Quasi-Epitaxial Growth of Ni Nanoshells on Au Nanorods

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Introduction

Nanorod assemblies can be constructed with various orientations, offering potential applications in waveguiding and construction of electronic devices

- **Gold nanorod alignment has been achieved by stretching in a polymer matrix**
- **Applying an external electric field**
- **Au rod strings made by bio-recognition-driven assembly**
- **Selective binding of chemical functionalities**
- **Assembly on modified carbon nanotubes**

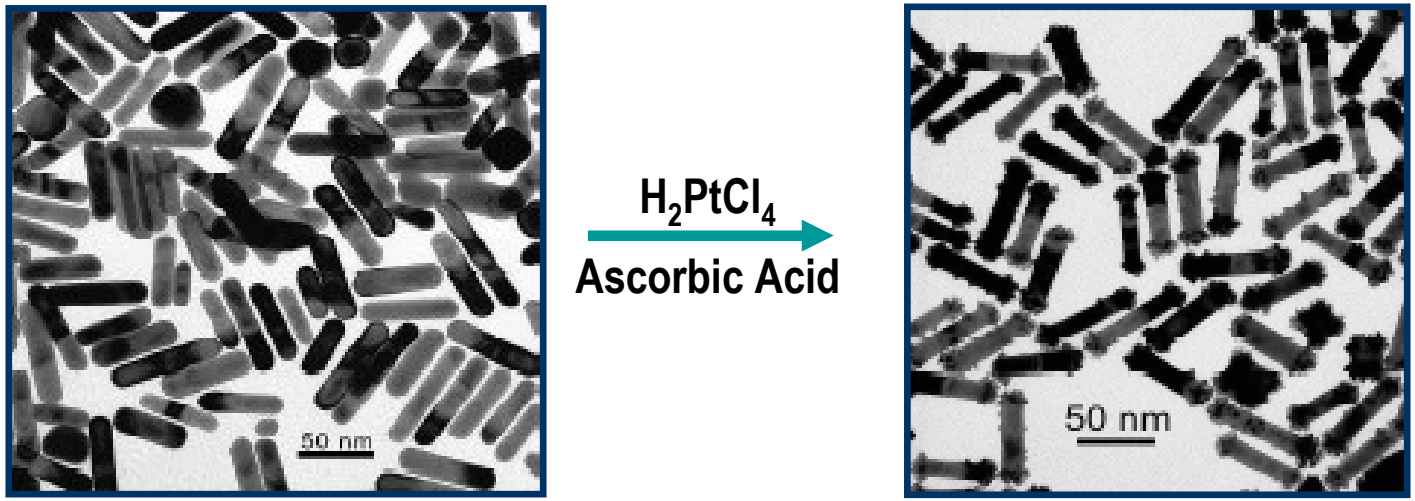
Synthetic Strategy

I. Synthesis of Au Nanorod

II. Pt coated Au Nanorod

III. Ni shell on Au Nanorod

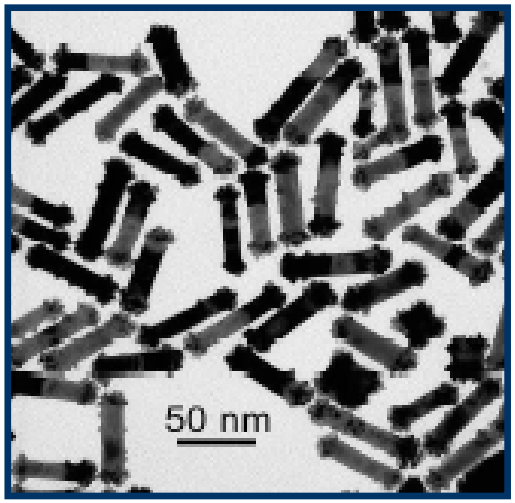
II.Pt coated Au Nanorod



Au Nanorod **Au Nanorod@Pt**

Liz-Marzan *et al.* J. Mater. Chem. **2006**, *16*, 3946
Liz-Marzan *et al.* J. Phys. Chem.C **2007,** *111,* 6183

