Thrust Area 4: Solar (Clean Drinking Water)

Clean Drinking Water using Advanced Solar Energy Technologies

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Description: The availability of fresh water is a big problem facing Florida. In many locations, Florida's water is contaminated from leaky underground tanks and agricultural pesticides. Although salt water desalination is possible, conventional systems are too energy intensive. Solar energy can supply the power, and innovative vacuum and humidification/dehumidification desalination systems can provide adequate fresh water for the state's needs. Another goal is to develop photocatalytic disinfection to remove contaminants and integrate these technologies with solar PV for complete water supply systems. Projects include: Natural Vacuum Solar Flash Desalination: Creating vacuum conditions above liquids increase their evaporation rates. This phenomenon can be integrated into a practical continuous desalination process by repeatedly flashing sea water in vacuumed chambers to produce water vapor that will be condensed producing fresh water. Solar PV Assisted Photocatalysis for Air/Water Disinfection: Improving titanium dioxide photocatalysts for purification and disinfection of water and air contaminated with organic, heavy metal and microbiological species, using solar energy. This can be integrated into a practical continuous desalination process by flashing sea water in vacuum chambers to produce water vapor that will be condensed, producing fresh water.

Budget: $326,756
Universities: USF

Progress Summary

Study of thermal desalination process using waste heat

Models were developed to study the thermal desalination process using waste heat, solar thermal energy and geothermal energy. Models were validated by using the experimental data available in the literature. A model was developed for Supercritical Organic Rankine Cycle (SORC) for geothermal application and model of Organic Rankine Cycle (ORC) was developed for solar thermal applications. Further study is needed to find out optimum condition of using thermal desalination system using waste heat.

Photocatalysis for Air/Water Disinfection and decontamination

Photocatalysis is a promising water treatment technology capable of utilizing solar light. However, the construction of an effective photocatalytic disinfection system for water purification is currently limited by the lack of reliable models to aid in the design and testing of these systems. Simplified models have been proposed, but most are inadequate because they rely on traditional disinfection theories which are not applicable to photocatalysis. Therefore, the major goal of this research is to develop a model for photocatalytic disinfection based on fundamental processes which may then be used to design water treatment systems in the state of Florida.

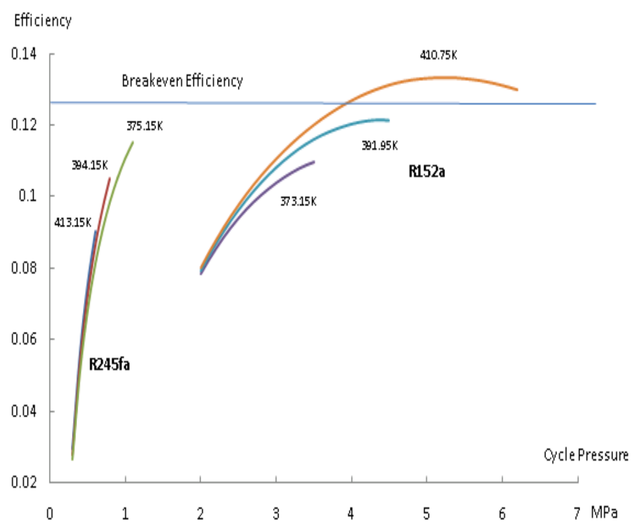
ZnO and ZnO/Fe nanowires have been synthesized on glass substrate by using conventional hydrothermal method. The characterizations of nanowires were investigated by using UV-visible spectrometer, SEM, XRD. The photocatalytic activities were studied for decontamination of dichlorobenzene and decolorization of methyl orange in water. The activities also compared with TiO2 (Degussa P25) film. In decontamination of dichlorobenzene test, ZnO/Fe nanowires showed more activity than P25 under visible light and similar activity with P25 under UV light. In decolorization of methyl orange test, P25 showed more activity than ZnO nanowires.

2011 Annual Report

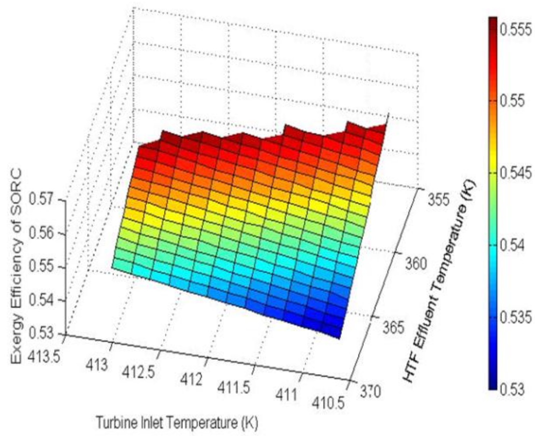
Supercritical Organic Rankine Cycle Driven Reverse Osmosis Desalination:

