Public Abstract
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Cryopreservation requires biological material to be stored at temperatures well below the freezing point of water. During the process of cryopreservation, the cooling rate should be carefully chosen to avoid cell damage due to the unbalanced pressure and the solution effect. Cellular thermal analysis that determines the thermodynamics properties of a micro-scale biological material is necessary for a successful cryopreservation procedure.
A micro-scale differential thermal analyzer (μDTA) was previously developed to obtain accurate thermal properties measurements of freezing cells. However, the thermal signal needs to be properly interpreted in terms of how much ice is created. Also, the future cooling profile needed to experimentally control the cooling rate needs to be developed. So a 3D numeric model was built in STAR CCM+ to study the temperature change of the water droplets while being frozen by a thermoelectric module. The heat flux profile for the boundary condition was scaled to accommodate the heat spread effect. The numeric model solutions successfully matched the temperature distribution results from the experiments. By using additional heat flux to accommodate the heat spread effect, the STAR CCM+ model generated relatively accurate results on a smaller geometry within a very short computational time. This is a big improvement compared with other high fidelity computational simulation models used to solve similar problems. After the 3D model was calibrated, the same STAR CCM+ model was used to predict the temperature distribution of different sizes of water droplets during the freezing process. This model allowed us to better understand the temperature distribution of a water droplet when the water droplet was being cooled until frozen. The modeling technique developed in this research will help establish the required cooling rates needed to control ice formation and establish thermodynamic properties of cell freezing solutions.