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# Bimetallic Nanoparticles as Antimicrobials

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## Introduction

Recently, the bimetallic nanoparticles (BNPs) have received great attention due to their unique optical, electronic, magnetic, and catalytic characteristics which are greatly difference from those of corresponding monometallic nanoparticles[1]. Bimetallic nanoparticles composed of two type metal elements, metallic nanoparticles can be categorized as bi-metallic or tri-metallic depending on the number of component metallic ingredients[1]. To prepare bimetallic nanoparticles from metal salts we can use two methods; co-reduction and successive reduction of two metal salts. The co-reduction protocol is easy method to combine the bimetallic nanoparticles, that is, the same as that of monometallic nanoparticles. The mean size of the bimetallic nanoparticles depends on the metal composition. A sol–gel process and stabilized in liquid and solid matrices were used to synthesize nanobimetallic particles consisting of Au–Pd, Au–Ag, and Au–Pt. The colloidal Au-Ag bimetallic nanoparticles (NPs) was studied as a friendly method to construct two metal element using glycerol as a reducing chemical in alkaline medium. The composition of colloidal NPs was confirmed by characterization method including; Ultraviolet spectroscopy (UV-Vis) and transmission electron microscopy (TEM)[2]. It was reported that the effect of pH on the synthesis of Ni-Au. Bimetallic nanomaterial have wide applications such as catalysts[3], staining pigments, antimicrobials[4], larvicidal and pupicidal[5], anti-malarial[6], coating on solar cells, photonics[7], sensors[8], in drug delivery, gene therapy, DNA detection and cancer management.

### Antimicrobial effects

A synergistic antimicrobial effect is achieved when silver nanoparticles are hybrid with other metal nanoparticles or oxides acting as a shell or a core to form bimetallic nanoparticles[9]. Ag-Cu bimetallic nanoparticles antimicrobial efficiency was as sayed[10]. The superparamagnetic bimetallic Ag/Co polymeric nanocomposite was evaluated as a bactericide activity during treatment of bacteria contaminated aqueous solutions[11]. The highly effects of Au-Ag core-shell BNPs antibacterial properties depends on more active silver atoms in the shell surrounding gold core due to high surface free energy of the Ag atoms, owing to shell thinness in the bimetallic NP structure[12]. Ag/Au bimetallic nanocomposites have a high antibacterial efficacy on *Bacillius* strains[13]. The antibacterial activity of AgCu-Zn against *Escherichia coli* DH5α strain was estimated to investigate the extended nanoclusters compared to AgCu[14]. Fe–Ag nanoparticles magnetic bimetallic have a high antibacterial and antifungal effects against a different types of pathogenic microorganisms[15]. Biosynthesis of bimetallic nanoparticles method is a good, low-cost and nontoxic method compared to physical and chemical methods which showed a high bioactive efficiency[1]. Ag-Au nanoparticles bimetallic were prepared from marine red alga, *Gracilaria sp*.,. Bimetallic nanoparticles have a good antibacterial activity against *Staphylococcus aureus* and *Klebsiella pneumonia*[16]. Bimetallic Cu–Ni NPs was showed a bacteriostatic effect against *S. aureus, E. coli* and *S. mutans*[17]. Ag-Au bimetallic nanoparticles was synthesized and assayed for their antibacterial activity against *S. aureus*. Ag-Au alloy nanoparticles antibacterial activity was increased when combined with penicillin G and piperacillin[18]. The combined Pt and Au have a strong bactericidal effect compared with each alone nontoxic to bacteria[19]. Bimetallic Au-Ag nanoparticles was synthesised by using *Ocimum basilicum* aqueous leaf and flower extracts and revealed a high antibacterial activity against *Staphylococcus aureus, Escherichia coli, Bacillus subtilis* and *Pseudomonas aeruginosa*[20]. The antibacterial efficiency of Cu-$TiO_2$ nanoparticles greater than either



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$TiO_2$ or Cu nanoparticles when used separately[21]. In the same work, the antibacterial efficiency of $TiO_2$ was greatly enhanced in the absence of light by including nano-Cu[22] or nano-Cu and chitosan[23]. High-efficient antibacterial CTD nanoparticles with low-toxicity exhibit enhanced antibacterial activity due to the synergistic antibacterial effect of Cu and $TiO_2$ based on the generation of destructive reactive oxygen species (ROS) even in the absence of light[24]. Polymer-stabilized bimetallic nanoparticles can be prepared and studying their antifungal activity in vitro and in vivo.

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