A novel idea of a Supercritical Organic Rankine Cycle (SORC) driven seawater reverse osmosis (RO) system (SORC-RO) was proposed. The proposed system is studied using two types of low-grade heat sources with a maximum temperature of 423.15K and compared with the conventional Organic Rankine Cycle driven seawater reverse osmosis system (ORC-RO). The results show that a SORC-RO system is particularly suitable for once-through heat source applications such as geothermal and industrial waste heat as energy sources for desalination. The proposed system using R152a as the working fluid operates at 6.048MPa pressure to directly drive a RO desalination system with a 50% recovery without converting the mechanical energy into electricity. The SORC using R152a has a thermal efficiency higher than 13% whatever the heat source is recirculating or once-through, while conventional ORC using R245fa is only suitable for stable, recirculating heat sources. This study is meaningful due to the facts that once-through heat sources including the geothermal and industrial waste heat sources are more commonly seen than the stable heat sources such as solar collectors. And if the heat source is waste heat, the SORC-RO system could make full use of the heat sources and reduce the thermal pollutions to the environment. A comprehensive list of the working fluids candidates for the SORC-RO using low-grade heat sources less than 423.15K is proposed based on the critical pressure and temperature of the fluids.

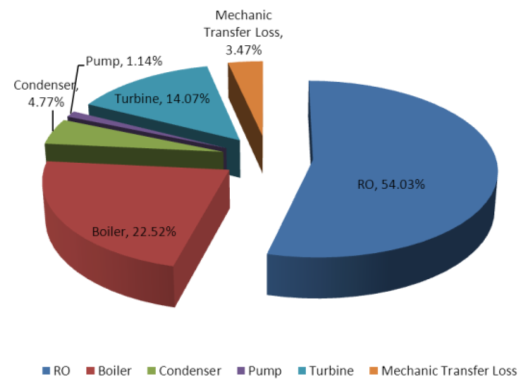
1. Modeled supercritical organic Rankine cycle for geothermal application



Thermal Efficiencies of R152a-based SORC and R245fa-based ORC with once-through heat source (356K-413K)

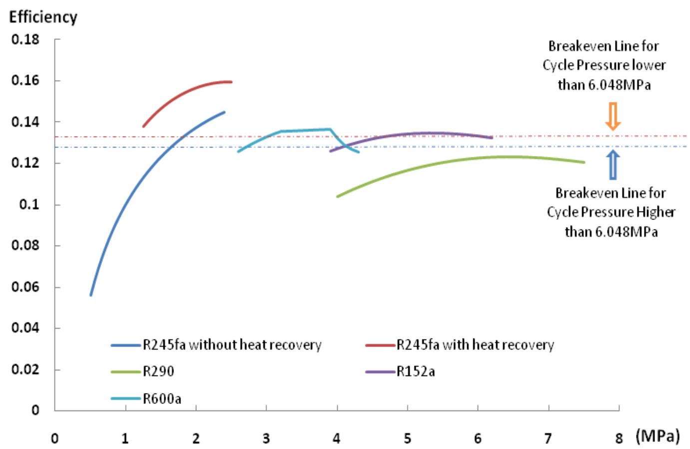


Exergy Efficiencies of SORC using 152a as working fluids



R152a-based SORC-SWRO Exergy destruction breakdown
(P=6.048MPa, HTF effluent 356.15K, Turbine Inlet 410.75K)

