

Investigation on Chaining of Au/Aniline Polymerid Nanocomposites with Different Electrodes Configuration and Characterization

J. F. Sun ^a, Zh. R. Guo ^b and N. Gu ^{c, ¶}

National Key Laboratory of Molecular and Biomolecular Electronics,
Department of Biological Science and Medical Engineering, SouthEast
University, Nanjing, 210096, China

[a](mailto:asunzaghi@seu.edu.cn)[sunzaghi@seu.edu.cn](mailto:asunzaghi@seu.edu.cn), [b](mailto:zhiruiquo@seu.edu.cn)zhiruiquo@seu.edu.cn, [c](mailto:guning@seu.edu.cn)guning@seu.edu.cn

¶Corresponding authors

Keywords: Coupling particle, Dielectrophoresis, One-dimensional structure

Abstract. A dumbbell-liked organ-metal composite was prepared with wet chemistry. Then the solution was subjected to AC e-field. Herein, three types of electrodes configuration were adopted to align the colloids. Theoretically, quasi one-dimensional structures should be observed, and it was the case in the third configuration. SEM, AFM and TEM were utilized to characterize the resultant morphology. The mechanism was described with dielectrophoresis theory.

With the colloidal preparation developing, diverse nanoparticles have sprung up, especially the hetero-structured, which attract many interests for their unique properties [1-3]. At one time, one-dimensional structures have been found increasing significance both in theory and in application [4-5]. It is certain that the combination of the two regimes will play major role in future nanotechnology. But until now, little relative works have been reported partly due to the complexity of composition and structure. Besides, as far as field-induced assembly is concerned, lithographic micro electrodes of interdigitated finger pattern are utilized to assemble particles into wires bridging the pair of electrodes [6-7]. This provides a new route for “wet electronics” and nano-integrate circuit. However, many tanglesome phenomena will emerge in electrodes area, which often hamper understanding of field’s role. In addition, SEM is preferred to characterize the resultant morphology. Nevertheless, characterization on some finer morphologies may be above bend of SEM. In this letter, we report some recent works on chaining of Au/aniline polymerid with different electrodes configuration and characterization with different instruments.

The dumbbell-liked Au/aniline polymerid nanocomposites are chosen as elements to align. The synthetic approach can be referred to Ref [8]. Briefly, a 50mL aqueous solution containing 0.1 wt% H₂AuCl₄ is prepared firstly and O₂ in it was degasified by N₂ bubbling. Then a fixed amount of distilled aniline dissolve in 1mL de-ionized water is dropped in it and stirred at 90 °C for about 1 hr. The polymerization of aniline and the reduction of H₂AuCl₄ occurred synchronously and Au/Aniline polymerid colloid suspension is obtained. The sizes of Au sphere and organic sphere

are 20 nm and 60nm, respectively. Fig. 1 is the TEM photo of original sample. Then, one globelet of suspension is dropped on the substrate between two electrodes. In our experiments, three pairs of electrodes consist with two lithographic micro-electrodes, two alnico plates spaced by a cover slide and two probes fixed in a micro-manipulator, respectively. Fig. 2 demonstrates these configurations. For (a), about 500 nm is spaced between two Au electrodes. For (b), strong magnetic attraction makes the space wide as the thickness of cover slide. The drained electric field is exploited to assemble particles. A mica plate with a droplet of suspension on is placed on the connection of two alnico plates. For (c), the two probes can be manipulated to separate several micrometers. AC power is connected to these electrodes for shunning the effect of solvent and electrolysis. We experiment different frequencies, as well as voltages to find the optimum parameters.

Fig. 3 shows the resultant morphologies corresponding to different cases. As for microelectrodes, under any accessible voltages or frequencies, the assembly is ineffectual because the narrow gap and small cross-section area of electrodes make DEP trapping mode [9]. The particles are trapped around the gap of electrodes. From the photo, little tropism could be observed mainly because of the characterization on SEM. For alnico electrodes, AFM is used to reveal chaining modality. Two typical parameters are present here. One is 50 V/100 KHz, the other is 250 V/50 Hz. In both circumstances, the same observations are obtained. The colloids conglomerate and distribute regularly with the dispersion positively correlative to the frequency. The mechanism behind this phenomenon is not well-known. Maybe the magnetic field plays some role. Finally, in the probe electrodes configuration, the satisfying results are obtained. In this case, copper mesh-grid is utilized as substrate sustaining droplet and matrix for TEM characterization. From the picture (c), some trend for chaining is ascertained. According to experimental data, about 1 KHz with 50 V voltages maximizes the performance of field inducing.

