

A Selective-Photochemistry Approach to Nanostructure Synthesis

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Synthesis of nanostructures, such as single and multiple quantum-well structures, photonic crystals, and artificial crystals, are at the core of nanotechnology. Traditionally, these nanostructures have been synthesized through MBE and CVD. More recently, chemical synthesis, including colloidal synthesis and ionic self-assembly, is attracting a lot of attention. In the paper, we propose selective photochemistry to synthesize nanostructures for electronic, photonic, and magnetic applications.

bond (unless resonant absorption occurs). On the other hand, a broad-spectrum photon source can activate several precursors with different bond dissociation energy simultaneously, and the selectivity of this photochemical approach is lost. Moreover, for this technology to bear a broad impact on nanostructure synthesis, a large number of wavelengths must be available for the wide range of bond dissociation energy in various precursors.

The excimer lamp is a monochromatic photon source,^{2,3} which emits at a single wavelength under suitable conditions.² Fig. 1 compares some of the wavelengths with dissociation energy of various chemical bonds. Fig. 2 illustrates the monochromaticity of a 172 nm Xe excimer lamp we have developed, where only a single peak is present at ~172 nm. We have also developed excimer lamps with other wavelengths. Fig. 3 shows a 126 nm Ar excimer lamp.

This selective-photochemistry approach can

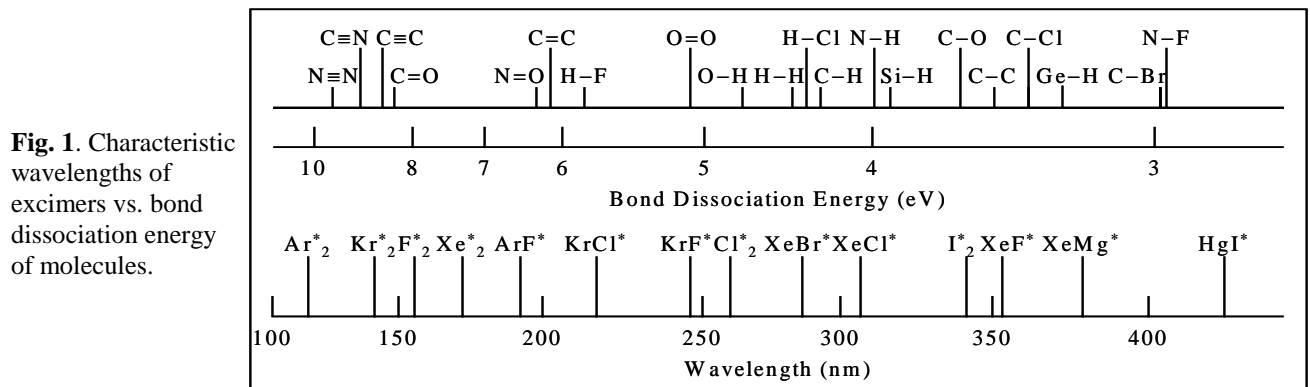
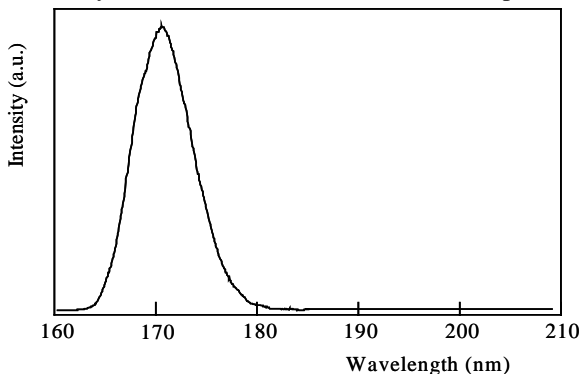


Fig. 1 is a collection of dissociation energies of various chemical bonds contained in precursors for material synthesis.¹ In a reactor where several precursors



with different bond dissociation energy exist, selective activation of a chemical bond requires a monochromatic light source. For example, if the N-H (~3.9 eV) and C-H



(~4.3 eV) bonds are present, a monochromatic photon source of 4.0 eV breaks the N-H bond, but not the C-H

produce nanostructures of metals, semiconductors, and dielectrics. Let's take SiC-Si nanostructures from SiH₄ and CH₄ as an example. When the two precursors are introduced separately and each has its own lamp for selective activation, we can choose to deposit either Si, C, or SiC by turning on the right lamp or lamps. Fig. 4 shows one switching sequence for the lamps and the resultant structure of alternating Si and SiC. By choosing the switching sequence, we can put these materials in an arbitrary order. For example, we can produce a multilayer structure that repeats the basic sequence of Si-SiC-C, i.e. a (-Si-SiC-C)_n structure. Examples of synthesis of other nanostructures will also be presented.

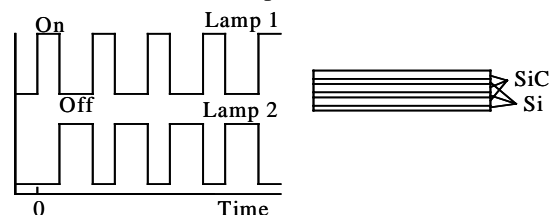


Fig. 4. A switching sequence of two lamps and the resultant structure.

CVD synthesis of such multilayer structures is through mechanically switching the precursors. In our approach, no gas switching is needed and multilayer structures are synthesized by electrically switching the lamps. Electrical switching is inherently quicker than gas switching. In practical terms, quicker switching means a more abrupt interface. Moreover, multilayer structures with layer thickness down to a very few monolayers can be achieved with quicker switching. Multilayer nanostructures with arbitrary periodicity and composition, therefore, can be produced for device applications.

¹ I.W. Boyd and J.Y. Zhang, Nucl. Instr. Meth. Phys. Res. B121, 349 (1997).

² B. Eliasson and U. Kogelschatz, Appl. Phys. B46, 299 (1988).

³ B. Eliasson and U. Kogelschatz, IEEE Trans. Plasma Sci. 19, 309 (1991).