Supplementary Information

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Supplementary Information: Photoluminescence Enhancement of Quasi-2D Perovskite Films by Plasmonic Silver Nanoparticles

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S1 From Films to Nanoparticles

The CY-MSP180G-DC equipment's primary function is not to fabricate nanoparticle coatings. According to its technical specifications, using it under standard operating parameters (1-minute deposition time, 1-5 Pa chamber pressure, and 30-250 W plasma power) produced uniform Ag deposits.

To begin, the deposition time was minimized (see Figure S1). A uniform Ag film with characteristic Ag reflection and zero transparency was achieved after a 1-minute deposition in a sputtering chamber at 2.5 Pa and 85 W of plasma power. The process was then repeated under the same chamber conditions with another glass substrate. After 10 seconds of deposition, the resulting film lost its high reflectivity, forming an opaque, dark coating. Finally, a 1-second deposition resulted in high transparency and blue reflectance, suggesting the formation of NPs due to the substrate absorbance.

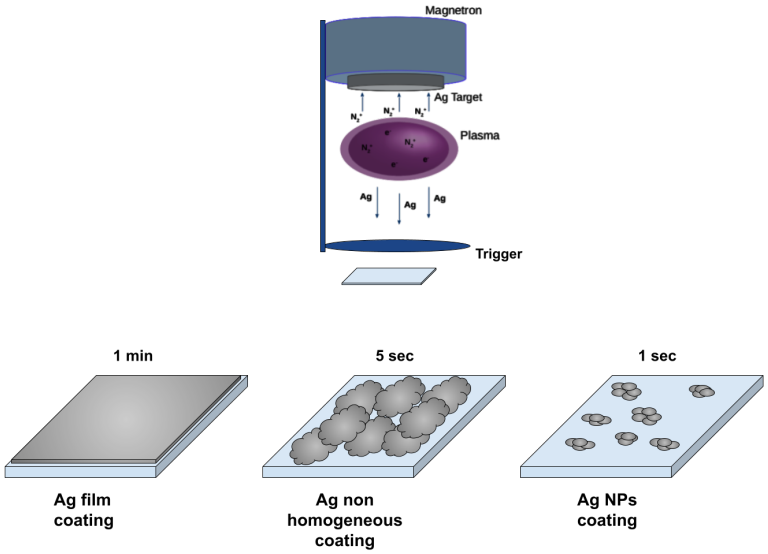

Fig. S1 Process for obtaining Ag NPs using a CY-MSP180G-DC sputtering system. Deposition time was gradually reduced until the formation of Ag NPs was suggested.

† *Electronic Supplementary Information (ESI): Sputtering process for Ag NP coatings, PL intensity measurements of perovskite films, and TEM images with size distributions of Ag NPs. Contact: emmanuel.d.pina@gmail.com*

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A new glass substrate with a TEM grid was placed in the sputtering chamber operated under conditions similar to those previously established. (77 W, 1-second deposition time, 2.4 Pa chamber pressure). TEM images revealed scattered and agglomerated NPs (see Figure S2). This confirmed that Ag NP deposition is feasible at high pressures (2.5 Pa) with a 1-second deposition time. However, TEM images indicated significant NP agglomeration, leading to a non-ideal deposition as only a few NPs would generate plasmonic resonance.

The sputtering base and substrate were heated to improve deposition. Starting at 30 °C, no color change was observed. Gradually increasing the temperature, a significant color change was noted at 75 °C, indicating deagglomeration of Ag NPs. These observations expedited the process, avoiding the long wait times typically required for TEM observations. Heating the sputtering base beyond 75 °C to 100 °C showed no further modifications. TEM images confirmed that the deposits at 75 °C (see Figure S2) significantly improved over the room-temperature deposits, with evenly dispersed Ag NPs and no agglomeration.

