Reducing Greenhouse Gas Emissions: A Grand Challenge with Materials Solutions

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It is a well-accepted fact that our current fossil-fuel-dominated energy-generation system is not sustainable because the raw materials, mainly coal, oil, and gas, take millions of years to produce and we burn them in years. Furthermore, concerns about greenhouse gas (GHG) emissions pose another grand challenge for fossil energy, and the future should rely on the renewable. However, in the foreseeable future, it is unrealistic to think we can shut down all the coal-based power plants and connect our grid with lots of wind farms and solar panels. In addition to the high costs, there are many other difficulties associated with applications of renewable energies.

Around the globe, besides investing in R&D on “green” energy technologies, governments, industries, and academia are all trying to find ways to improve efficiencies and reduce GHG emissions to meet the challenges of energy and environment. For instance, my colleague Carl Irwin at West Virginia University recently introduced the concept of “Transtech,” which refers to energy technologies that significantly reduce GHG emissions, improve industrial competitiveness, and are available for implementation sooner rather than later. They are not necessarily completely “GreenTech” or “CleanTech,” but are essential parts of the transition to an advanced, sustainable, lower carbon economy of the future.

In this *JOM* topic, there are four papers that focus on the interests of the newly formed TMS Energy Committee. The authors are from three continents and four countries—Brazil, Switzerland, Ukraine, and the United States—to provide a global perspective on energy-saving and GHG-reduction efforts.

Most current research on solvent-based CO₂ capture and sequestration (CCS) is focused on ammine-based solvents. However, studies at the National Energy Technology Laboratory (NETL) have shown that this will cost an additional 85% for power generation with CCS compared to no capture. This means the price of electricity would be doubled if the ammine-based CCS were utilized today. Neale Neelameggham and Brian Davis propose an innovative concept for one of the lowest-cost CO₂ capture methods from power plants and other facilities. Their thermo-chemical calculations point out that the thermodynamic energy required for creating CO₂ hydroxyl-carbonate ions from using the resultant carbonate/bicarbonate solutions are less than 12% of the fuel energy needed in coal-based power generation, which is much lower than the current ammine-based method.

Luis Venancio from Federal University of Para Brazil and his colleagues show the results of ten years’ efforts from the cement industry in Brazil to recycle and develop useful applications for two major solid residues from aluminum smelting: red mud and spent pot lining. They demonstrate that this approach, although engineering-

intensive, can reduce CO₂ emission and save huge amounts of wasted energy in transport and processing when compared with dedicated recycling or neutralizing processes.

Peter G. Loutzenhiser et al. illustrate the use of concentrated solar radiation as the energy source of a high-temperature process heat to carbothermally reduce silica to silicon, which is an important raw material for semiconductor and solar industries. They demonstrate that reducing the total pressure in the carbothermal reduction of SiO₂ causes a shift in equilibrium that forecasts the formation of Si(g) at lower temperatures. Using a solar reactor, they can reduce SiO₂ to Si at $\sim 3 \times 10^{-3}$ bar, and when the reducing agent is derived from a biomass source, the solar-driven carbothermal process is CO₂ neutral. This is very interesting exploratory research that provides an alternative application of solar energy.

Another paper focusing on the application of concentrated solar energy is from Yuri Lytvynenko from Ukraine. The author presents a new method of aluminothermic reduction of aluminum and titanium with solar radiation as the energy input. The experiments prove the fundamental possibility of this process and propose how to improve the weakness of current method.

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