2. Modeled organic Rankine cycle for solar thermal application.



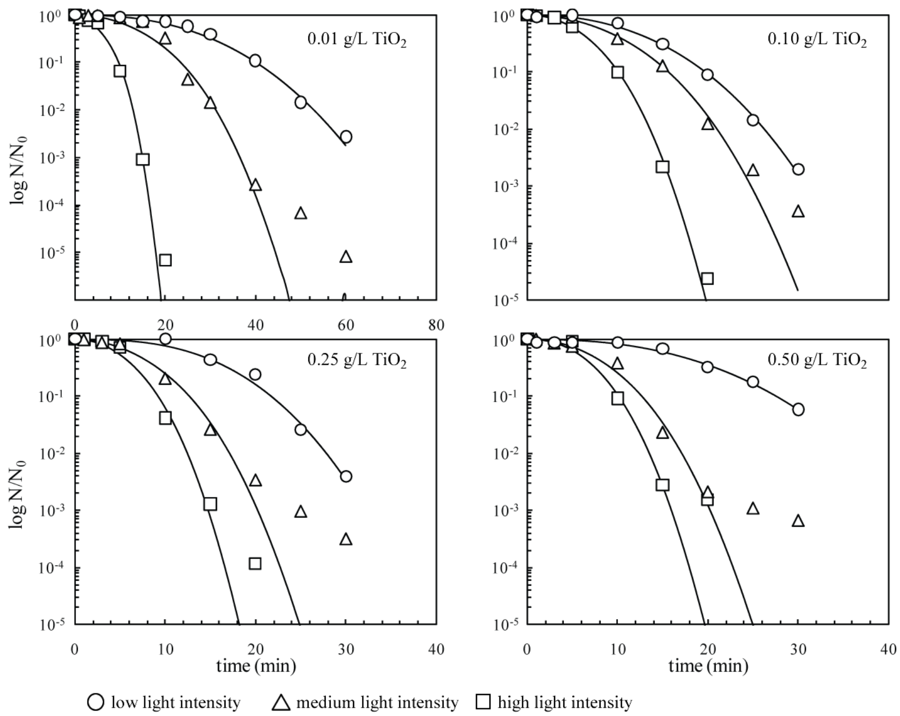
Thermal Efficiencies of R152a-based SORC and R245fa-based ORC with solar thermal heat sources

Photocatalytic Disinfection

A comprehensive mechanistic model for photocatalytic disinfection was developed to optimize the design of the photocatalytic disinfection process. A major benefit of the mechanistic model is the significant cost reduction associated with performing fewer preliminary experiments to determine the effectiveness of various combinations of catalyst concentration and light intensity for a given organism. The model simulates the effect of light intensity and catalyst concentration on the disinfection process and shows good agreement with the experimental data for stable colloidal suspensions, that is, suspensions in which rapid aggregation of cells and TiO_2 do not occur.

The following summarizes the main findings of the study:

- Most efficient disinfection achieved at high light intensity and lowest catalyst concentration (0.01 g/L)
- Model predicted disinfection rate constants (k_{dis}) within 2 orders of magnitude, with less variation at lower TiO_2 concentration (within an order of magnitude)
- Disinfection has log-linear relationship with light intensity within the range in our research
- Small variation in disinfection efficiency for 0.10-0.50 g L^{-1}, especially at low and medium light intensity
- Generation rate per mass of catalyst reduces exponentially with catalyst concentration
- Colloidal interactions play a significant role in the disinfection process
- TiO_2 appears to be strongly and specifically adsorbed to cells
- Model shows disinfection does not vary significantly from pH 6-8



Photocatalytic Decontamination Results:

Photocatalytic Decontamination Results:

1. UV-vis absorbance spectrum

The ZnO nanowires show larger enhancement absorption under visible light compare to ZnO nanoparticles. The ZnO/Fe nanowires show more absorption not only under visible light but also under UV light.

2. Structural studies

Scanning electron microscopy (SEM) image (Fig.1) showed the diameter of ZnO nanowires were 50-100nm with hexagonal structure. The X-ray diffraction (XRD) patterns showed a dominate diffraction peak for (002), indicating a high degree of orientation with the c-axis vertical to the substrate surface. The XRD results imply that the samples were highly crystallized type.

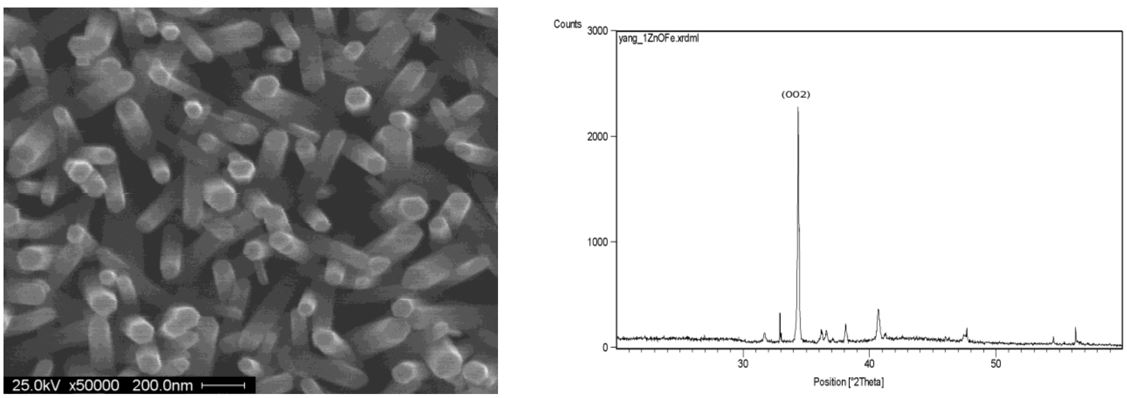


Figure 1: SEM image (left) and XRD pattern (right)

3. Photocatalysis studies

Under visible light studies (Fig.2), for dichlorobenzene (DCB) decontamination, ZnO nanowires show a similar photoactivity with P25. However, ZnO/Fe shows a better photoactivity than P25. For methyl orange (MO) decolorization, P25 was better activity than ZnO nanowires.