III.Ni Shell on Au Nanorod



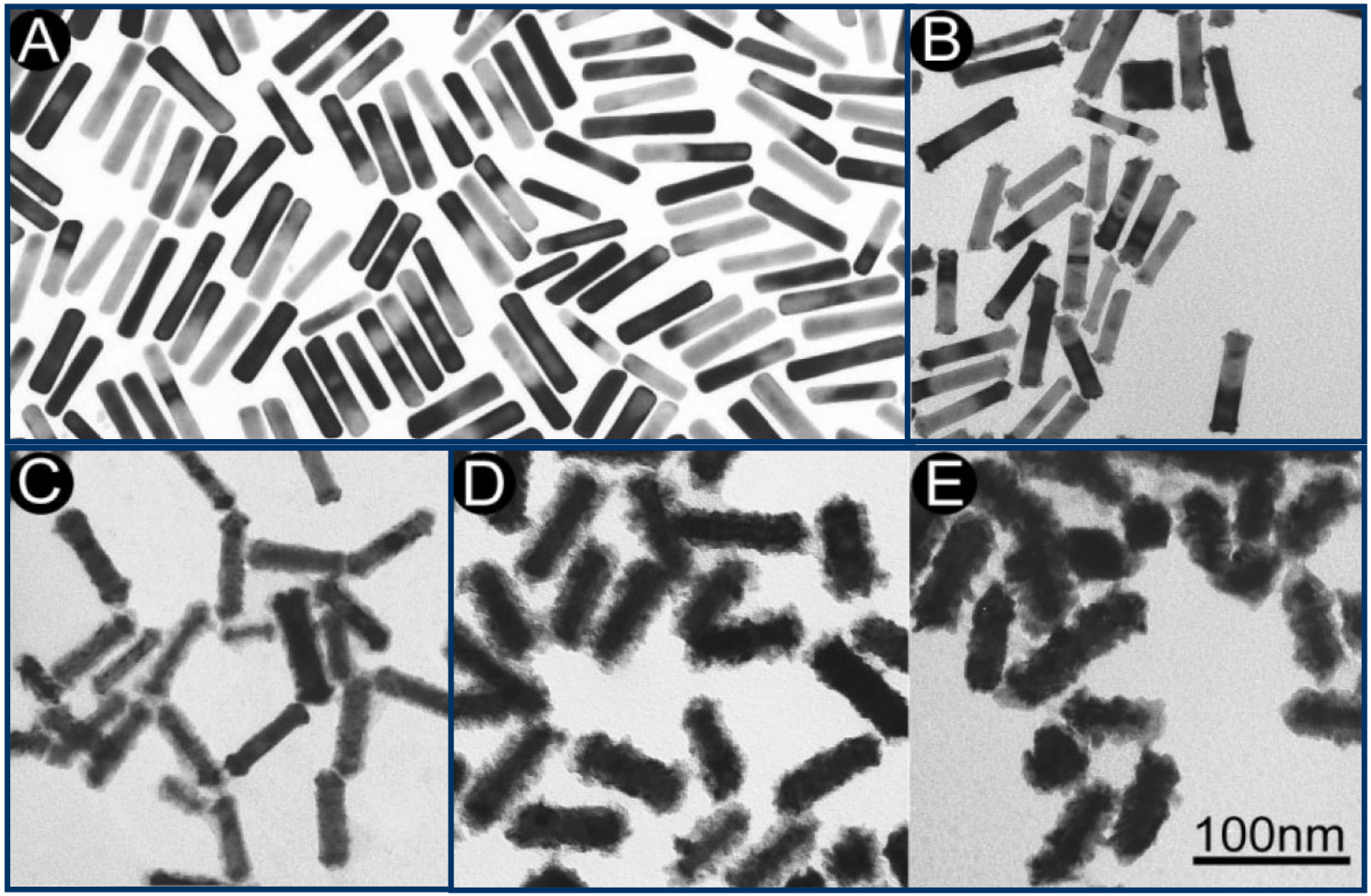
Au Nanorod@Pt

0.25M $NiCl_2$

2.5 M Hydrazine

Au Nanorod@Ni

Characterization



TEM images showing gold nanorods before (A) and after tip-coating with platinum (B) and full coating with Ni (C,D,E) for Ni/Au molar ratios of 1, 5, and 10, respectively.