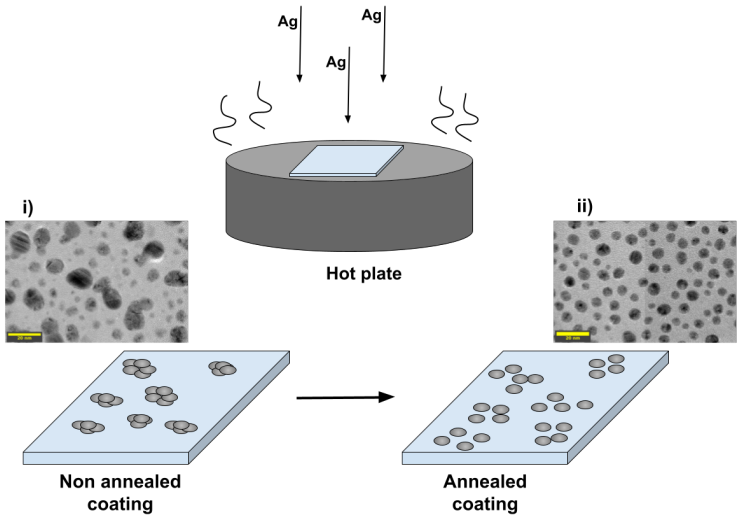

Fig. S2 Deagglomeration of Ag NPs through annealing of the substrate base at 75 °C (scale bar at 20 nm in SEM images).

Coatings using a plasma power of 40 W generated NPs with dimensions centered around 2 nm, as indicated by TEM images (see Figure S3). As the plasma power was increased, larger Ag NPs were produced. Deposits created with power near 75 W resulted in NPs size centered at 5 nm. At power levels close to 100 W, the size distribution peak was around 6.5 nm. However, as the power surpassed 100 W, there was a tendency towards larger Ag NPs. Deposits generated with 115 W of plasma power showed NPs with a length centered at 7.5 nm (scale bar at 20 nm in SEM images).

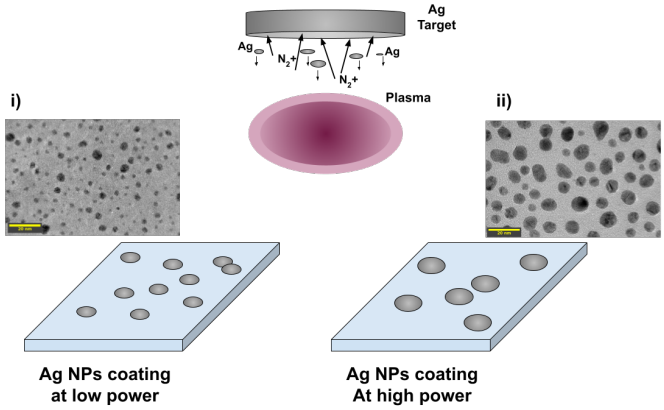

Fig. S3 Control of NP size by adjusting sputtering power. Deposits produced at the minimum power of 40 W (i) resulted in Ag NPs with sizes centered around 2 nm. In contrast, deposits at a higher power of 120 W (ii) generated Ag NPs with sizes ranging from 7 to 9 nm.

Up to this point, the Ag NPs mainly exhibited circular and ellipsoidal shapes. Further increases in power up to 120 W resulted in NPs with varied morphologies.

S2 PL Intensity Measurements

The PL measurements of the perovskite films before and after being coated with Ag NPs are presented. Figure S4 shows the PL spectra of the perovskite films with phase $n = 5$. The PL spectra of the films after being coated with Ag NPs is displayed, with the corresponding pre-coating spectra plotted in a darker shade for direct comparison. The changes in PL intensity before and after the deposition of Ag NPs can be noticed. Maximum PL increase was achieved with a deposit at 115 W.

