Carbon states in the anodic alumina films formed in electrolytes containing formic acid

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The carbon obtained during the aluminum anodic oxidation in formic acid with ammonium heptamolybdate or oxalic acid additives and embedded in the oxide matrix exists as luminescent and biocompatible carbon nanoparticles with a diameter of 20–25 nm that can be extracted from the initial films. The films have a wide blue fluorescence in the wavelength range of 350–700 nm with a maximum at ca. 460 nm. The fluorescence decay is non-exponential and has an average lifetime of 1.54 and 1.59 ns for ammonium heptamolybdate and oxalic acid, respectively. The fluorescence spectrum is a superposition of several decay components. Besides oxygen vacancies, these are hydroxyl, carbonyl, and carboxylate groups. Carbon nanoparticle solutions also exhibit an excitation-dependent emission behavior at 280–450 nm excitation wavelengths with average lifetimes of 7.25–8.04 ns, depending on the composition of the initial film. Since the carbon nanoparticles were obtained by the dissolution of anodic alumina films without additional treatment, such as ultrasonication, we can conclude that carbon is obtained during the anodic oxidation of formate ions and is incorporated in the alumina in the form of amorphous carbon that can be extracted from the initial films. The alumina matrix significantly quenches the fluorescence of the embedded carbon.

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