the sum of the maximum power outputs $V\mathrm{mp_i}\,J\mathrm{mp_i}$ of the subcells. On the other hand, if the subcells do not all have the same value for $\mathrm{Jmp_i}$, then in their series-connected multijunction combination, some of the subcells must necessarily operate away from their maximum-power points.

The consequences of this last point are especially important when, as is the case for high-quality III-V junctions, the subcells do not leak or quickly break down in reverse bias. The adding of series $J-V$ curves in this case is illustrated graphically in Figure 9.5, which shows $J-V$ curves for a GaInP top subcell, a GaAs bottom subcell, and the two-junction series-connected combination of these two subcells. In this example, the bottom subcell has a higher J_{SC} than the top subcell; the top subcell is slightly shunted, to make the illustration of its behavior at the tandem J_{SC} easier to see. For any given value of current, the tandem voltage satisfies $V_{\mathrm{tandem}} = V_{\mathrm{top}} + V_{\mathrm{bottom}}$, as can be verified by the inspection of the figure. The region of current near the tandem cell $J_{SC} = -14$ mA/cm^2, shown in expanded scale in the bottom panel of the figure, is of special interest. At $J = -13.5$ mA/cm^2, both subcells are in forward bias, with voltages only slightly less than their respective open-circuit voltages (V_{OC}s). As the magnitude of the current density is further increased to -14 mA/cm^2 and beyond, the bottom subcell remains in forward bias near its V_{OC}. At the same time, in contrast, the top subcell voltage becomes rapidly more negative, so that at $J = -14$ mA/cm^2, it has reached a negative bias of about -1 V, equal in magnitude but opposite in sign to the top subcell's forward bias of $+1$ V. At this

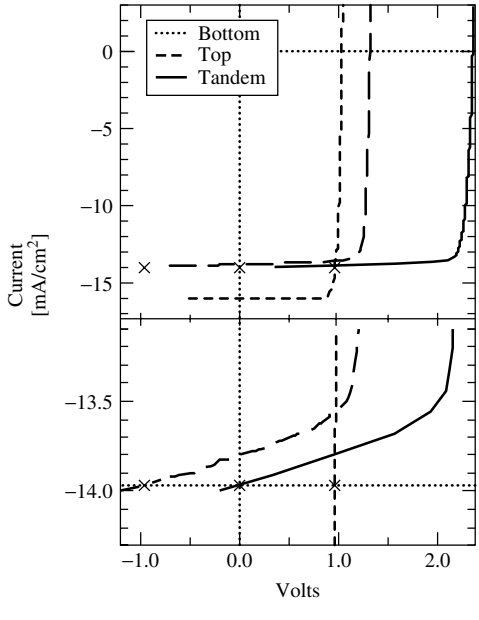

Figure 9.5 Illustration of the addition of $J-V$ curves for two series-connected subcells. The lower panel is an expanded view of the current range in the vicinity of the current-limiting top subcell J_{SC}, showing how the tandem J_{SC} is limited to the lesser of the subcell currents. The $J-V$ of the top subcell in this example is slightly leaky, which makes the addition of the subcell $J-V$ curves near J_{SC} easier to see. The X's mark voltage of the top, bottom, and tandem when the tandem is at short circuit of 14 mA/cm^2