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DNA assisted fragmentation of nickel nanoparticle clusters and their spectral properties

Natarajan Prabakaran, Periakaruppan Athappan *

Department of Inorganic Chemistry, Madurai Kamaraj University, Madurai-625 021, India

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ABSTRACT

Nickel nanoparticle (NiNP) clusters in the range of 60–70 nm size on interaction with herring-sperm DNA (B-DNA) form a self-assembled duplex helix DNA structure with fragmented NiNPs as small as 5–15 nm, as evident from atomic force microscopic studies. Scanning electron microscope (SEM) and transmission electron microscope (TEM) images also corroborate the findings. The properties of these self-assembled NiNPs–DNA structures have been further investigated by UV–visible, emission and circular dichroic (CD) spectral studies.

1. Introduction

Research on nano scale metal structures is of considerable interest as their electrical, magnetic, and catalytic properties are different from the macro scale metal containing materials [1]. Self-assembly, the spontaneous association of components into organized structures, using non-covalent interactions is the chief method that nature uses to achieve complex structures. Of the natural self-assembling molecules, DNA is arguably the most remarkable one. DNA is emerging as an attractive tool for nanoscience and it is a highly promising template for organizing nanomaterials in a programmable way [2,3]. Over the past decade, researchers have developed DNA nanoparticle conjugates, which consist of a nanoparticle core (typically 2–250 nm in size) and many oligonucleotide strands covalently attached to their surface [4–6], exhibit several unusual properties that make them attractive for both diagnostic and therapeutic applications [7–10]. Recent success in using DNA as a molecular glue to direct gold nanoparticles (AuNPs) into the periodic 3D crystalline lattices, further demonstrates the power of DNA as building blocks for 3D nanoengineering [11,12]. Furthermore, there has been recently reported the use of DNA to control the assembly of AuNPs into tubular architectures, the incorporation of AuNPs into a planar DNA tile array by conjugating each AuNPs with a single DNA strand, which may lead to interesting properties for nanoelectronics and photonics applications [13]. To date, scientists have applied *in situ* methods to form DNA-templated materials with metals such as silver [14], platinum [15], palladium [16], gold [13,17], cobalt [18], nickel [1,19,20] and copper [21,22] and semiconductors such as cadmium sulfide [23] and iron oxide [24]. In some cases the metal cations change the conformation of DNA [25]. Metal nanoparticles capped with lysine [26], aniline [27] and trimethyl(mercaptoundecyl)ammonium [28] and thiocholine modified with CdS nanoparticles have been already reported on predefined DNA templates. Wei et al. have reported the electrostatic assembly of CTAB capped positively charged silver nanoparticles on λ-DNA template with variable time and pH [29]. In the past few years we had been interested in the study of transition metal complexes that bind DNA non-covalently [30,31]. Therefore we wanted to step in to the nature of interaction of these curiously studied metal nano particles with DNA. Even though *in situ* preparation of self-assembled DNA–metal nano particles including nickel are addressed by many researchers [13–24], we report for the first time, the use of DNA molecule to fragment the pre-formed NiNPs clusters of size 60–70 nm into 5–15 nm and to form a well organized NiNPs embedded tubular DNA structure, which was characterized by AFM, TEM and UV–vis, emission and circular dichroic (CD) spectral studies.

2. Materials and methods

2.1. Materials

Nickel(II) nitrate hexahydrate, hydrazine hydrate (99%), thiophenol, oleic acid, Tris(hydroxymethyl)aminomethane hydrochloride (Tris–HCl), sodium chloride, sodium hydroxide, toluene (Merck), herring sperm DNA and Cetyltrimethylammonium bromide (CTAB) (Sisco

* Corresponding author. Tel.: +91 452 245 8410; fax: +91 452 2459181.
E-mail address: athappan_pr@rediffmail.com (P. Athappan).

