# Supporting Information

## Enhanced Stability of Ge-Doped CsPb(I$_{1-x}$Br$_x$)$_3$ Perovskite Solar Cells

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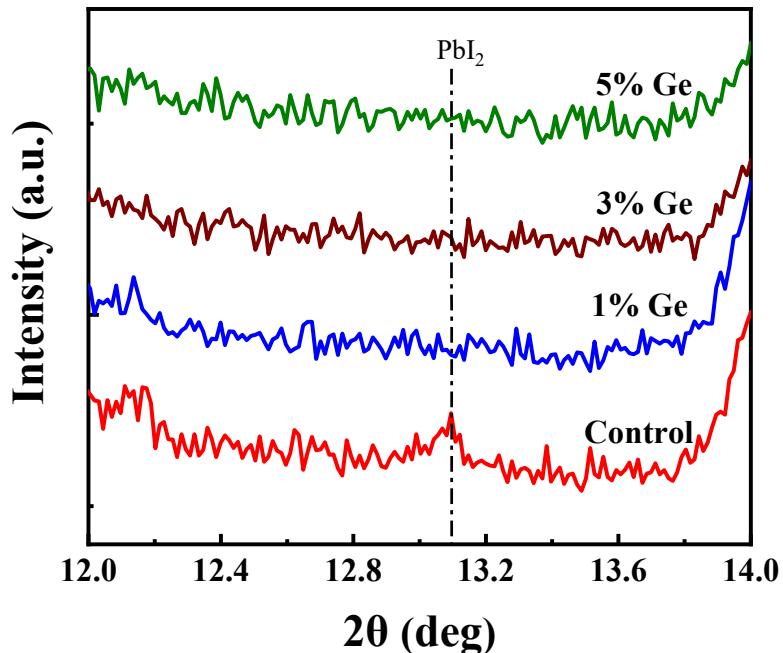
**Figure S1.** XRD phase analysis of samples with different Ge contents.
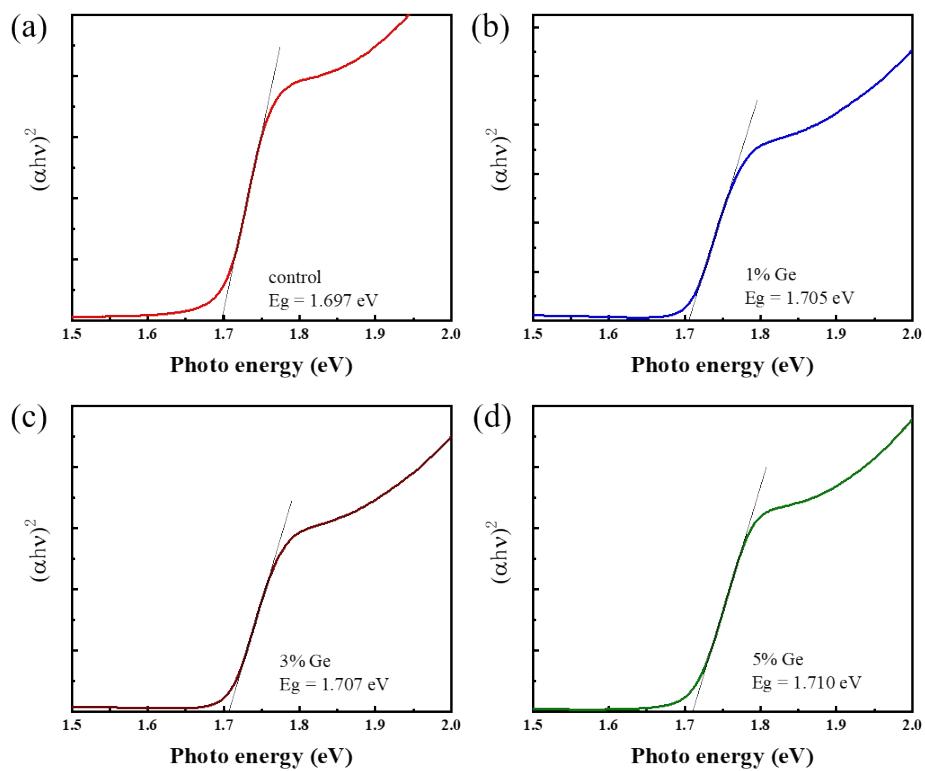


