom gates in region 1, respectively, and C_2 is the geometric capacitance between the TMD and the bottom gate in region 2. The geometric capacitances are defined by $C_i = \frac{\varepsilon_0 \varepsilon_r A_i}{d_i}$, where ε_r is the dielectric constant of the gate dielectric, and A_i and d_i denote the relevant capacitor area and separation. C_Q and R are the quantum capacitance and resistance of region 1, respectively. The ODRC signal measures the modulation induced optical contrast change in region 2, which can be understood as the optical response to an effective voltage change on region 2 (ΔV_2) due to the AC capacitive excitation in region 1 ($\Delta\tilde{V}$):

$$\Delta V_2 = \Delta\tilde{V}\left(1 - \frac{\frac{1}{i\omega C_1}}{\frac{1}{i\omega C_1} + \frac{1}{i\omega C_B + \frac{1}{\frac{1}{i\omega C_Q} + \frac{1}{i\omega C_2} + R}}}\right)\frac{\frac{1}{i\omega C_2}}{\frac{1}{i\omega C_Q} + R + \frac{1}{i\omega C_2}},$$

which can be simplified to:

$$\Delta V_2 = \Delta\tilde{V}\left(\frac{C_1}{C_1 + C_B}\right)\frac{\frac{1}{C_2}}{\frac{1}{(C_1 + C_B)} + \frac{1}{C_Q} + \frac{1}{C_2} + i\omega R}.$$

For simplicity, we define an effective capacitance as

$$\frac{1}{C_{eff}} = \frac{1}{(C_1 + C_B)} + \frac{1}{C_2} + \frac{1}{C_Q},$$

so

$$\Delta V_2 = \Delta\tilde{V}\left(\frac{C_1}{C_1 + C_B}\right)\frac{\frac{1}{C_2}}{\frac{1}{C_{eff}} + i\omega R}.$$

The effective voltage change leads to a total charge change $\Delta\tilde{Q}$ in region 2:

$$\Delta\tilde{Q} = \Delta V_2 C_2 = \Delta\tilde{V}\left(\frac{C_1}{C_1 + C_B}\right)\frac{1}{\frac{1}{C_{eff}} + i\omega R},$$

and corresponding change in hole density:

$$\Delta\tilde{n} = \frac{\Delta\tilde{Q}}{A_2 e} = \frac{1}{A_2 e}\Delta\tilde{V}\left(\frac{C_1}{C_1 + C_B}\right)\frac{1}{\frac{1}{C_{eff}} + i\omega R}$$

where e is the electron charge. The ODRC signal, ΔOC, is related to $\Delta\tilde{n}$ by the optical detection responsivity α, which describes the change in the optical absorption for a given change in doping:

$$\Delta OC = \alpha\Delta\tilde{n} = \frac{\alpha}{A_2 e}\Delta\tilde{V}\left(\frac{C_1}{C_1 + C_B}\right)\frac{1}{\frac{1}{C_{eff}} + i\omega R}.$$

The responsivity α is set to 1.4 x 10^{-12} cm^2, so that $\frac{1}{C_{eff}} = \frac{1}{(C_1+C_B)} + \frac{1}{C_2}$ at high doping, where the quantum capacitance is much larger than the geometry capacitances and has negligible contribution. This value of α is also consistent with the value determined by the doping-dependent optical absorption of region 2.