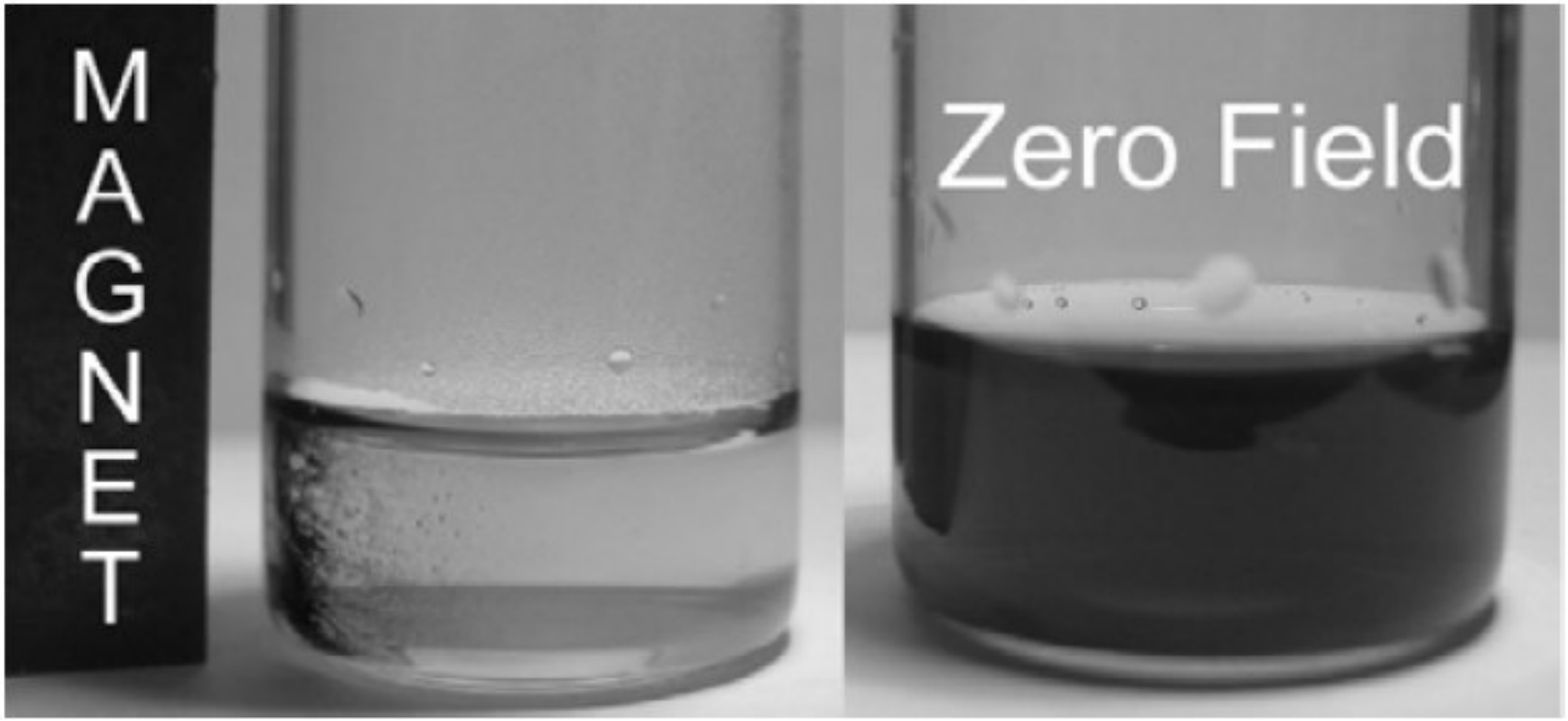
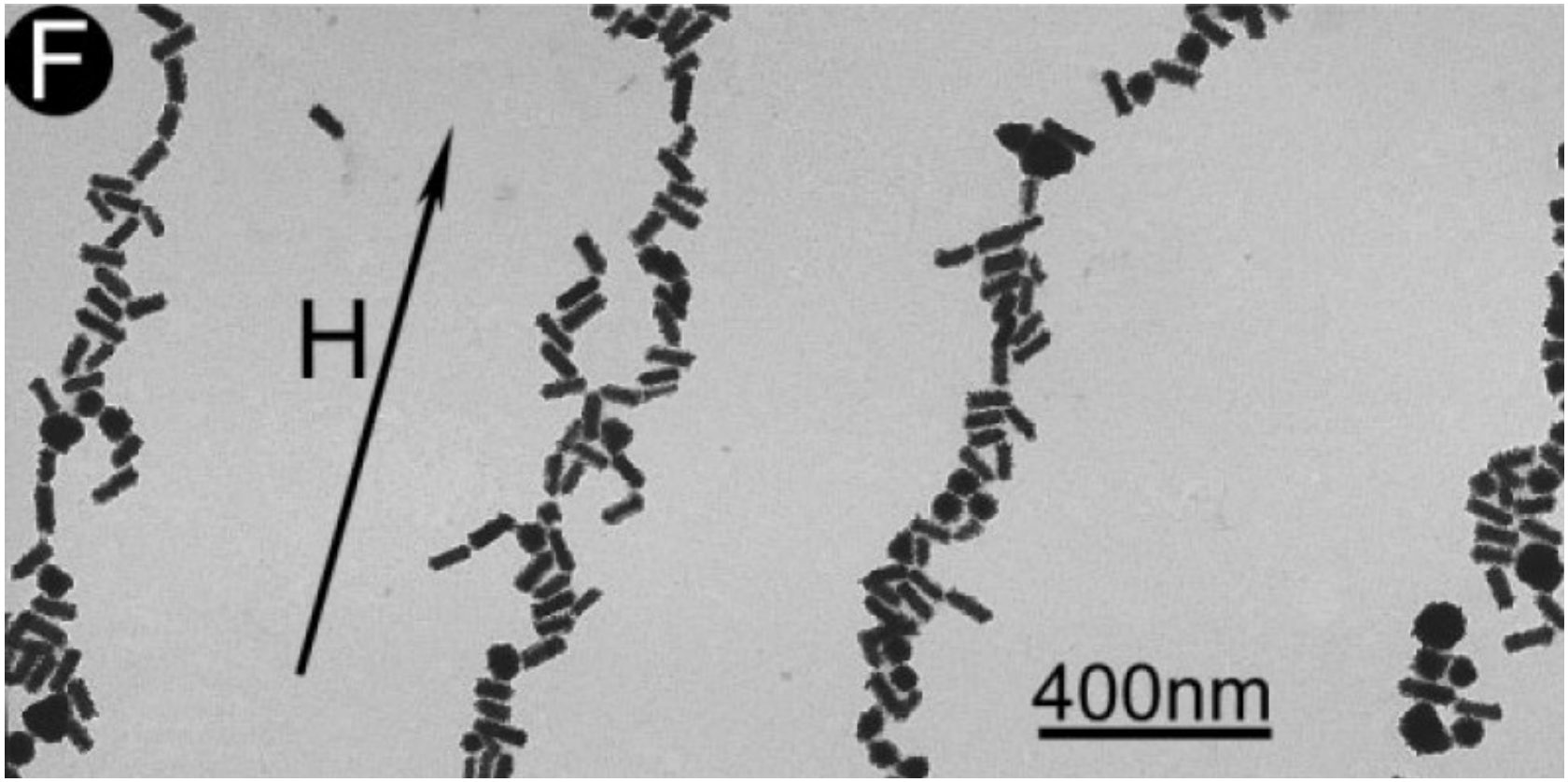
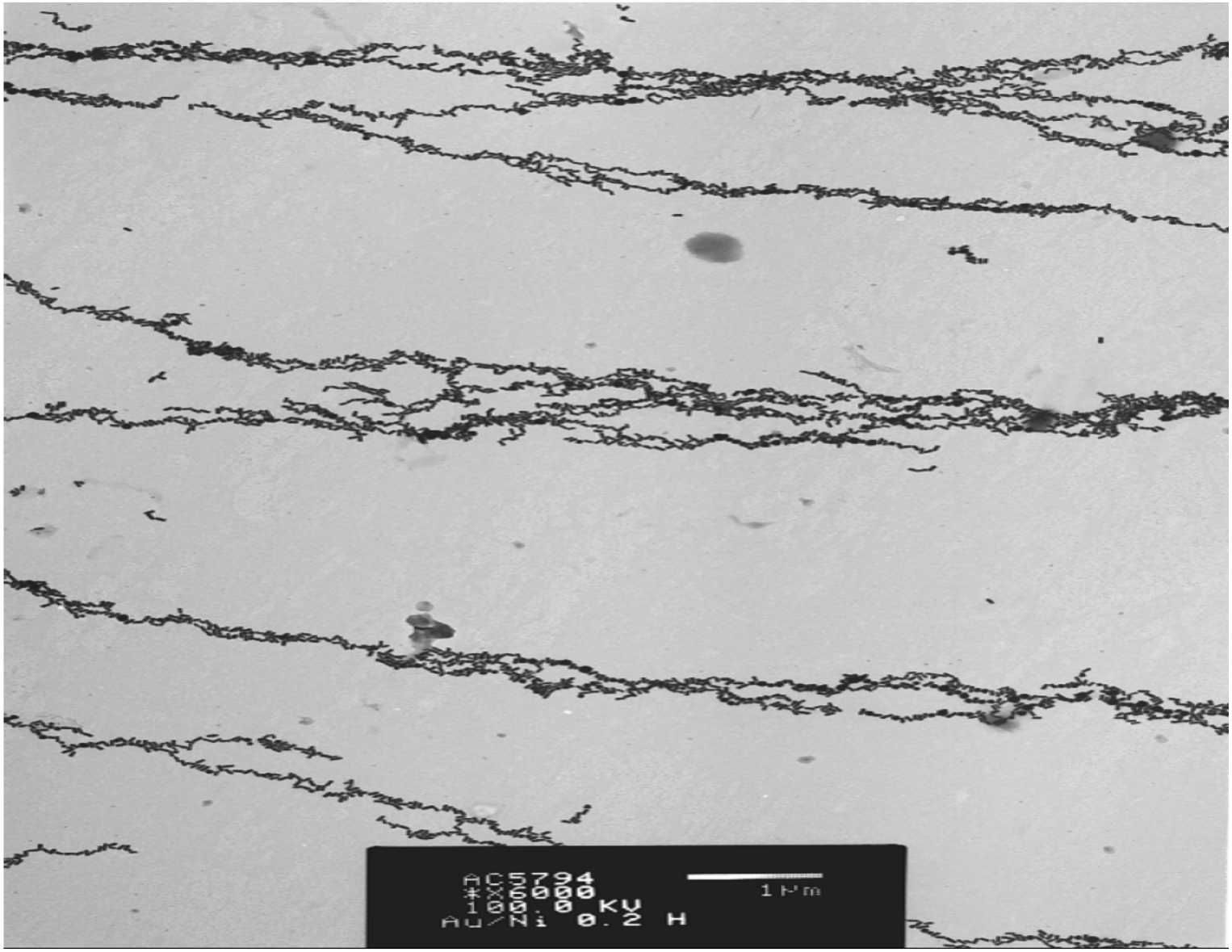


