During the last several years, ample experimental observations have documented the existence of steady and transient shear banding in unidirectional shear flow of entangled polymeric fluids. However, continuum level linear stability analyses with the most advanced reptation-based constitutive equations, such as Rolie-Poly, have had limited success in describing this phenomenon; i.e., only transient shear banding has been predicted. Hence, additional molecular level information is required before conclusively determining the existence of flow instability and shear banding in this class of flows. Therefore, we have developed a hi-fidelity coarse-grained dissipative particle dynamics (DPD) simulation methodology for determining the critical conditions for the onset of shear banding as well as developing a mechanistic understanding of this phenomenon in highly entangled polymeric liquids. To this end, large scale DPD simulations in a broad range of entanglement densities and system sizes were performed to check for the existence of transient and steady shear banding. Our detailed flow-microstructure coupling analyses have shown that spatially inhomogeneous entanglement densities give rise to a localized jump in the first normal stress driving an elastic instability which evolves into shear banded structure. This is the first time that a computational study has revealed the connection between the spatially inhomogeneous entanglement density and occurrence of shear banding. Overall, we have achieved not only consistent results with experiments, but also a simple explanation for the mechanism of shear banding via a computationally efficient coarse-grained molecular simulation.