Challenges and Perspectives of 2D Perovskites for Optoelectronic Applications

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Two-dimensional perovskites (2DPVKs), one member of the family known as Van der Waals materials, attract intensive attention for a wide range of applications in nanoscale due to their outstanding optoelectronic properties, such as robust room temperature light absorption and bright emission [1], strong nonlinear properties [2] and thickness tunable bandgap.[3] In fact, they have been one of the most promising materials studied for advanced photodiodes6, photodetectors [3] and photovoltaic devices.[4,5] In spite of these promising properties, these materials suffer from poor long-term stability, which is a major a critical issue limiting their future commercial applications where operating under ambient conditions for long time periods and with a minimum loss of efficiency is required. Here, we present an environmental stability analysis of $BA_2(MA)_{n-1}PbnI3_{n+1}$ ($BA=C_4H_{12}N^+$, $MA=CH_6N^+$) two-dimensional perovskites with the lowest quantum well thicknesses of n=1 and n=2, after one year of aging under ambient humidity, oxygen content, and light conditions. We have applied X-ray photoemission spectroscopy techniques, as well as optical techniques (micro-photoluminescence, micro-Raman spectroscopy). As expected, 2DPVKs degrade with time, resulting in the removal of organic components and crystal decomposition into PbI_2, Pb oxides and Pb hydroxides. However, we have found significant differences between perovskites degraded under light/dark ambient conditions, not only in their morphology but also in their photoactivity. Both crystal phases that are exposed to ambient light aged into a morphology characteristic by the formation of several pinholes and voids, accompanied by loss of their photoactivity, suggesting the action of photo-promoted oxidative surface degradation processes resulting in considerable loss of iodine atoms. Regarding crystal phases aged in air at dark conditions, these morphologically degrade into microrods maintaining some photoactivity even after one year of aging. We attribute the different behaviour of dark-stored samples to the occurrence of slower surface oxidation processes into Pb salts, which seem to act as a protection barrier against oxidation and hydration degradation processes of the inner parts of the crystals. These results reveal that light is the most critical external factor affecting the 2DPVKs stability under long-term exposition to ambient air, which is relevant for implementation of this material into cheap, stable and high efficiency 2DPVKs commercial devices.

References

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