Materials joining is a key enabling technology for manufacturing from microelectronics to large scale equipment, for example shipbuilding. Among the different technologies used for materials joining, fusion and solid state welding are among the most used processes. Such welding processes impose dynamic and complex conditions on the materials, which has limited the full understanding of the physics involved and the materials evolution during the processes and their effect on the joints performance. The understanding of such processes and the associated materials evolution requires a multidisciplinary approach and the use of advanced experimental and modeling tools. In this presentation we will address the use of characterization techniques, including SEM, TEM, APT and Synchrotron-XRD along with materials modeling to uncover the materials evolution during welding of different metallic materials. Finally, due to the intrinsic similarities of several additive manufacturing (AM) and welding technologies, we have used the welding community background to address powder-bed laser fusion AM and some of these results will also be presented.