This assembly based on electric field drive is due to the dielectrophoretic force generated by separated electrodes with AC power [10]. This force can be described as [11]:

$$\langle \overline{F}_{DEP} \rangle = 2\pi r_p^3 \varepsilon_M \operatorname{Re}[K_e^*] \nabla E_{rms}^2 \quad (1)$$

Where $\langle \overline{F}_{DEP} \rangle$ is the time-averaged vector of the force, r_p is the radius of the polarizable particle, ε_M the real part of the dielectric permittivity of the continuous phase, \overline{E}_{rms} the dielectric field intensity, and $\operatorname{Re}[K_e^*]$ the real part of the effective polarizability, known as:

$$\operatorname{Re}[K_e^*] = \frac{(\sigma_p - \sigma_m)}{(\sigma_p + 2\sigma_m)} \left[\frac{\omega^2 \left(\frac{\varepsilon_p - \varepsilon_m}{\sigma_p - \sigma_m} \right) \left(\frac{\varepsilon_p + 2\varepsilon_m}{\sigma_p + 2\sigma_m} \right) + 1}{\omega^2 \left(\frac{\varepsilon_p + 2\varepsilon_m}{\sigma_p + 2\sigma_m} \right)^2 + 1} \right] \quad (2)$$

Eq. (2) reveals a strong relation between $\operatorname{Re}[K_e^*]$ and the electric field frequency. Higher frequency can bring about more effective polarizability, as well as violent oscillation of dipolar moment, which will influence the stability of chaining. If frequency is too low to polarize particle perfectly, the dipolar interaction between particles will be too weak to form a stable chains. So, excessively high or low frequency is inadvisable.

In conclusion, we try three electrodes configurations. The results manifest different electrodes

will lead to diverse assemblies. Therefore, the electric field-driven assembly has a strong affinity to electrodes, including structures, components, composition and so on. Besides, not only SEM, but also TEM, even AFM may be appropriate for characterization according to the substrates and colloids. With the development of nanotechnology, more complex substantial structures and higher resolution keep increasing demand. Even at this exploratory stage, our method and conclusions will play greatly important roles.

This work is supported by grants from the National Natural Science Foundation of China (NSFC, 60171005, 60371027, 90406023). Mr. Xu Aiqun would be greatly appreciated for technique assistance.

References

- [1]. C. Burda, X. Chen, R. Narayanan and M. A. El-Sayed: *Chem. Rev.*, Vol. 105 (2005), p. 1025.
- [2]. R. Shenhar and V. M. Rotello: *Acc. Chem. Res.*, Vol. 36 (2003), p. 549.
- [3]. N. L. Rosi and C. A. Mirkin: *Chem. Rev.*, Vol. 105 (2005), p. 1547.
- [4]. Zh. Tang and N. A. Kotov: *Adv. Mater.*, Vol. 17 (2005), p. 951.
- [5]. K. D. Hermanson, S. O. Lumsdon, J. P. Williams, E. W. Kaler and O. D. Velev: *Science*, Vol. 294 (2001), p. 1082.
- [6]. P. A. Smith, C. D. Nordquist, T. N. Jackson and T. S. Mayer: *Appl. Phys. Lett.*, Vol. 77 (2000), p. 1399.
- [7]. Y. Huang, X. Duan, Q. Wei and C. M. Lieber: *Science*, Vol. 291 (2001), p. 630.
- [8]. Zh. Guo: in submission to *Chem. Mater.*
- [9]. T. Schnelle, T. Muller, R. Hagedorn, A. Voigt and G. Fuhr: *Biochim. and Biophys. Acta*, Vol. 1428 (1999), p. 99.
- [10]. H. A. Pohl: *J. Appl. Phys.*, Vol. 22 (1951), p. 869.
- [11]. A. Docoslis and P. Alexandridis: *Electrophoresis*, Vol. 23 (2003), p. 2174.