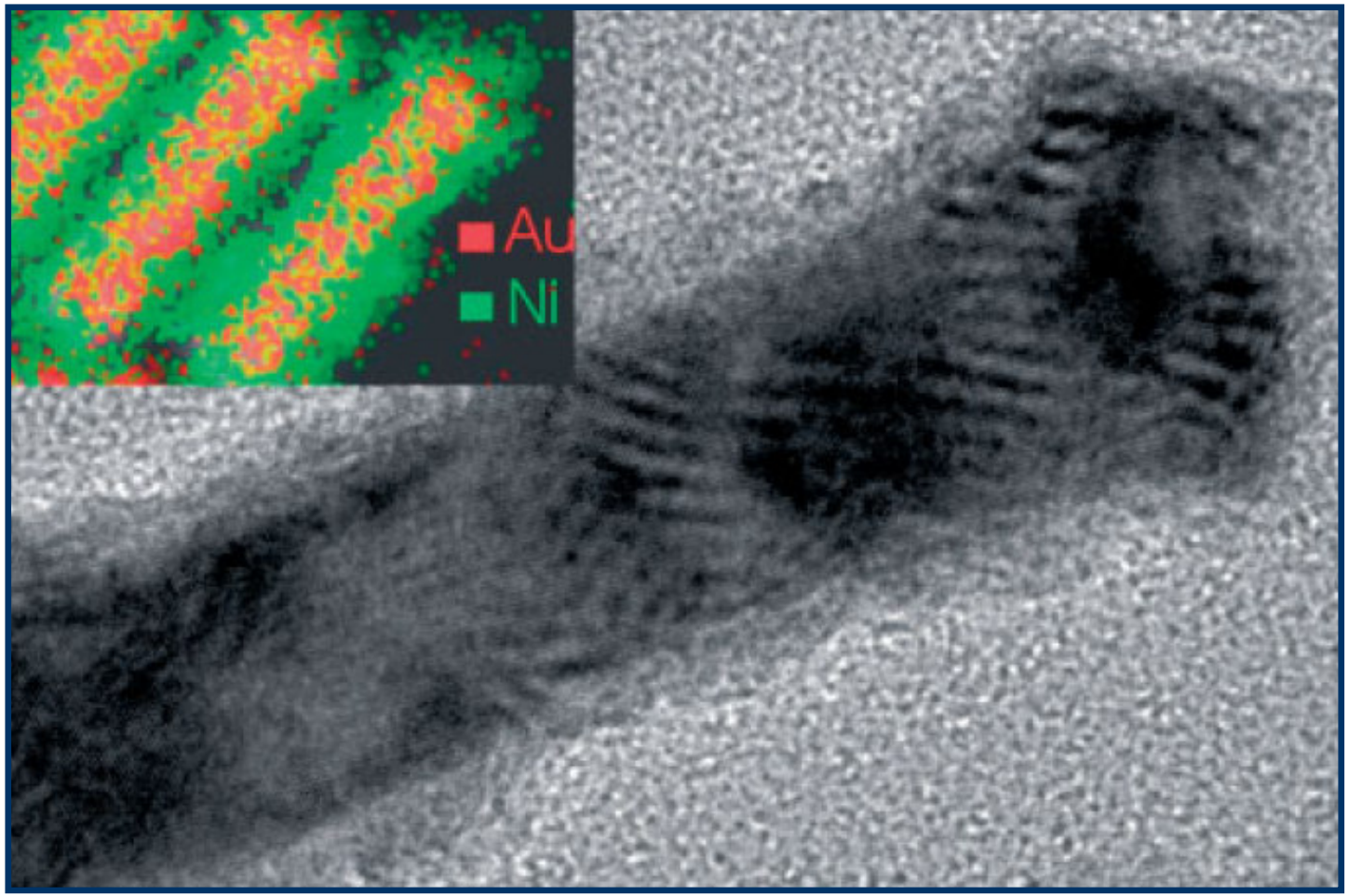
Image of prepared gold nanorods with nickel ([Ni] = 0.5 mM) in zero field environment, and after 20 min standing next to a handheld magnet (0.1 T)