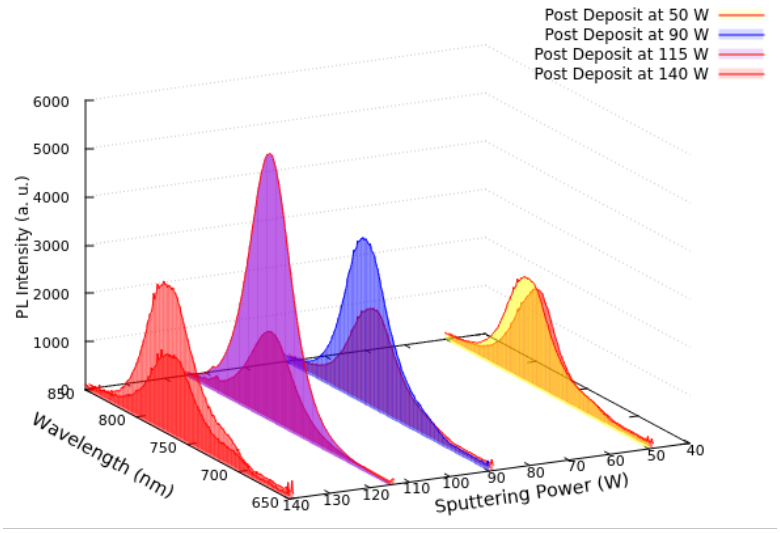

Fig. S4 PL intensity measurements of perovskite films with phase $n = 5$ before (dark shade) and after (color spectra) being coated with Ag NPs at different sputtering power.

Similarly, in Figure S5, the PL measurements of perovskite films with phase $n = 10$ are presented, both before and after the deposition of Ag NPs. A consistent increase in PL intensity is observed as the sputtering power increases. The maximum enhancement is achieved with sputtering power at 120 W, resulting in a 7.4-fold increase in PL intensity.

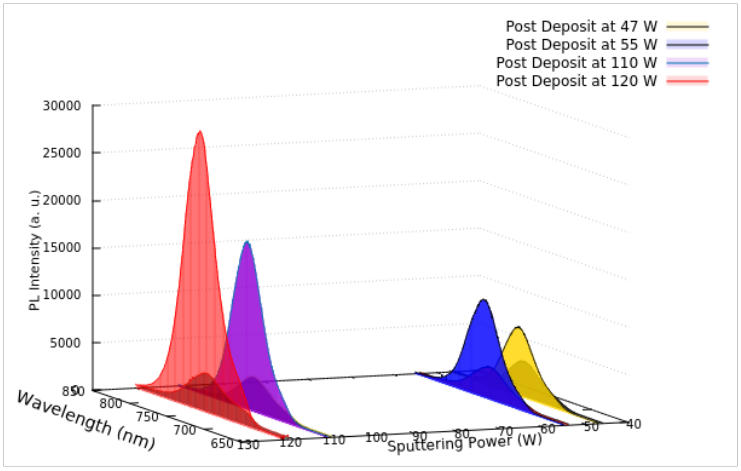

Fig. S5 PL intensity measurements of perovskite films with phase $n = 10$ before (dark shade) and after (color spectra) being coated with Ag NPs at different sputtering power.

S3 TEM images and size distributions of Ag NPs

SEM images of the Ag NPs coatings and the corresponding NPs size distributions observed across the deposition are presented (Figure S6). An increase in nanoparticle size distribution was observed up to a sputtering power of 120 W, resulting in a size distribution centered at 8 nm of diameter. When the sputtering power was increased beyond 120 W, a decrease in the size distribution of the Ag NPs was observed, which was associated with instability in the plasma. The sputtering equipment working at 140 W generated Ag NPs with size distribution predominantly centered at 3 nm.

