Supporting Information for:

Gold core-labeled TiO₂ nanoparticles for tracking behavior in complex matrices: synthesis, characterization, and demonstration

Alyssa R. Deline, William M. Young, and Jeffrey A. Nason*

Oregon State University School of Chemical, Biological and Environmental Engineering 116 Johnson Hall Corvallis, OR 97331

*Corresponding Author Phone: (541) 737-9911; E-mail: jeff.nason@oregonstate.edu.

Contents:

22 Pages 10 Supporting Figures

Conversion of electrophoretic mobility values to ζ -potentials

	AuNP	Cores	Au@Ti	O2 NPs	TiO ₂ NPs		
Surface	360 kDa polyvinylpyrrolidone						
functionalization							
Shape	Sphe	erical	Ellips	soidal	Ellips	soidal	
D _h , nm	6	0	17	76	18	185	
	<u>pH</u>	<u>EPM</u>	<u>рН</u>	<u>EPM</u>	<u>рН</u>	<u>EPM</u>	
	3.31	-0.61	3.38	-1.84	3.24	-1.18	
	3.40	-0.39	3.39	-1.97	3.35	-0.92	
	3.87	-0.30	3.88	-2.48	3.85	-1.02	
	4.44	-0.15	4.48	-2.88	4.43	-1.51	
	4.99	-0.61	4.97	-2.87	4.89	-1.82	
nH and Average	5.68	-1.06	5.58	-2.81	5.66	-2.53	
pH and Average	6.15	-1.63	6.19	-2.99	6.16	-2.74	
medility (FDM)	7.15	-1.80	6.88	-3.28	6.65	-2.62	
μm·cm/V·s	7.16	-1.61	7.45	-3.34	7.20	-2.59	
	8.67	-1.90	8.04	-3.40	8.18	-2.53	
	8.88	-2.01	8.81	-3.31	8.41	-2.57	
	9.44	-1.82	8.99	-3.61	8.99	-2.71	
	9.72	-1.94	9.25	-3.72	9.25	-3.06	
	10.25	-1.70	9.74	-3.86	9.73	-3.08	
	10.78	-1.72	10.24	-4.19	10.24	-3.07	
			10.77	-3.83	10.77	-3.32	
Model used to							
compute ζ-	Smoluchowki						
potential							
Sample	10 mg/L NPs, 1 mM KCl, KOH or HCl for pH adjustment as						
composition	applicable						
Viscosity	0.887 mPa						
Measurement	3 replicates performed at 20 cycles each for each data point						
Measurement details	3 replicates performed at 20 cycles each for each data point						

Table S1. Information used for calculating ζ -potentials from electrophoretic mobility values.

Acid digestion of samples for ICP analysis

For the spike-and-recovery experiment performed in distilled deionized (DDI) water, and the accompanying measurements of NP stock concentrations, the following procedure was used for acid digestion prior to ICP-MS analysis:

- 1. Samples were all digested and analyzed in triplicate, and a method blank sample of DDI water was also digested and analyzed during each experiment.
- 2. Each sample was transferred to a teflon beaker and heated on a hot plate set to 225°C until less than 0.5 mL of solution remained.
- 3. 8 mL of concentrated (70% w/w) HNO₃ and 2 mL of concentrated (49% w/w) HF was added to each beaker. Each beaker was heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 4. 5 mL of concentrated (37% w/w) HCl was added to each beaker, and heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 5. 5 mL of concentrated HNO₃ was added to each beaker, and heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 6. 8 mL of 2N HNO₃ was added to each beaker. Each beaker was covered with a watch glass, heated on a hot plate until boiling, and then removed from heat. The 2N HNO₃ solution was permitted to remain in the beakers overnight.
- 7. For each beaker, the solution was diluted to 10 mL using 2N HNO₃, and stored in a polypropylene centrifuge tube. Prior to analysis, each sample was diluted to a 2% HNO₃ concentration using DDI water.

This resulted in a Ti:Au ratio of the Au@TiO₂ NP stock of 1.45. In the spike-and-recovery experiment, 80.4% of the total added gold and 98.7% of the total added titanium was recovered. Adjustments were made to the acid digestion procedure to increase gold recovery and address the organic components of more complex environmental samples.

