Nitriding of stainless steel causes a surface zone of expanded austenite, which improves the wear resistance of the stainless steel while preserving the stainless behaviour. During nitriding huge residual stresses are introduced in the treated zone, arising from the volume expansion that accompanies the dissolution of high nitrogen contents in expanded austenite. An intriguing phenomenon during low-temperature nitriding is that the residual stresses evoked by dissolution of nitrogen in the solid state, affect the thermodynamics and the diffusion kinetics of nitrogen dissolution. In the present paper solid mechanics was combined with thermodynamics and diffusion kinetics to simulate the evolution of composition-depth and stress-depth profiles resulting from nitriding. The model takes into account a composition-dependent diffusion coefficient of nitrogen in expanded austenite, short range ordering (trapping) of nitrogen atoms by chromium atoms, and the effect of composition-induced stress on surface concentration and diffusive flux. The effect of plasticity and concentration-dependence of the yield stress was also included.