Mechanical Engineering Doctoral Defense

Thermo-Responsive Materials for Dehumidification in Air Conditioning

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Abstract

Air conditioning is a significant energy consumer in buildings, especially in humid regions where a substantial portion of energy is used to remove moisture rather than cool the air. Traditional dehumidification methods, which cool air to its dew point to condense water vapor, are energy-intensive. This process unnecessarily overcools the air, only to reheat it to the desired temperature.

This research introduces thermoresponsive materials as efficient desiccants to reduce energy demand for dehumidification. A system using lower critical solution temperature (LCST) type ionic liquids (ILs) as dehumidifiers is presented. Through the Flory-Huggins theory of mixtures, interactions between ionic liquids and water are analyzed. LCST ionic liquids demonstrate superior performance, with a coefficient of performance (COP) four times higher than non-thermoresponsive desiccants under similar conditions. The efficacy of ionic liquids as dehumidifiers is assessed based on properties like LCST temperature and enthalpic interaction parameter.

The research also delves into thermoresponsive solid desiccants, particularly polymers, using the Vrentas-Vrentas model. This model offers a more accurate depiction of their behaviors compared to the Flory-Huggins theory by considering elastic energy stored in the polymers. Moisture absorption in thin film polymers is studied under diverse conditions, producing absorption isotherms for various temperatures and humidities. Using temperature-dependent interaction parameters, the behavior of the widely-used thermoresponsive polymer (TRP) PNIPAAm and hypothetical TRPs is investigated. The parameters from the model are used as input to do a finite element analysis of a thermoresponsive dehumidifier. This model demonstrates the complete absorption-desorption cycle under varied conditions such as polymer absorption temperature, relative humidity, and air speed. Results indicate that a TRP with enhanced absorption capacity and an LCST of 50℃ achieves a peak moisture removal efficiency (MRE) of 0.9 at 75% relative humidity which is comparable to other existing thermoresponsive dehumidification systems. This system also uniquely recovers water in liquid form. Preliminary efforts in copolymer synthesis aim to enhance the absorption capacity and elevate the LCST temperature of PNIPAAm by integrating it with other hygroscopic monomers.

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