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Realizing high efficiency and air-stable tin-based perovskite solar cells via $GeBr_2$ doping

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Self-doping of tin-based perovskite materials upon exposure to air as a result of tin oxidation from Sn^{2+} to Sn^{4+} increased the charge carrier density of the perovskite material. This increased of charge carrier density result in higher recombination reaction and thus leading to degradation of solar cells over time even in N_2 atmosphere and much so in ambient atmosphere. In this work, we doped the tin-based perovskite material with $GeBr_2$ to control the charge carrier density and improve the air stability of the solar cells. The performance of $GeBr_2$-doped perovskite solar cell achieved a high efficiency of 4.2 % compared to 2.9 % for $FA_{0.75}MA_{0.25}SnI_3$ when measured in air. The increased in efficiency comes from the significant increase of short circuit current due to the reduction of charge carrier concentration. The reduction of trap states upon addition of $GeBr_2$ has also been confirmed by thermally stimulated current measurement. The formation of monolayer GeO_2 reduced the surface oxidation of the perovskite and helped to improve the air stability of the perovskite solar cell.