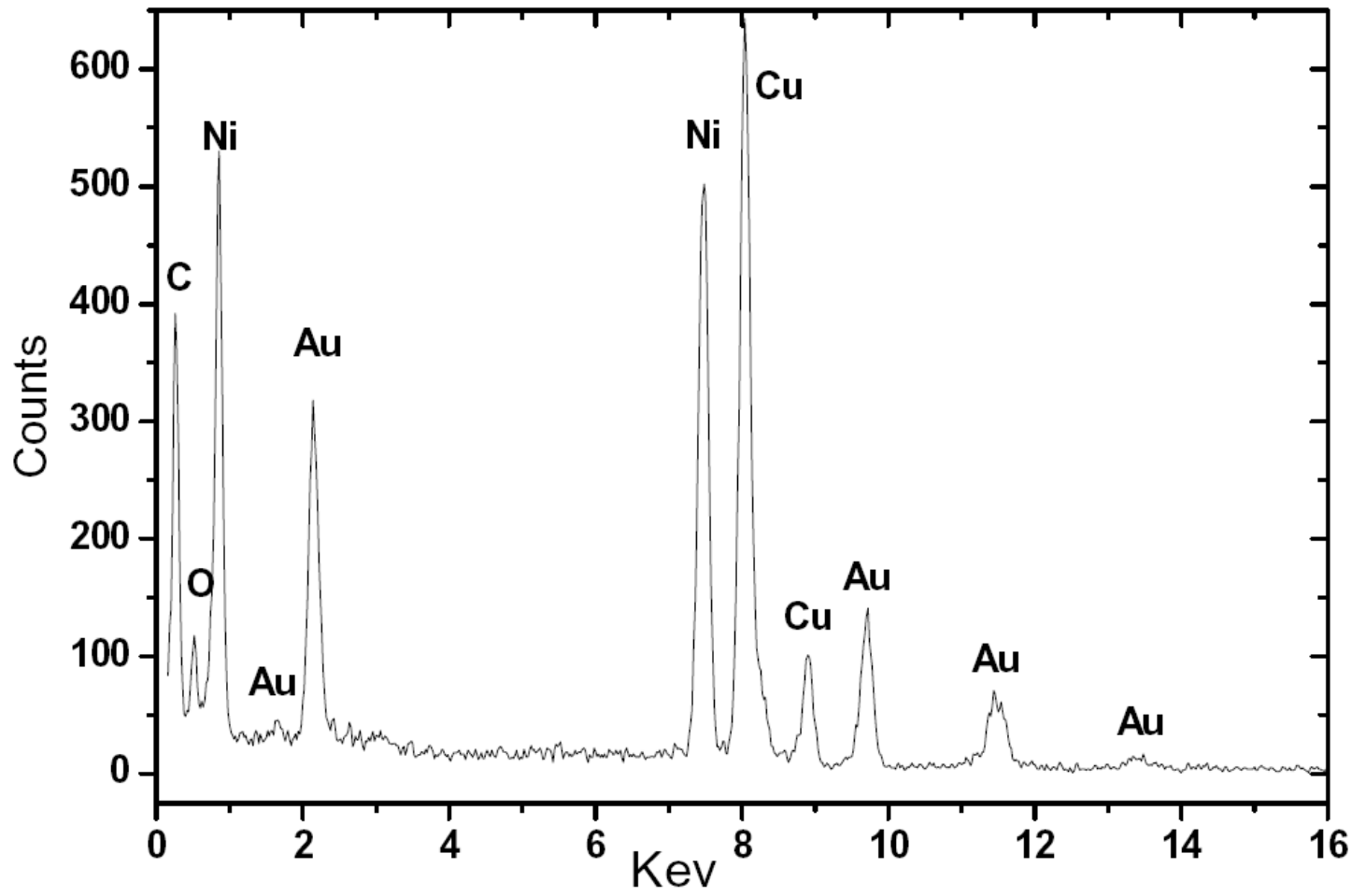
(F) Nickel-coated gold nanorods (Ni/Au ratio as in D), dried on the TEM grid under an external magnetic field (0.2 T)



