and $b = 0.04$ for the Mo-based and W-based alloys, respectively[29]. The calculated compositions for ALH1 are $MoS_{0.64}Se_{1.36}$ ($x = 0.68$) and $WS_{0.68}Se_{1.32}$ ($x = 0.66$). Similarly, compositions of $MoS_{1.04}Se_{0.96}$ ($x = 0.48$) and $WS_{1.08}Se_{0.92}$ ($x = 0.46$) were obtained for ALH2. Notably, a complete miscibility of S and Se was achieved for each individual $MoSe_{2(1-x)}S_{2x}$ and $WS_{2(1-x)}Se_{2x}$ domain, as the photoluminescence peak positions are constant within the domains. This is the first demonstration, to our knowledge, of the controlled synthesis of an alloy-based lateral heterostructure composed of multiple junctions.

Figure 4 displays a detailed electrical characterization of single junctions composed of $MoSe_2$ and WSe_2 domains, as well as MoS_2 and WS_2 domains, grown by chemical vapour deposition. For the different samples, we used distinct configurations of contacts allowing us to characterize the individual domains as well as the electrical transport across their interface (Fig. 4a). We find that the WSe_2 and WS_2 domains show a hole-doped-like response when contacted with gold on titanium, which is attributable to the Fermi level pinning close to their valence bands[30] (Fig. 4b, e). By contrast, the $MoSe_2$ and MoS_2 domains display a pronounced, electron-doped-like response given that gold on titanium is expected to pin the Fermi level closer to their conduction bands. Equally important is the fact that the current–voltage characteristics of, for example, the individual $MoSe_2$ and WSe_2 domains, display a nearly linear response (Fig. 4b, inset). This indicates that thermionic emission processes promote passage of the charge carriers across the misaligned bands of the semiconducting channel relative to those of the metallic contacts, or the Schottky barriers. That is, any nonlinearity observed for currents flowing across the $MoSe_2$–WSe_2 junction (Fig. 4c) cannot be attributed to these Schottky barriers. In fact, the current–voltage characteristics across the junction display a typical rectification or diode-like response, indicating the formation of a well-defined p–n junction. Additionally, as expected for a diode, illumination of the junction area leads to pronounced photoinduced currents (Fig. 4c, d). Figure 4e, f indicates that the MoS_2–WS_2 junctions show a similar overall response when compared to the $MoSe_2$–WSe_2 junctions; that is, a clear diode-like response or a well-defined p–n junction, although for this particular sample the current–voltage characteristics display a more pronounced nonlinearity. All domains show ON/OFF current ratios between 10^5 and 10^6 with relatively modest threshold gate voltages, that is inferior $V_{bg} = 10$ V when the I_{ds} as a function of V_{bg} is plotted in a logarithmic scale. This behaviour is comparable to that of samples fabricated from exfoliated single crystals, suggesting similar crystallinity.

The synthetic method developed here follows a different approach from previous methods, and is versatile and scalable. The continuous assembly of planar multi-junctions by a controlled sequential edge-epitaxy may allow for the realization of periodic one-dimensional quantum wells and planar superlattices. The controlled and sequential integration of alloy-based two-dimensional materials with tuned optical properties is another step forward, which could widen the range of possible material combinations for the design of spectral-selective two-dimensional heterogeneous materials for optoelectronic applications.

Online Content Methods, along with any additional Extended Data display items and Source Data, are available in the online version of the paper; references unique to these sections appear only in the online paper.

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Supplementary Information is available in the online version of the paper.

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Author Contributions P.K.S. and H.R.G. conceived the idea and designed the experiments. P.K.S. performed the synthesis, Raman and photoluminescence characterization, and related analysis. S.M. and L.B. performed device fabrication, electrical measurements and analysis. Y.X. conducted aberration-corrected STEM imaging with assistance from P.K.S. and H.R.G. H.R.G. carried out TEM data analysis. P.K.S. and H.R.G. analysed the results and wrote the paper with input from L.B., S.M. and Y.X. All authors discussed the results and commented on the manuscript. H.R.G. supervised the project.

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