For the spike-and-recovery experiment performed in a sunscreen-river water mixture, and the accompanying measurements of NP stock concentrations, the following procedure was used for acid digestion prior to ICP-OES analysis:

- 1. Samples were all digested and analyzed in triplicate, and a method blank sample of DDI water was also digested and analyzed during each experiment.
- 2. Each sample was transferred to a teflon beaker and heated on a hot plate set to 225°C until less than 0.5 mL of solution remained.
- 1 mL of concentrated (70% w/w) HNO₃ and 2 mL of 30% H₂O₂ was added to each beaker. Each beaker was heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 4. 6 mL of concentrated (70% w/w) HNO₃ and 4 mL of concentrated (49% w/w) HF was added to each beaker. Each beaker was heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 4.5 mL of concentrated (37% w/w) HCl and 1.5 mL of concentrated HNO₃ was added to each beaker. Each beaker was heated on a hot plate set to 225°C until a single viscous drop of solution remained.

- 6. 5 mL of concentrated HNO₃ was added to each beaker along with one drop of concentrated HCl, and heated on a hot plate set to 225°C until a single viscous drop of solution remained.
- 8 mL of 2N HNO₃ was added to each beaker along with one drop of concentrated HCI. Each beaker was covered with a watch glass, heated on a hot plate until boiling, and then removed from heat. The 2N HNO₃ solution was permitted to remain in the beakers overnight.
- 8. For each beaker, the solution was diluted to 10 mL using 2N HNO₃, and stored in a polypropylene centrifuge tube. Prior to analysis, each sample was diluted to a 2% HNO₃ concentration using DDI water.

This resulted in a Ti:Au ratio of the Au@TiO₂ NP stock of 2.25. In the spike-and-recovery experiment, 94-105% of the total added gold and 80% of the total added titanium was recovered. As discussed in the main text, the lower titanium recovery in this experiment was likely due to the presence of the rutile phase of titanium from the sunscreen mixture.

Additional TEM images of Au@TiO2 NPs



Figure S1. TEM image of Au@TiO₂ NPs.



Figure S2. TEM image of Au@TiO₂ NPs.

Estimation of Lattice Mismatch

The lattice mismatch between the AuNP core and the anatase TiO₂ shell was estimated using the following values¹ and calculation.

Lattice constant for Au (as reported for bulk Au surfaces at room temperature): 0.408 nm

Lattice constants for anatase TiO₂ (as reported for bulk surface at room temperature):

a = 0.378 nm, c = 0.951 nm

Lattice mismatch = $\frac{|a_{Au} - a_{Ti}|}{a_{Au}} \times 100\% = \frac{|0.408 \ nm - 0.378 \ nm|}{0.408 \ nm} \times 100\% = 7.4\%$

Calculation of number of AuNP cores per TiO₂ shell

TEM analysis

For each of the Au@TiO₂ nanoparticles imaged, the number of AuNP cores contained was recorded. This number was averaged over N=120 particles and found to be 2 ± 1 AuNP core per Au@TiO₂ NP.

Sp-ICP-MS analysis

AuNPs were analyzed before and after coating with TiO_2 NPs. After coating, the mass Au per particle increased, which was attributed to multiple AuNPs within one TiO_2 shell appearing as a single peak with larger intensity. The mean and mode values of peak intensity and AuNP size are summarized below in Table S2.

	AuNPs (no coating)	AuNPs (after coating with TiO ₂)
Mean Peak Intensity	11.26	17.80
Mode Peak Intensity	8.67	9.67
Mean NP Size, nm	35.6	40.8
Mode NP Size, nm	33.7	35.4

Table 32. Summary of results of sprice in Scholarysis of Aune cores before and after coaling

The mass of Au is directly related to the intensity peak signal, allowing for the intensity values to be used directly in the calculation of AuNP cores per shell. The calculation is performed below:

$$Np = \frac{Mean intensity_{coated AuNPs}}{Mode intensity_{uncoated AuNPs}} = \frac{17.80}{8.67} = 2.05$$

Calculation of Ti:Au ratio

TEM Analysis

For each of the TiO_2 and $Au@TiO_2$ nanoparticles imaged, the long and short axes were measured using ImageJ. The long axis average ± standard deviation was reported as the primary particle diameter for each NP type in the main text. For the $Au@TiO_2$ NPs, the number of AuNP cores in each particle was also recorded.