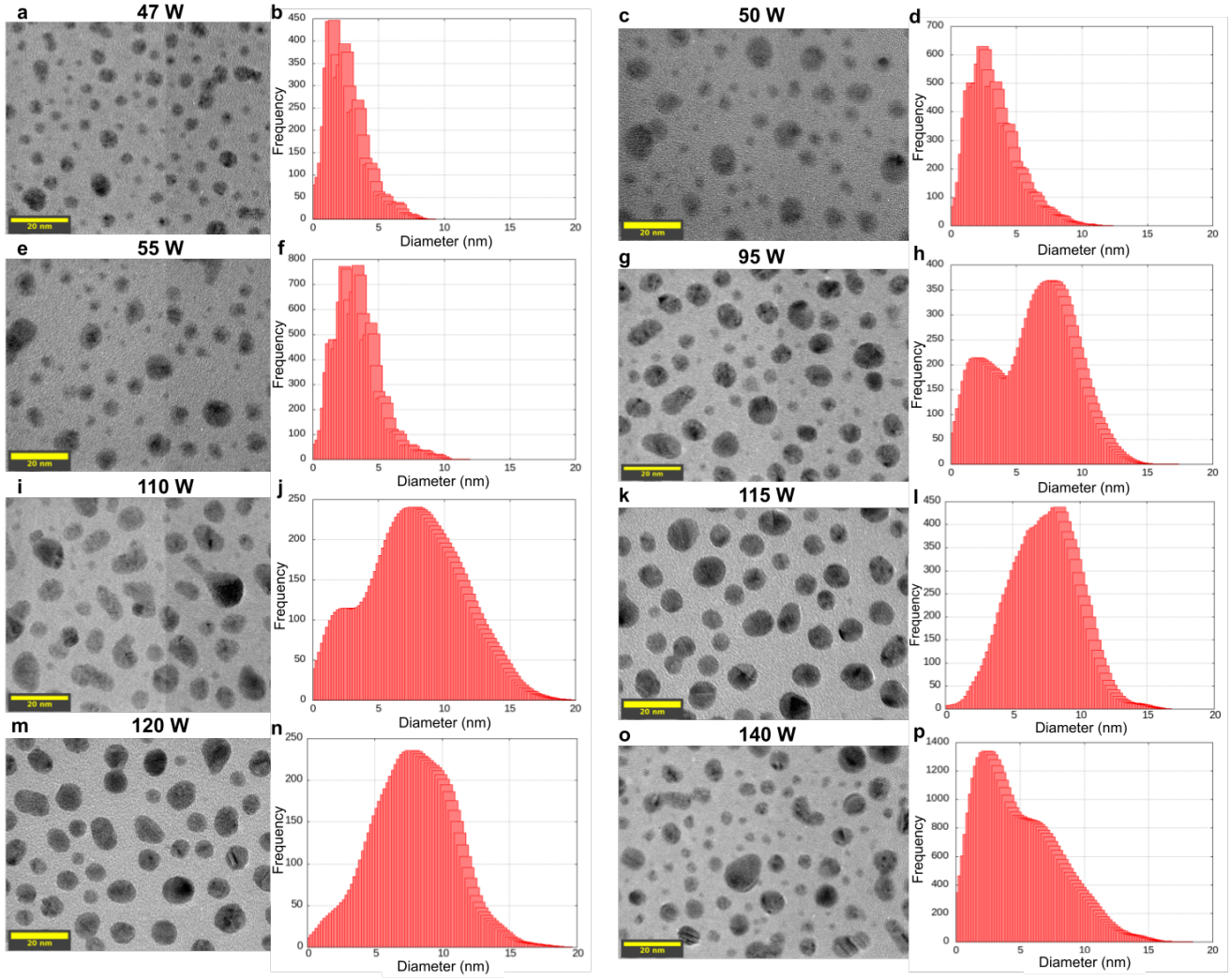

Fig. S6 TEM image and size distribution of Ag NPs deposit generated at (a, b) 47 W, (c, d) 50 W, (e, f) 55 W, (g, h) 95 W, (i, j) 110 W, (k, l) 115, (m, n) 120 W, and (o, p) at 140 W, respectively (scale bar at 20 nm).