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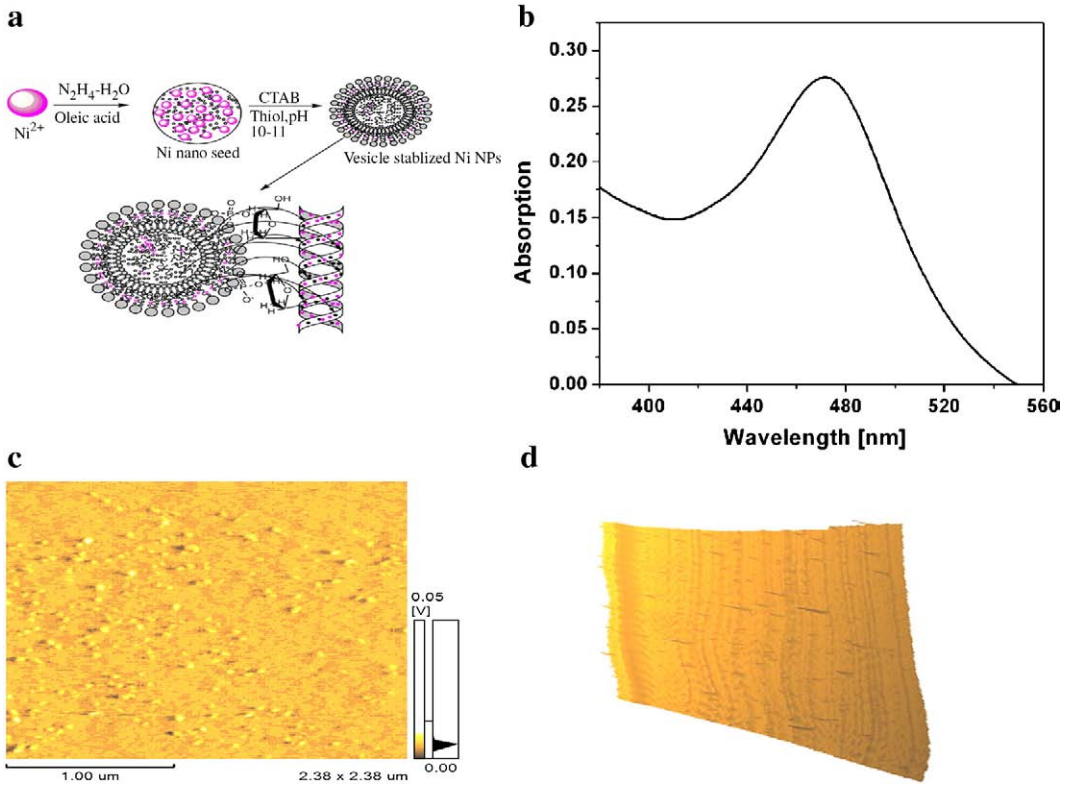

Fig. 1. (a) Schematic diagram of Ni Nanoparticles assembled DNA; (b) UV–vis surface plasmon spectrum of NiNPs in toluene as dispersing solvent; (c) The AFM 2D image of NiNPs; and (d) The 3D image of NiNPs.

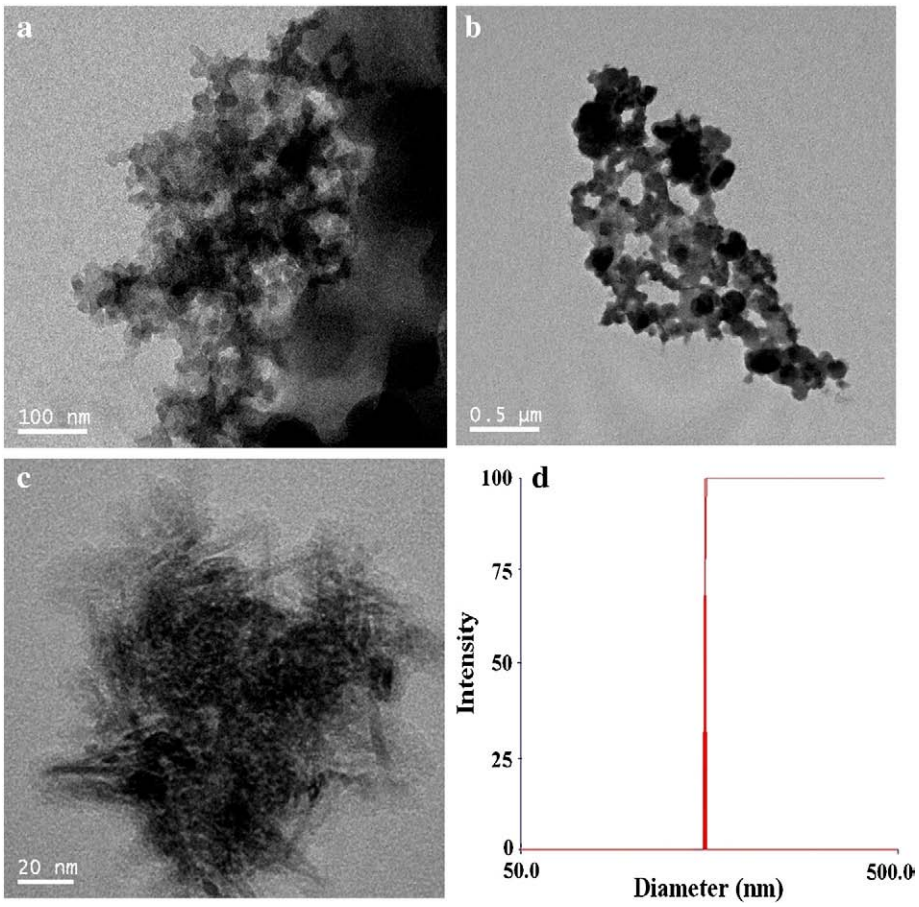

Fig. 2. TEM images of NiNP clusters (a) and (b), their high-resolution TEM (HRTEM) (c) and particle size distribution measured by particle size analyzer (X-axis in logarithmic scale) (d).