To estimate a possible range of 3-dimensional ellipsoidal volumes from the 2-dimensional TEM images, two calculations were performed on each Au@TiO₂ and TiO₂ NP:

For the lower limit,

$$\Psi$$
, Au@TiO₂ NP = $\frac{4}{3}\pi \left(\frac{long axis}{2}\right) \left(\frac{short axis}{2}\right)^2$

For the upper limit,

$$\Psi$$
, Au@TiO₂ NP = $\frac{4}{3}\pi \left(\frac{long axis}{2}\right)^2 \left(\frac{short axis}{2}\right)$

The diameter of each of the AuNP cores (as imaged inside of Au@TiO₂ NPs) was measured using ImageJ. The diameter average \pm standard deviation was reported as the primary particle diameter in the main text. The volume of each AuNP core was calculated by assuming a spherical shape:

$$\Psi, AuNP = \frac{4}{3}\pi \left(\frac{diameter}{2}\right)^3$$

The results of these analyses are summarized below in Table S3.

analyses of NP stocks.	Table	e S3.	Particle	size	and	volume	data,	reported	as	average	±	standard	deviation,	from	TEM
	analy	ses c	of NP sto	cks.											

	TiO ₂ NPs	Au@TiO₂ NPs	AuNP Cores	
Primary Size, nm	169 ± 75	206 ± 85	35 ± 4	
Spherical Volume, nm ³			2.4E+4 ± 1.0E+4	
Ellipsoidal Volume	2 22E+6 + 2 66E+6	2 72E+6 + 7 86E+6		
(upper limit), nm ³	2.322+0 1 2.002+0	5.232+0 1 2.802+0		
Ellipsoidal Volume				
(lower limit), nm ³	1.42E+0 ± 1.50E+0	$1.05E+0 \pm 1.57E+0$		
Number of cores/shell		2 ± 1		
N _p analyzed	120	100	120	

To estimate the average mass of gold present in each AuNP core, the following equation was used:

Average Mass AuNP = $(\overline{\Psi}, AuNP)(\rho_{Au})$,

where $\bar{\mathcal{V}}$, AuNP is the average volume of the AuNP cores and ρ_{Au} is the bulk density of gold.

Average Mass AuNP = $(2.4 \times 10^4 \text{ nm}^3) \left(1 \times 10^{-21} \frac{\text{cm}^3}{\text{nm}^3}\right) (19.3 \frac{g}{\text{cm}^3}) = 4.6 \times 10^{-16} \text{g Au}$ Average Mass AuNP = $4.6 \times 10^{-16} \text{g Au}$

To estimate the mass of gold present in each $Au@TiO_2$ NP, the following calculation was performed on each imaged $Au@TiO_2$ NP:

Mass Au in Au@TiO₂ NP = $(\#_{cores})$ (Average Mass AuNP),

where $\#_{cores}$ is the number of cores in the Au@TiO₂ NP being analyzed.

To estimate a possible range of the mass of titanium present in each $Au@TiO_2$ and TiO_2 NP, the following calculations were performed on each imaged $Au@TiO_2$ NP, using both the upper and lower limits for the elliptical $Au@TiO_2$ volume:

 $\begin{aligned} \Psi, TiO_2 &= (Volume, Au@TiO_2 NP) - (\bar{\Psi}, AuNP \times \#_{cores}) \\ \\ Mass Ti in Au@TiO_2 NP &= (Volume, TiO_2) (\rho_{TiO_2}) (\frac{g Ti}{g TiO_2}), \end{aligned}$

where ρ_{TiO_2} is the bulk density of anatase TiO₂ and $\frac{g Ti}{g TiO_2}$ is the mass fraction of titanium in TiO₂.

An example calculation is included below using the average upper limit for the Au@TiO₂ volume and a value of 2 cores per Au@TiO₂ NP:

$$\forall, TiO_2 = (3.23 \times 10^6 nm^3) - (2.4 \times 10^4 nm^3 \times 2) = 3.\overline{18} \times 10^6 nm^3$$

 $Mass Ti in Au@TiO_2 NP = (3.\bar{1}8 \times 10^6 nm^3) \left(1 \times 10^{-21} \frac{cm^3}{nm^3}\right) \left(3.78 \frac{g}{cm^3}\right) \left(\frac{0.595 g Ti}{g TiO_2}\right)$ Mass Ti in Au@TiO_2 NP = $7.2 \times 10^{-15} g Ti$

The Ti:Au ratio was calculated for each Au@TiO₂ particle and averaged.