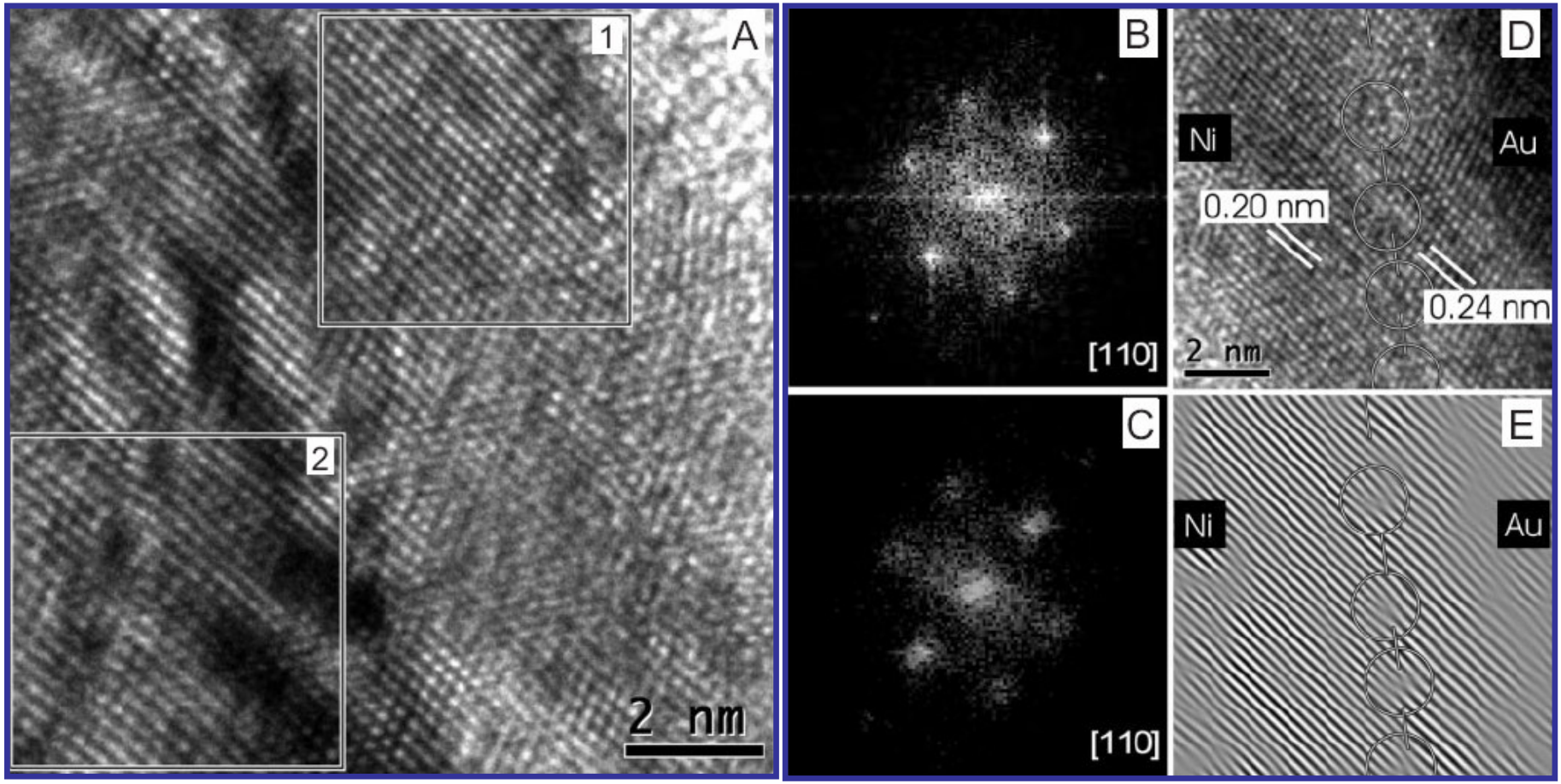
Low magnification TEM micrograph showing long range alignment in Nicoated gold nanorods dried under an external magnetic field (0.2 T).



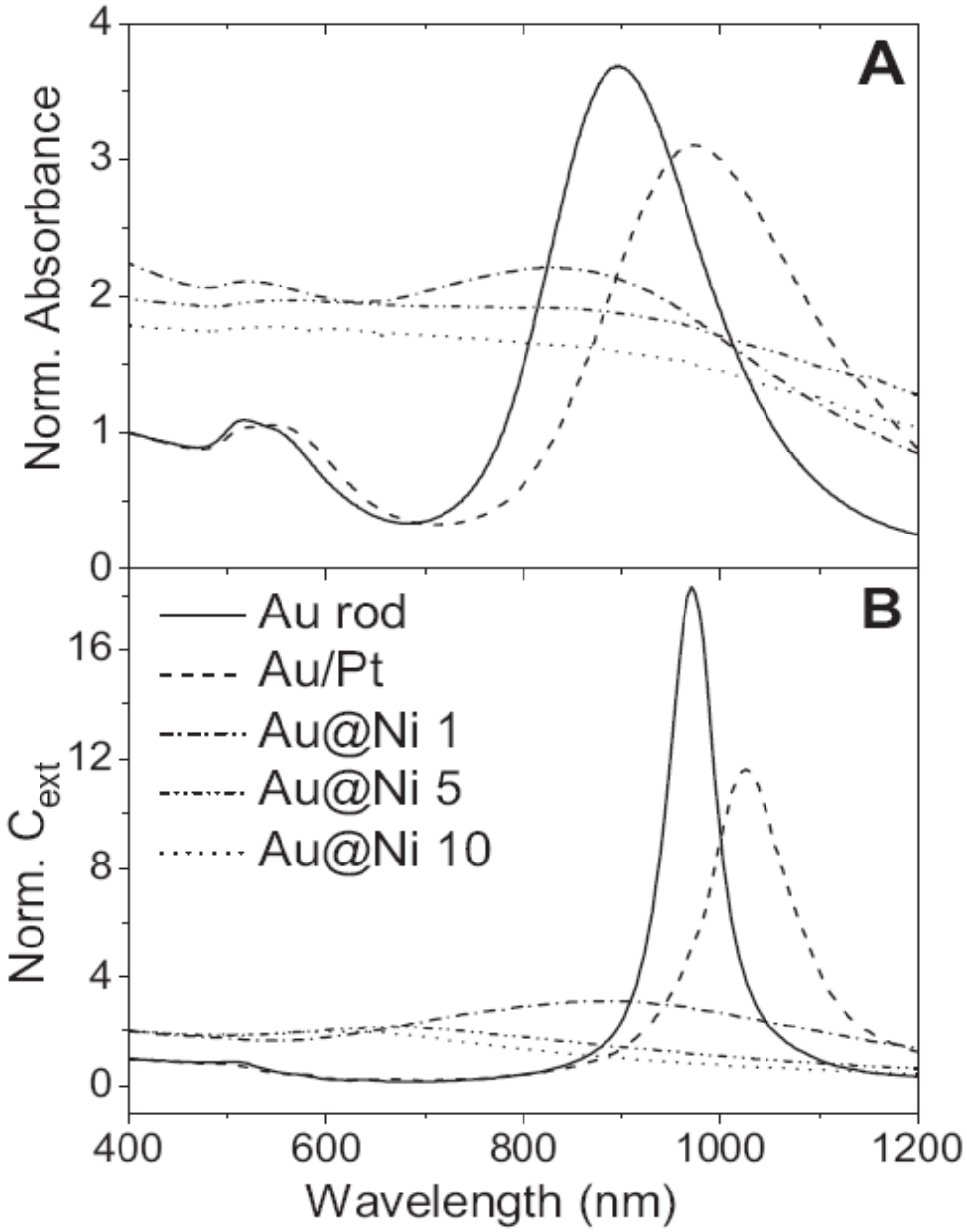
HRTEM image evidencing the perfect core–shell morphology of the obtained nanorods. The inset is an RGB image obtained by STEM–XEDS analysis of Au@Ni nanorods, showing the relative distribution of the elements (Au = red; Ni = green).



