



$$\text{---} V_{diode} \text{---} J * R_{ser} \text{---}$$

$$J = J_{\text{rec}}(V_{\text{diode}}) + J_{RBB}(V_{\text{diode}}) + G_{sh} V_{\text{diode}} - J_{\text{photo}}$$

$$J_{\text{rec}}(V_{\text{diode}}) = J_{01} \left[e^{\frac{qV_{\text{diode}}}{kT}} - 1 \right] + J_{0n} \left[e^{\frac{qV_{\text{diode}}}{nkT}} - 1 \right] + J_{0a} \left[e^{\frac{3qV_{\text{diode}}}{2kT}} - 1 \right] + \dots$$

$$J_{\text{photo}} = J_{\text{ext}} + J_{\text{LC}}$$

$$J_{em} = J_{db} \left[e^{\frac{qV_{\text{diode}}}{kT}} - 1 \right]$$

$$J_i^{db}(\tilde{E}_i^g, T) = \frac{2\pi q(kT)^3}{h^3 c^2} \left[\left(\frac{\tilde{E}_i^g}{kT} \right)^2 + 2 \frac{\tilde{E}_i^g}{kT} + 2 \right] e^{-\tilde{E}_i^g/kT}$$

$$J_{0n}(T) \propto [J_i^{db}(\tilde{E}_i^g, T)]^{1/n}$$