Synchrotron X-ray Investigations of Co-carbide Nanoparticles, a New Permanent Magnet Material for Green Energy Technology

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Permanent magnets are important components in numerous technologies, including green energy technologies such as electric motors and wind turbine systems. Most materials used to make permanent magnets contain rare-earth elements. Rare-earth permanent magnets can have maximum energy products (BH_{max}), the figure of merit for permanent magnets, that exceed the best permanent magnets without rare-earth elements by roughly a factor of four. However, rare-earth elements are costly and introduce volatility into the supply chain of the end product in which the magnets are used. Thus, much recent effort has been devoted to the development of new rare-earth free permanent magnets, including Co-carbide nanoparticles, which have recently been shown to have large BH_{max} and coercivity in the as synthesized state. Through optimization of the properties of Co-carbide such as phase and morphology, there is potential to create a rare-earth free permanent magnet competitive with those that contain rare-earths. To guide this effort, we have undertaken basic studies of atomic structure, magnetic properties, and reaction kinetics of Co-carbide nanoparticles using synchrotron x-ray techniques. The nanoparticles are coated in a carbon shell as a result of the wet chemical polyol process used for synthesis. This leads to challenges in performing soft x-ray absorption spectroscopy (XAS) on the nanoparticles. Our efforts to overcome these challenges and measure reliable XAS of Co-carbide nanoparticles will be discussed. The results of our XAS and x-ray magnetic circular dichroism measurements elucidate the local electronic and magnetic structure of the Co and C ions and provide insight into the nature of the magnetic properties of Co-carbide nanoparticles. In addition, we have applied quick x-ray absorption fine structure (QEXAFS) spectroscopy to examine the kinetics of the polyol reaction by which these nanoparticles are synthesized.