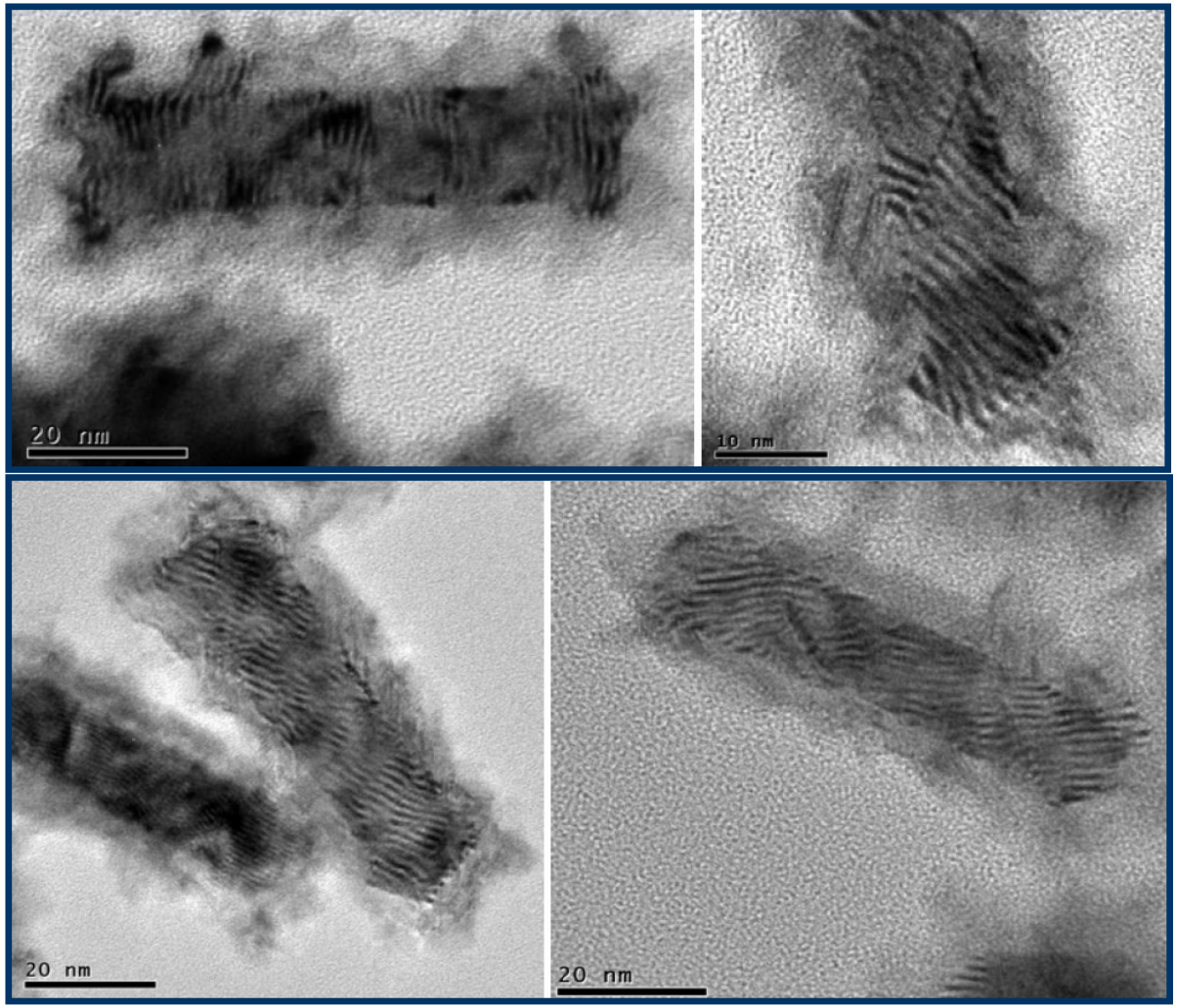
EDS spectra of gold nanorods coated with nickel shell. Clearly visible signal coming from gold and nickel. Absence of platinum in the spectra could be related with very low amount of platinum (Au:Pt=20 [mol]) during reaction

