Enhanced Production of Small Water Clusters by Sn, In, and Ni Nanoparticles and Their Applications

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The design

➢ Electron blockade (EBK)

1. Excite the surface electrons of metallic nanoparticles (NPs) with 514.5nm LED green light. (Fig. 1)
2. Electrons will weaken the hydrogen bonds between water molecules.

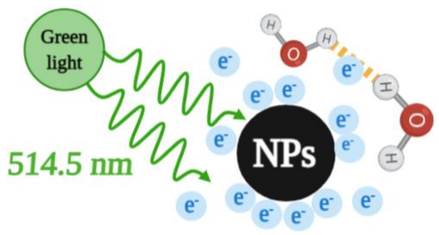


Fig. 1. Schematics of EBK.

➢ Surface plasma resonance (SPR)

1. Setup refers to the ATR geometry.
2. Nanoparticles coated on a prism.
3. Excite the surface electrons of NPs with 650nm red laser. (Fig. 2)

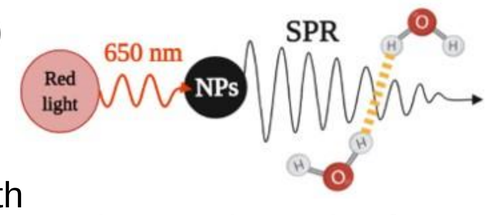


Fig. 2. Schematic of SPR.

Materials and Methods

➢ Fabrication of nanoparticles with thermal evaporation

1. Evaporate metal ingots by heating the boat.
2. Add Ar gas in the chamber to keep vapor atoms from combining together. (Fig. 3)
3. Adhere a piece of glass or prism and set temperature at 77K to coat NPs on them.
4. Au, Ag, Ni, Sn, and In NPs were fabricated.

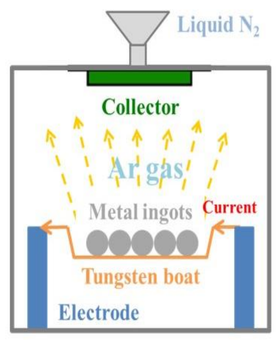


Fig. 3. Setup for thermal evaporation.

NPs	Au	Ag	Ni	Sn	In
Mean size (nm)	10	20	14	71	54

Table 1. Mean sizes of the 5 NPs I fabricate.

➢ Particle size of NPs by X-ray diffraction

1. Assume a lognormal size distribution and cut it into 15 sizes. (Fig. 4)
2. Calculate the peak profile of the 15 slices.
3. Adjust the mean size and width of the distribution to fit the observed profile.

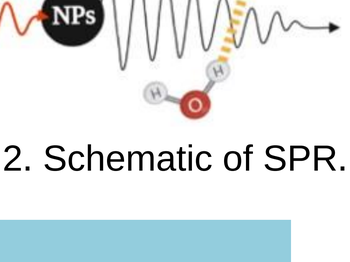


Fig. 4. Size distribution of NPs.

- NP Assembly: A group of NPs with different sizes.
- Peak profile = superposition of profile from each NP.

Results and Discussion

➢ Raman vibrational modes of pure deionized (DI) water

1. Measure the with extremely low excitation power.
2. Vibrations at 3018, 3223, and 3393 cm^{-1} are from hydrogen-bonded water, while the two vibrations at 3506 and 3624 cm^{-1} are from small water clusters. (Fig. 5a)
3. Surprisingly, 23% of H_2O molecules in DI water at 25 ^oC are already in small cluster form without interference. (Fig. 5b)

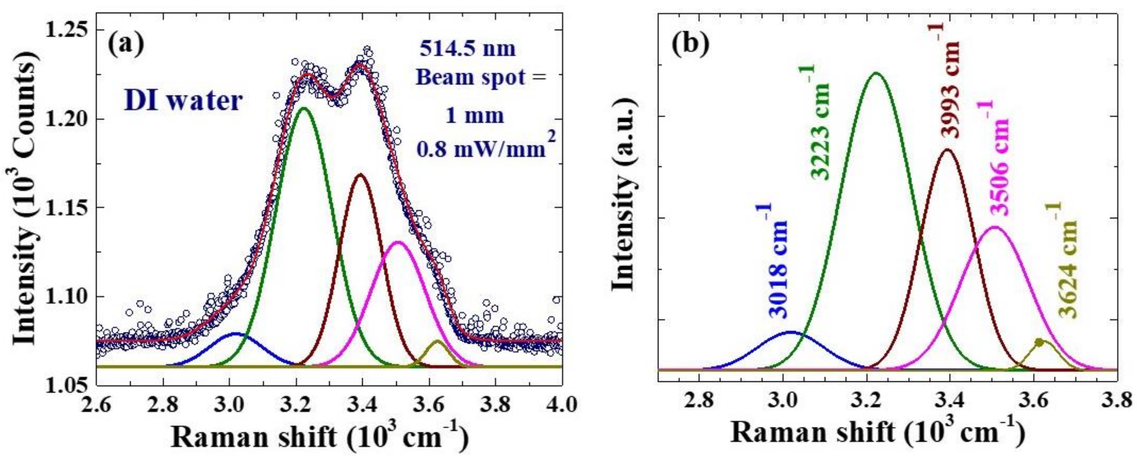


Fig. 5. (a) Raman spectra of DI water taken at 0.8 mW/mm^2.
(b) The five Raman modes observed in DI water.

➢ Production of SWCs with electron blockade (EBK)

1. A 3% increase of SWCs in water is detected from the EBK of 54nm In NPs. (Fig. 6)
2. 14nm Ni NPs provide the highest enhancement, while Au and Ag NPs generate little.