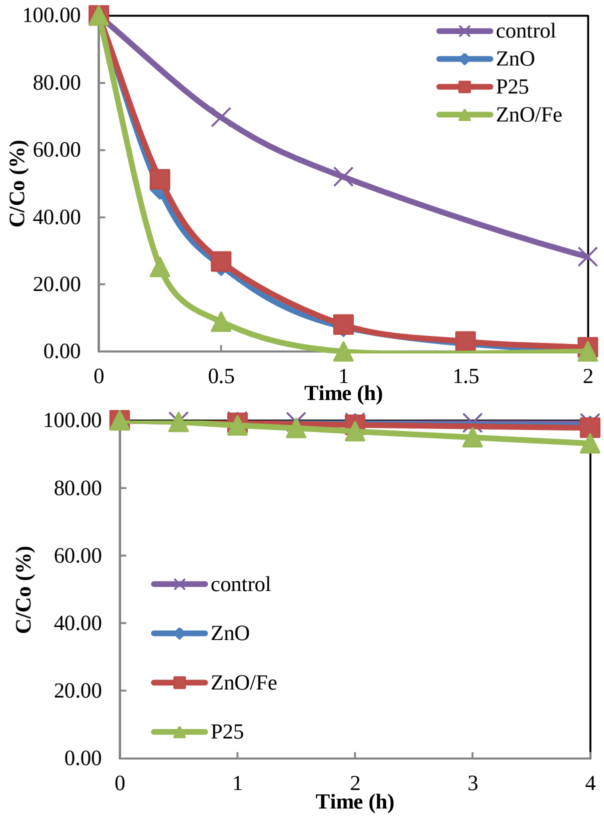


Figure 2: Photocatalysis under visible light test (Left: DCB test. Right: MO test)

Under UV light studies (Fig.3), for DCB decontamination, ZnO nanowires show a less photoactivity than P25 but ZnO/Fe shows a similar photoactivity with P25. For MO decolorization, P25 shows better activity.

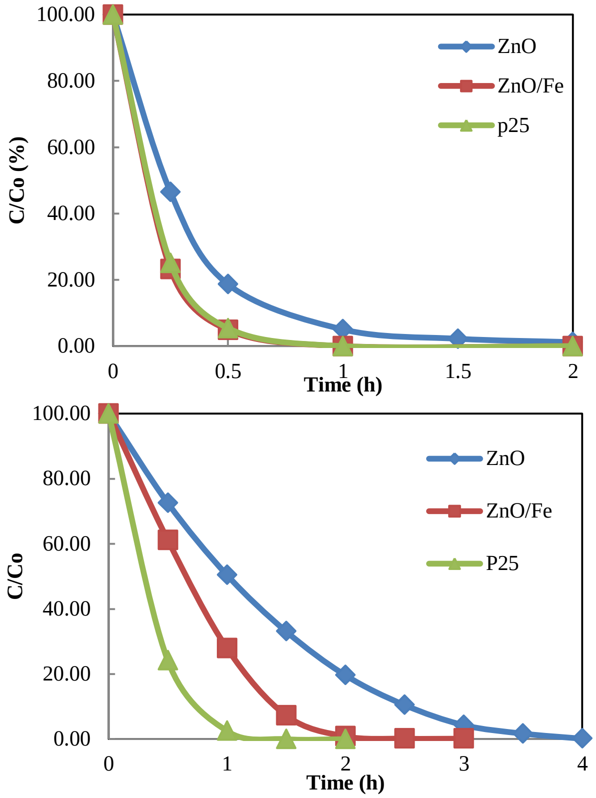


Figure 3: Photocatalysis under UV light (Left: DCB test. Right: MO test)

Compare ZnO nanowires with P25 photoactivity in DCB test. ZnO nanowires showed similar activity with P25 under visible and less activity than P25 under UV light. Thus, ZnO nanowires have less activity under total UV-vis light. However, when compare ZnO/Fe with P25, the activity of ZnO/Fe shows better activity than P25 under visible light and similar activity with P25 under UV light. Therefore, ZnO/Fe nanowires should have more activity than same amount of P25 under total UV-vis light or sun light for decontamination of DCB. For MO decolorization, P25 shows better activity in both under visible light and UV light test.