ICP Analysis

The Ti:Au ratio for all ICP analyses was determined using the averages of the gold and titanium concentrations measured in 3 replicate Au@TiO₂ NP stock samples (each digested separately).

XPS Analysis

Avantage software was used to perform peak analysis and determine atomic ratios within each sample. Table S4 summarizes the atomic ratios determined for the Au@TiO₂ NPs.

Peak Name	Binding Energy	Atomic %
Au 4f	83.2 eV	3.6
C 1s	284.8 eV	30
I 3d	618.1 eV	0.4
N 1s	399.4 eV	2.7
0 1s	529.7 eV	43.2
Ti 2p	458.4 eV	20.1

Table S4. Atomic ratios and peak binding energies determined using XPS for $Au@TiO_2$ NP stock. Two 500 μ m areas were analyzed on one sample, with identical results.

The atomic % was converted to a Ti:Au ratio using the following calculations:

 $Atomic/Molar \ ratio, Ti: Au = \frac{Atomic \ \%, Ti}{Atomic \ \%, Au} = \frac{20.1}{3.6} = 5.58 \frac{mols \ Ti}{mols \ Au}$

Mass ratio, Ti: $Au = (Molar ratio, Ti: Au) \left(\frac{MW_{Ti}}{MW_{Au}}\right)$

$$Mass \ ratio, Ti: Au = \left(5.58 \frac{mols \ Ti}{mols \ Au}\right) \left(\frac{47.867 \ g \ Ti}{mols \ Ti}\right) \left(\frac{mols \ Au}{196.967 \ g \ Au}\right) = 1.4 \ \frac{g \ Ti}{g \ Au}$$

XPS Spectra

XPS analysis was performed on a sample of $Au@TiO_2$ NP stock that was dropcast onto a silicon wafer. The XPS spectra for the Ti2p, O1s, and Au4f regions are included below.



Figure S3. XPS spectrum of Ti2p region for Au@TiO₂ NPs.



Figure S4. XPS spectrum of O1s region for Au@TiO₂ NPs.



Figure S5. XPS spectrum of Au4f region for Au@TiO₂ NPs.

Calculation of Au wt %

The Ti:Au ratios were converted to Au wt % using the following equations:

$$Au: Ti = \frac{1}{Ti: Au}$$

$$Au wt \% = \left(\frac{wt Au}{wt Au + wt TiO_2}\right) \times 100\%$$

Note that for each (Au:Ti) g of Au there is 1 g of Ti.

$$Au \ wt \ \% = \left(\frac{Au: Ti \frac{g \ Au}{g \ Ti} \times 1 \ g \ Ti}{Au: Ti \frac{g \ Au}{g \ Ti} \times 1 \ g \ Ti + 1 \ g \ Ti \times 1.679 \frac{g \ TiO_2}{g \ Ti}}\right) \times 100\%$$

Both the upper and lower limits of Ti:Au were used for TEM calculations to provide a range of Au wt %.

Calculation of deviation of density from unlabeled TiO₂ NPs

TEM analysis

A possible range of particle densities was calculated using the upper and lower limits for elliptical volumes in the equation below:

$$\rho_{Au@TiO_2} = \frac{Average Mass Au in Au@TiO_2 NP + (Average \Psi_{TiO_2} \times \rho_{TiO_2})}{Average \Psi_{Au@TiO_2}}$$

$$\rho_{Au@TiO_{2,lower}} = \frac{7.\bar{9}7 \times 10^{-16}g Au + (3.\bar{1}9 \times 10^6 nm^3 \times 1 \times 10^{-21} \frac{cm^3}{nm^3} \times 3.78 \frac{g}{cm^3})}{3.\bar{2}3 \times 10^6 nm^3 \times 1 \times 10^{-21} \frac{cm^3}{nm^3}}$$

$$= 3.\bar{9}8 \frac{g}{cm^3}$$

$$\rho_{Au@TiO_{2,upper}} = \frac{7.\bar{9}7 \times 10^{-16}g Au + (1.\bar{6}0 \times 10^6 nm^3 \times 1 \times 10^{-21} \frac{cm^3}{nm^3} \times 3.78 \frac{g}{cm^3})}{1.\bar{6}5 \times 10^6 nm^3 \times 1 \times 10^{-21} \frac{cm^3}{nm^3}}$$