**Figure S2.** $(\alpha h\nu)^2$ versus light excitation energy hv. (a) The Control, (b) 1% Ge doped perovskite film, (c) 3% Ge doped perovskite film, (d) 5% Ge doped perovskite film.
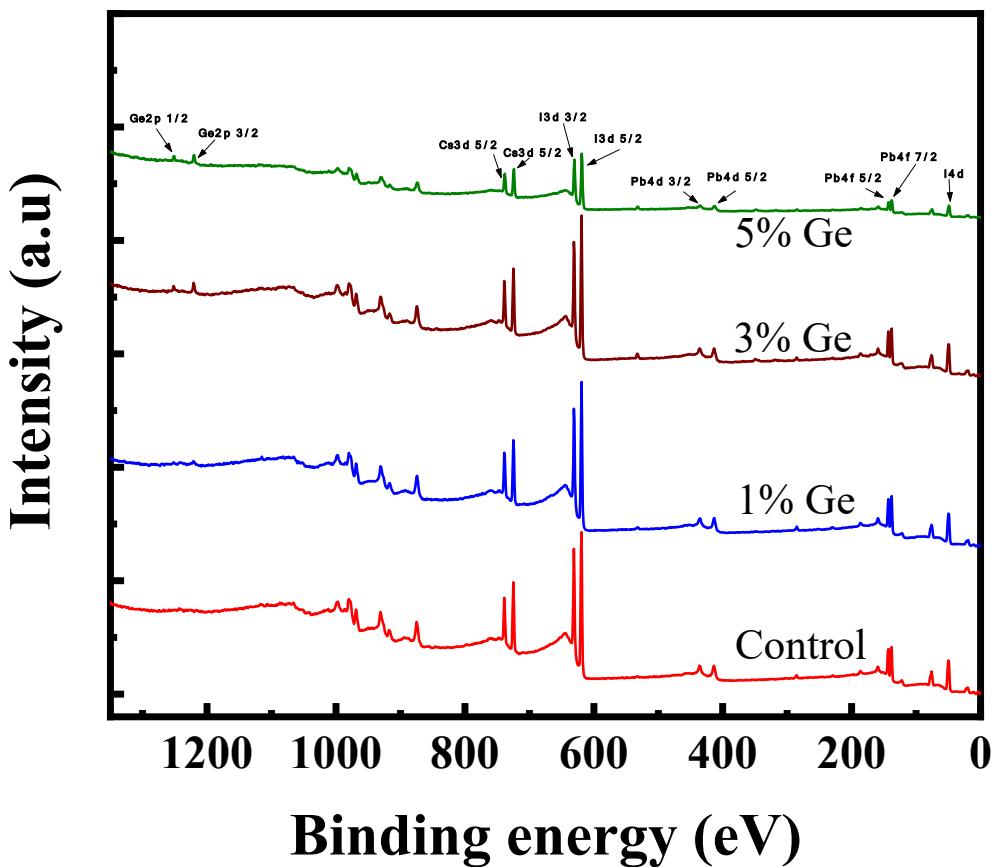
**Figure S3.** XPS profiles of the control and Ge-doped perovskite films.