NPs	Au	Ag	Ni	Sn	In
SWCs	≡ 1	7	26	16	18

Table 2. Enhancement factor from EBK.

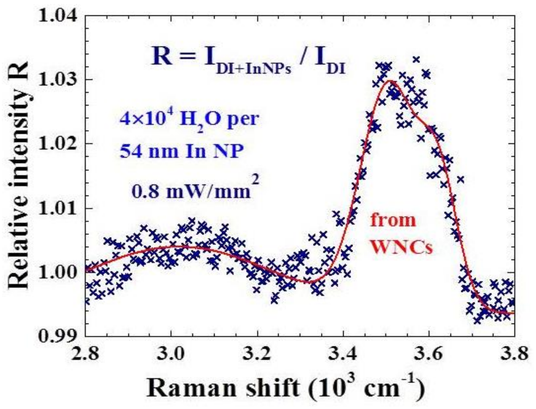
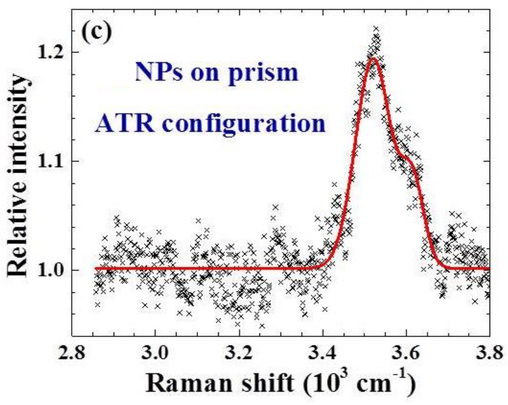


Fig. 6. Intensity ratio of water with and without EBK effect.

➢ Production of SWCs with surface plasma resonance (SPR)

1. DI water is placed on the base of a prism coated with NPs.
2. SPR is seen at incident angles of 39~44^o. ATR signals from the 14nm Ni NPs are higher than those from 20nm Ag NPs.
3. SWCs has increased by 21% with the SPR effect. (Fig. 7, right)



➢ SWCs on cell culture (In NPs)

1. HCT-15: Human rectal cancer cell
   CDDP: Cisplatin, drug for cancer
2. Apply the SPR setup for a more sensitivity cytotoxicity assay

Table 3. Cell viability of HCT-15 in different media		
DI water	<	DI water + CDDP
SWC **(In NPs)**	>	SWC + CDDP

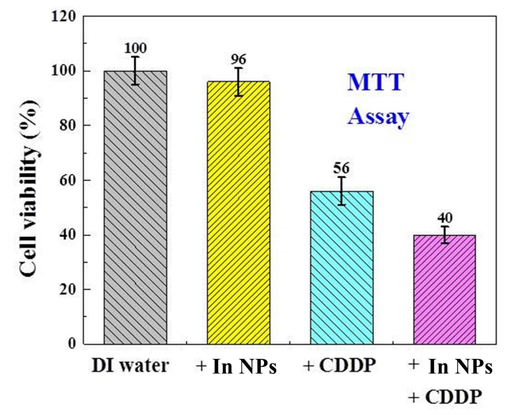
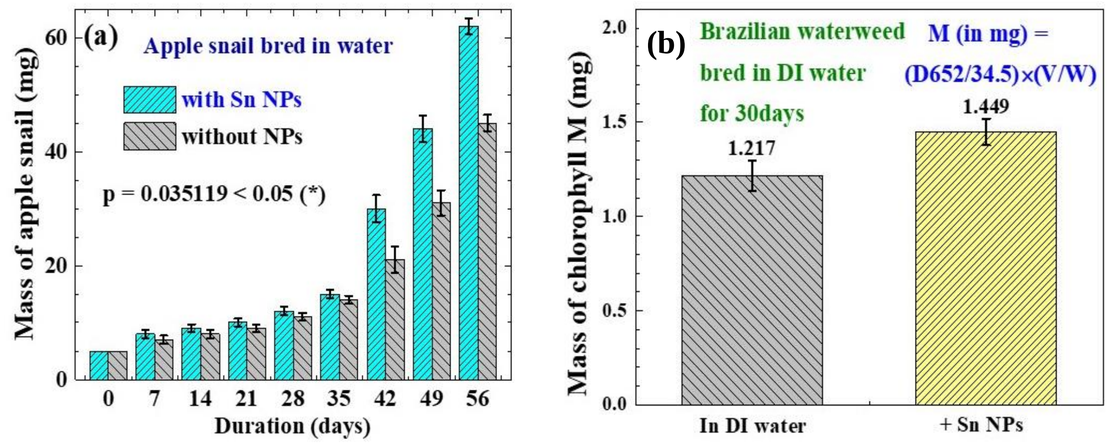


Fig. 8. MTT assay of HCT-15 cells in various media.

➢ SWCs on animal & plant growth (Sn NPs)



- SWC: Method 1 (EBK) + Sn NPs in tank for longer life span
- Apple snails: Total mass was 42% more during incubation period between week 6 and 7. (Fig. 9a)
- Brazilian waterweed grew 1.2 times faster. (Fig. 9b)

Conclusions

1. Light irradiation onto water (PIR), light irradiation onto NPs merged in water (EBK) , and excitations of SPR in metallic NPs can all interrupt the hydrogen bonding between H_2O molecules to form small water clusters (SWCs).
2. Ni, Sn and In NPs are more effective in producing SWCs than Au and Ag NPs. Moreover, an increase 21% of SWCs in DI water can be achieved by exciting SPR on Ni NPs.
3. SWCs can efficiently expedite the growth rate of cells, and even potentially facilitate the therapeutic effect of drugs on human rectal cancer cells.