The range of deviation in density compared to unlabeled anatase TiO_2 was found to be 5.3-10% using the equation below:

% Deviation = $\frac{\rho_{Au@TiO_2} - \rho_{TiO_2}}{\rho_{TiO_2}} \times 100\%$

Size distribution histograms for AuNP cores



Figure S6. Comparison of AuNP core size as measured via TEM and sp-ICP-MS analyses. The sp-ICP-MS data represents samples of the AuNP cores measured prior to the coating procedure.



Figure S7. Comparison of AuNP core size determined via sp-ICP-MS analyses before and after coating with TiO₂.

Homoaggregation studies for Au@TiO2 and TiO2 NPs



Figure S8. Hydrodynamic diameter measured over time for Au@TiO₂ NPs in KCl solutions varying from 100-500 mM.



Figure S9. Hydrodynamic diameter measured over time for TiO₂ NPs in KCl solutions varying from 100-500 mM.

Calculation of primary TiO₂ crystallite size from XRD spectra

The anatase TiO₂ peaks at $2\theta \approx 25^{\circ}$ were to calculate the average TiO₂ crystallite size using the Scherrer equation, which is included below.

Crystallite size $= rac{K\cdot\lambda}{eta\cdot\cos heta}$,

where K is a dimensionless shape factor (assumed here to be 0.9), λ is the wavelength of the CuK α radiation source used (0.15405 nm), β is the full width of the peak at half maximum intensity (determined using EVA software), and θ is the Bragg angle of the peak.

The crystallite size was determined to be 5.8 nm for the unlabeled TiO_2 NPs and 6.0 nm for the Au@TiO_2 NPs.

River water characterization

Samples of Willamette River water were collected from the Taylor Drinking Water Treatment Plant in Corvallis, OR. The pH and turbidity of the water was measured at the facility. Total suspended solids were measured using Standard Method 2540 D. Conductivity was measured using a conductivity probe. The alkalinity was calculated using a gran function plot. The characteristics of the collected water samples are summarized in Table S6. The ionic strength was estimated by the measured conductivity using the following equation:

$$I(M) = 1.6 \times 10^{-5} \times EC(\frac{\mu S}{cm})$$
, where I is the ionic strength and EC is the electrical conductivity².

The total natural organic matter content of the Willamette River was measured on a different batch of river water than the batch used for experiments and is provided in Table S6 as a recent measurement of the scale of the organic matter content in Willamette River water. The organic matter content for the Willamette River has been consistently measured by our within the range of 1-2 mg C/L in our lab³.

рН	7.41		
Turbidity	3.55 NTU		
Total Suspended Solids	7.1 ± 2.6 mg/L		
Conductivity	90.5 μS/cm		
Alkalinity	25.5 ± 0.9 mg CaCO₃/L		
Ionic Strength	1.4 mM		
Natural Organic Matter	1.13 ± 0.05 mg C/L		

Table S6. Characteristics of Willamette River water used in spike-and-recovery experiments.

Activated sludge characterization

Return activated sludge was collected from the Corvallis Wastewater Treatment Plant, stored in the refrigerator, and used within 24 hours. The sludge was analyzed for total dissolved solids and total suspended solids using Standard Methods 2540C and 2540D. Triplicate samples were analyzed and the average \pm standard deviation is reported here. The total dissolved solids concentration was 371 \pm 68 mg/L. The total suspended solids concentration was 8811 \pm 233.3 mg/L.

Calculation of limits of detection and quantification

The limit of detection (LOD) and limit of quantification (LOQ) were determined for Ti in the river water-sunscreen mixture, and for both Au and Ti in the return activated sludge matrix. The LODs and LOQs for each matrix were estimated based on a conservative blank determination method using the equations below:

$$LOD = \bar{X}_{blank} + 3.3 \times S_{blank}$$

 $LOQ = \bar{X}_{blank} + 10 \times S_{blank}$,

where \bar{X}_{blank} represents the mean concentration measured in triplicate samples of the matrix with no NPs added, and S_{blank} represents the standard deviation measured in triplicate samples of the matrix with no NPs added^{4,5}.