| Control | 1 % Ge | 3 % Ge | 5 % Ge |
|---|---|---|---|
| Rq=19.255 nm | Rq=11.874 nm | Rq=12.010 nm | Rq=14.439 nm |
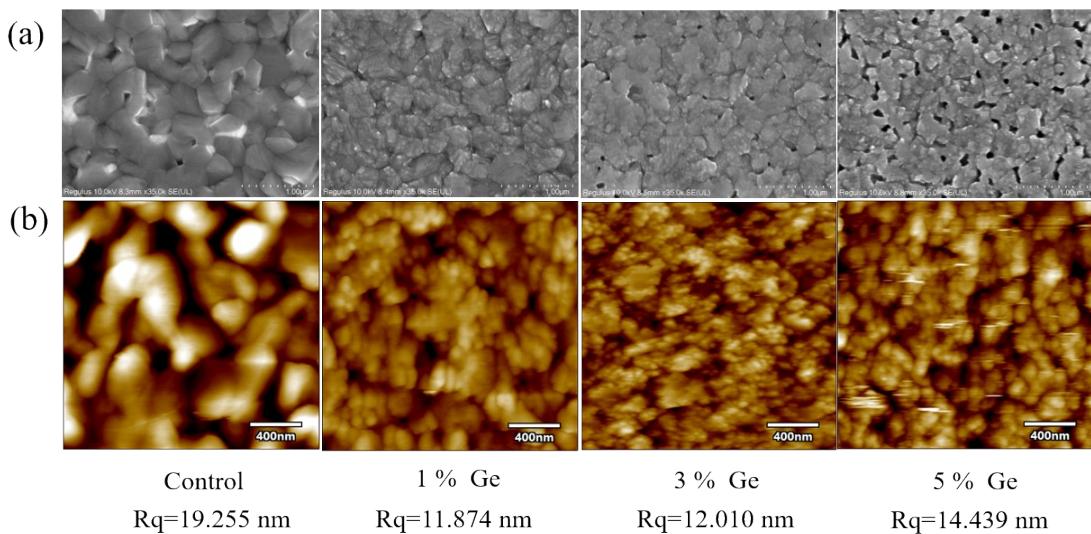
**Figure S4.** SEM (a) and AFM (b) image of perovskite films with and without Ge.
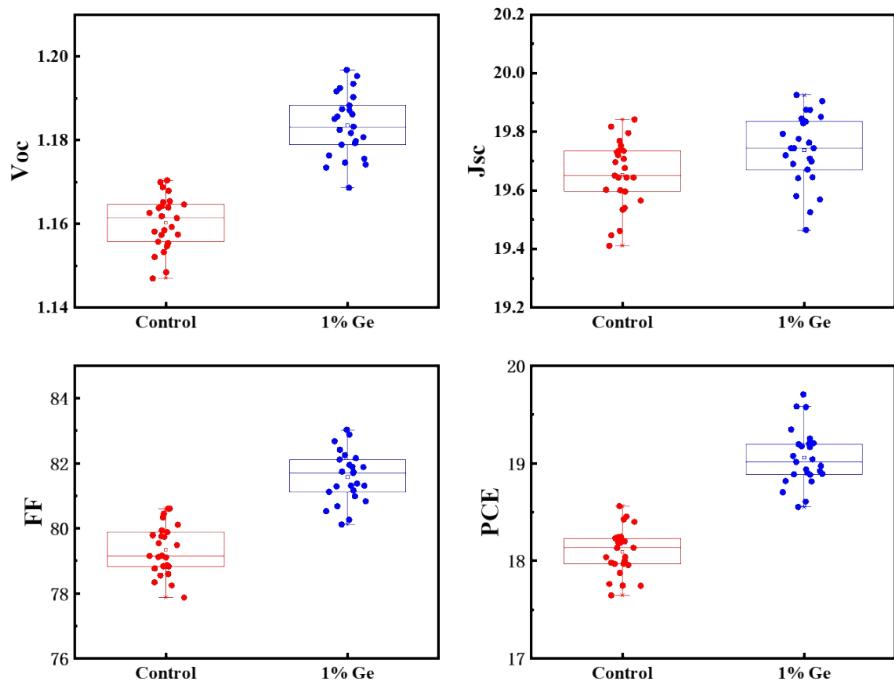
**Figure S5.** Statistical data of photovoltaic performance parameters of the Control and 1% Ge doped devices.
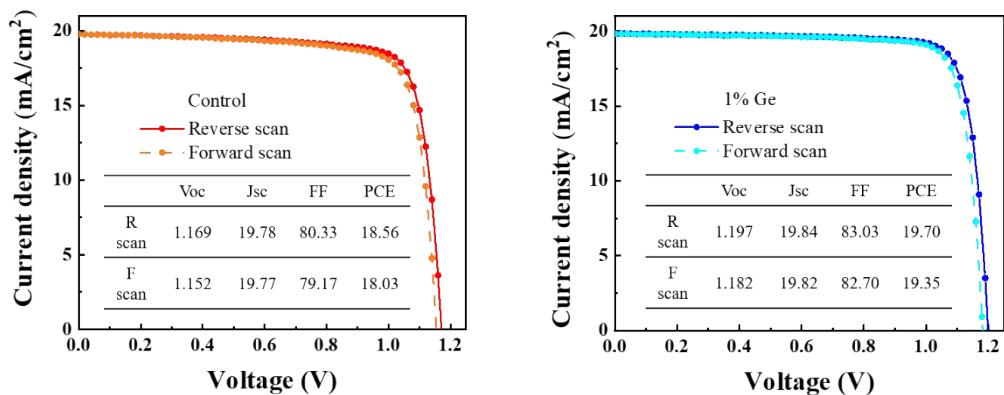