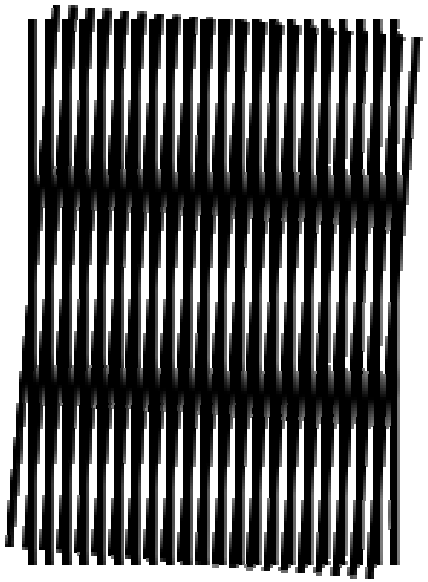


HRTEM analysis of a small area around the Au/Ni boundary in a coated nanorod. The FFT diagrams from areas 1 and 2 in (A) are identified as Ni (B) and Au (C) fcc lattices, respectively, in the (110) zone axis. For Au, the spots are thicker because of the satellite spots from the Ni lattice above and below it. In (D), the interplanar distance was measured for Ni and Au, while (E) shows the corresponding FFT filtered image clearly revealing dislocations at the edge, marked with circles

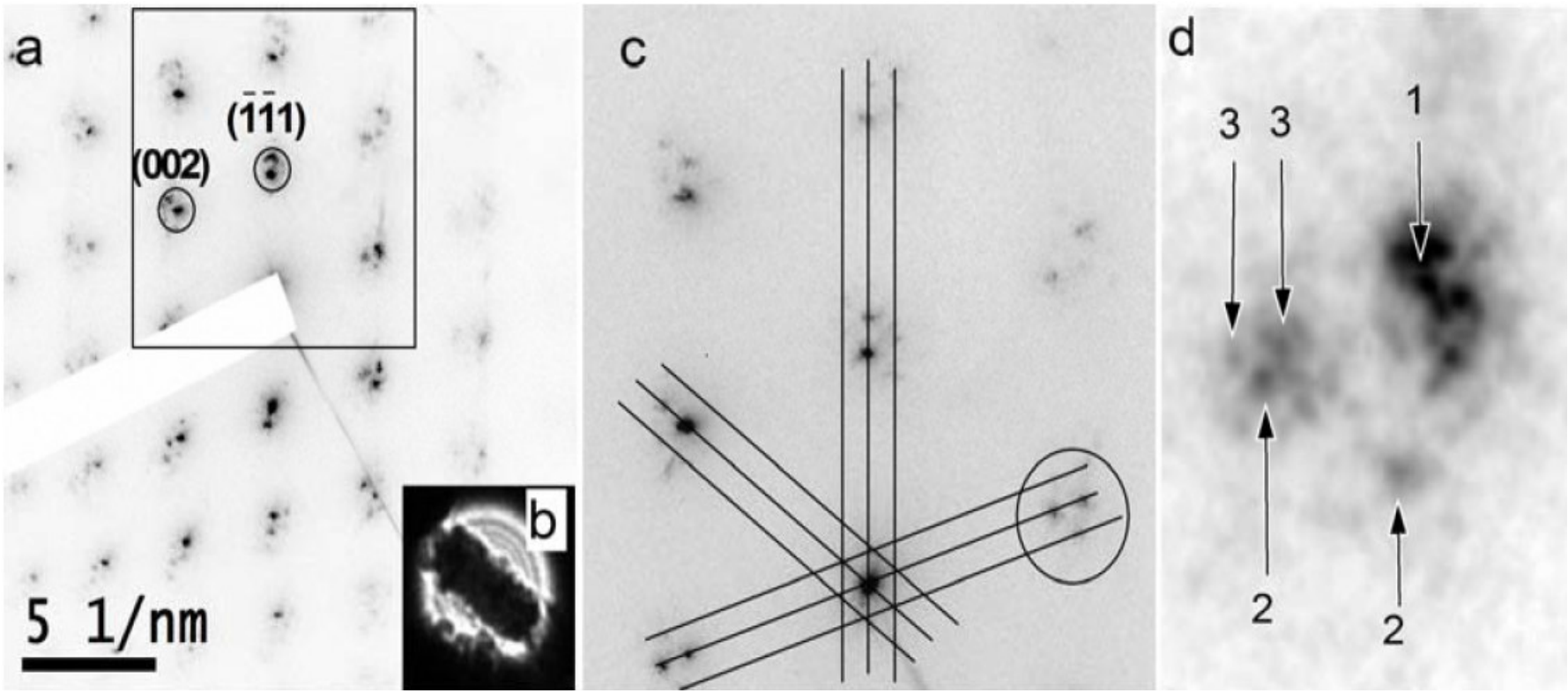


Experimental (A) and calculated using BEM (B) UV-vis-NIR spectra of gold nanorods, with Pt tips, and with Ni shells grown at Ni/Au molar ratios of 1, 5, and 10, as indicated in the labels





Examples of HRTEM images of Au@Ni nanorods with thicker (upper images) and thinner shells, where Moiré patterns are perfectly visible.



(a) Nano-beam diffraction (NBD) pattern from the central part of an Au@Ni nanorod. (b) Orientation of the coated nanorod with respect to the diffraction pattern shown in (a), which was identified as corresponding to a (110) zone axis. (c) Magnification of the area indicated in (a), where the drawn lines demonstrate a relationship between the orientation of the main spots and the satellite spots in the diffraction pattern, which was identified as parallel or nearly parallel, indicating the presence of two crystalline lattices with nearly parallel orientation. (d) Magnification of the set of main and satellite spots within the circle drawn in (c). Labelled as 1 is the main spot, which is surrounded by several single satellite and arc-shaped spots; labelled as 2 are the satellite single spots arising from a secondary diffraction; while spots labelled as 3 are identified as arising from a third diffraction.

Summary

✓Pt-doped Au nanorods were homogeneously coated with metallic Ni through hydrazine reduction in aqueous solution, leading to quasi-epitaxial growth, as demonstrated by HRTEM and NBD experiments.

✓Core–shell nanoparticles can be aligned under an external magnetic field, which can be useful for optical patterning.

✓It can be expected to display a large magnetic anisotropy, with potential uses in data storage.