Spike-and-recovery in river water-sunscreen mixture

For the samples of river water mixed with sunscreen, no background Au was detected. The values of \bar{X}_{blank} and S_{blank} for Ti were 285 µg/L and 33 µg/L, respectively. The LOD and LOQ are calculated below:

$$LOD = 285 \frac{\mu g}{L} + 3.3 \times 33 \frac{\mu g}{L} = 394 \frac{\mu g}{L}$$

$$LOQ = 285 \ \frac{\mu g}{L} + 10 \times 33 \ \frac{\mu g}{L} = 615 \ \frac{\mu g}{L}$$

Spike-and-recovery in return activated sludge

Return activated sludge samples contained both Au and Ti in the background. The values of \bar{X}_{blank} and S_{blank} for Au and Ti are calculated below based on INAA and TSS analyses.

Mass of Au per mL of sludge = 28.7 ± 0.6 ng Mass of Ti per mL of sludge = 370 ± 580 ng TSS concentration of sludge = 5358 ± 577 mg/L

$$\bar{X}_{blank,Au} = \frac{(28.7 ng Au) \left(\frac{1 \mu g}{1000 ng}\right)}{\left(5358 \frac{mg}{L}\right) (0.001 L) \left(\frac{1 kg}{10^6 mg}\right)} = 5356 \frac{\mu g Au}{kg RAS}$$

$$S_{blank,Au} = 5356 \frac{\mu g Au}{kg RAS} \sqrt{\left(\frac{577}{5358}\right)^2 + \left(\frac{0.6}{28.7}\right)^2} = 588 \frac{\mu g Au}{kg RAS}$$

$$\bar{X}_{blank,Ti} = \frac{(370 ng Ti) \left(\frac{1 mg}{10^6 ng}\right)}{\left(5358 \frac{mg}{L}\right) (0.001 L) \left(\frac{1 kg}{10^6 mg}\right)} = 69.1 \frac{mg Ti}{kg RAS}$$

$$S_{blank,Ti} = 69.1 \frac{mg Ti}{kg RAS} \sqrt{\left(\frac{577}{5358}\right)^2 + \left(\frac{580}{370}\right)^2} = 109 \frac{mg Ti}{kg RAS}$$

The LODs and LOQs for both Au and Ti are calculated below:

$$LOD_{Au} = 5356 \frac{\mu g}{kg} + 3.3 \times 588 \frac{\mu g}{kg} = 72\overline{9}6 \frac{\mu g}{kg} = 7.30 \frac{mg \, Au}{kg \, sludge}$$

$$LOQ_{Au} = 5356 \frac{\mu g}{kg} + 10 \times 588 \frac{\mu g}{kg} = 11\overline{2}40 \frac{\mu g}{kg} = 11.2 \frac{mg \, Au}{kg \, sludge}$$

$$LOD_{Ti} = 69.1 \frac{mg}{kg} + 3.3 \times 109 \frac{\mu g}{kg} = 42\overline{8}.8 \frac{mg}{kg} = 429 \frac{mg \, Ti}{kg \, sludge}$$

$$LOQ_{Ti} = 69.1 \frac{mg}{kg} + 10 \times 109 \frac{\mu g}{kg} = 11\overline{5}9 \frac{mg}{kg} = 1160 \frac{mg \, Ti}{kg \, sludge}$$

UV-Vis standard curve for Au@TiO2 NPs



Figure S10. Standard curve for UV-Vis measurements of $Au@TiO_2$ NPs in DDI water ranging in concentration from 0.5-5 mg/L.

References

- 1 R. W. G. Wyckoff, *Crystal Structures Volume 1.*, Interscience Publishers, New York, 1963.
- 2 L. L. Russell, University of California, Berkeley, 1976.
- 3 J. Silvertooth, Oregon State University, 2014.
- 4 M. Nič, J. Jirát, B. Košata, A. Jenkins and A. McNaught, Eds., *IUPAC Compendium of Chemical Terminology*, IUPAC, Research Triagle Park, NC, 2009.
- 5 A. Shrivastava, V. Gupta and R. Article, *Chronicles Young Sci.*, 2011, **2**, 21–25.