**Figure S6.** J-V curves of a) the Control and b) 1% Ge PSC under reverse and forward scans.
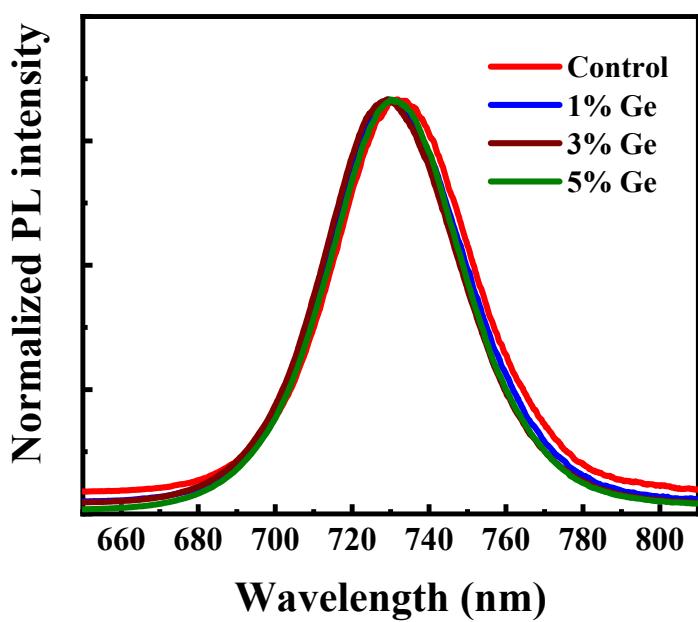
**Figure S7.** Steady-state PL spectra of the Control and Ge-doped perovskite films.



**Figure S8.** Photos of perovskite precursors with varying Ge element ratios.

**Table S1.** Calculation parameters of XRD

| Sample | a=b=c/Å | Refinable parameter U | Refinable parameter V | Refinable parameter W | FWHM (110) | FWHM (220) | Preferred G1 |
|--------|---------|------------------------|------------------------|------------------------|------------|------------|--------------|
| Control | 6.1919(5) | 0.4915 | -0.1505 | 0.0202 | 0.0091 | 0.0140 | 16.4366 |
| 1%Ge | 6.1907(4) | 0.6258 | -0.2002 | 0.0251 | 0.0099 | 0.0151 | 17.1380 |
| 3%Ge | 6.1816(5) | 0.2115 | -0.0100 | 0.0099 | 0.0120 | 0.0213 | 13.3433 |
| 5%Ge | 6.1799(6) | 0.1852 | -0.0069 | 0.0101 | 0.0122 | 0.0207 | 9.9189 |

**Table S2.** The PCE data of 1% Ge devices

| Voc | Jsc | FF | PCE |
|-----|-----|-----|-----|
| 1.193 | 19.87 | 81.16 | 19.24 |
| 1.173 | 19.79 | 80.53 | 18.70 |
| 1.192 | 19.69 | 81.29 | 19.08 |
| 1.181 | 19.57 | 81.88 | 18.92 |
| 1.176 | 19.72 | 81.12 | 18.81 |
| 1.179 | 19.64 | 80.17 | 18.56 |
| 1.190 | 19.71 | 81.70 | 19.16 |
| 1.180 | 19.64 | 82.16 | 19.04 |
| 1.183 | 19.52 | 81.73 | 18.87 |
| 1.174 | 19.84 | 82.25 | 19.15 |
| 1.187 | 19.77 | 81.74 | 19.18 |
| 1.174 | 19.90 | 80.83 | 18.89 |
| 1.188 | 19.87 | 82.88 | 19.57 |
| 1.179 | 19.70 | 80.99 | 18.81 |
| 1.182 | 19.67 | 81.37 | 18.92 |
| 1.182 | 19.58 | 82.12 | 19.00 |
| 1.187 | 19.46 | 81.95 | 18.93 |
| 1.192 | 19.92 | 82.41 | 19.57 |
| 1.175 | 19.85 | 81.31 | 18.97 |
| 1.186 | 19.76 | 81.89 | 19.20 |
| 1.197 | 19.83 | 83.03 | 19.70 |
| 1.168 | 19.68 | 80.23 | 18.44 |
| 1.185 | 19.74 | 82.68 | 19.34 |
| 1.192 | 19.45 | 81.34 | 18.85 |
| 1.183 | 19.72 | 80.68 | 18.82 |

**Table S3.** The fitting parameters of the TRPL spectra

| Sample | $A_1$ | $\tau_1$ | $A_2$ | $\tau_2$ | $\tau$ (ns) |
|--------|-------|----------|-------|----------|-------------|
| Control | 0.64 | 1.6 | 0.37 | 4.26 | 3.21 |
| 1% Ge | 0.19 | 1.95 | 0.56 | 7.09 | 6.65 |