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Transport of Nanoparticles From Coated Surfaces Through Physical Contact
Application Note

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Introduction

With the growing use and incorporation of nanoparticles (NPs) into consumer products, concern about human exposure to NPs has also increased, leading to the question: Are nanoparticles in consumer products transferred to humans? Since user interaction with these products occurs mostly via physical interaction, it is important to understand how NPs are transferred through physical contact.

This work explores the transfer of nanoparticles from nano-enabled surfaces to wipes, focusing on several characteristics of nanoparticle release: total mass concentration, particle number concentration, and particle size distribution. Because of their wide use due to antimicrobial properties, silver (Ag) NPs were examined, along with CuO NP transfer from painted surfaces. A more detailed description of this work is available[1], so only an overview will be given here.

Experimental

Samples and Sample Preparation

In this work, two different types of consumer products were examined: Ag-containing silicone keyboard covers and wooden blocks painted with CuO-containing paint (Table 1). To evaluate NP transport from these products, two types of wipes were used in conjunction with synthetic sweat.[2] The different wipes were used to minimize the Ag and Cu backgrounds: one wipe had a lower Ag background and was used for the Ag NP testing, while the second one had a lower Cu background, making it the better choice for the Cu NP evaluation.

Table 1. Products Tested for Dermal Nanoparticle Transport.

Product	Description	Nanoparticle	Notes
Silicone Keyboard Covers	Antimicrobial Properties	Ag	Advertised That Contains Ag NPs Antimicrobial Properties
	No Antimicrobial Properties	---	Control; No Claim of Antimicrobial Properties
Wooden Blocks	CuO-containing Paint	CuO	Contains CuO NPs
	Paint Without CuO	---	Control; Certified Not to Contain CuO NPs

NP transfer studies were conducted by wetting a 5 x 5 cm wipe with 0.5 mL artificial sweat and then rubbing the wetted wipe, as described in the NIOSH guideline Elements on Wipes: Method 9102.[3] To ensure consistency, the wiping was done in a specific overlapping "S" pattern while the sample was sitting on a scale to ensure equivalent pressure was being exerted on each sample. Immediately after a wiping event was complete, the wipe was placed in a plastic container with 20 mL of deionized water, sonicated for 10 min, and then the suspension was immediately analyzed by single particle ICP-MS (SP-ICP-MS). For the wooden blocks, wiping was conducted both prior to and after simulated wear. The simulated wear was accomplished by sanding the blocks by hand three times, following the same procedure as the wiping, except using 180 grit sandpaper.

To check for the recovery and extraction of nanoparticles from the wipes, four fundamental tests were performed, as described in Table 2. After the artificial sweat and/or nanoparticles were added, the samples were submerged in 20 mL of deionized water, sonicated for 10 minutes in an ice-bath, and then immediately analyzed by SP-ICP-MS. These tests were performed with both 30 nm Ag NPs (Cline, Sweden) and 30-50 nm CuO NPs (PlasmaChem GmbH, Germany).

Table 2. Recovery and Extraction Tests.

Test Number	Wipe	Artificial Sweat	NP Suspension
1	Yes	0.5 mL Added to Wipe	0.25 mL Added to Wipe
2	Yes	0.5 mL Added to Wipe	No
3	No	0.5 mL Added to Water	0.25 mL Added to Water
4	No	0.5 mL Added to Water	No

Instrumental Conditions and Analysis

All analyses were performed on a PerkinElmer NexION® ICP-MS coupled with the Syngistix™ Nano Application software module and operating in Single Particle mode (SP-ICP-MS) using the conditions shown in Table 3. The transport efficiency of the system was determined with 60 nm gold nanoparticles, while the sample uptake rate was measured daily by determining the mass difference of water over a given time period.

Table 3. Instrumental Parameters for SP-ICP-MS Analysis.

Parameter	Ag Analysis	CuO Analysis
Cell Gas Flow (mL/min)	No Gas	5.7 (He)
Measurement Time (s)	100	100
Dwell Time (µs)	100	100
Analytical Mass	107	63
Mass Fraction	1.00	0.80
Density (g/cm^3)	10.49	6.31
Transport Efficiency (%)	8.89	8.74
Sample Uptake Rate (mL/min)	0.304	0.307

Results and Discussion

To validate the extraction of nanoparticles from the wipes, the tests outlined in Table 3 were performed in triplicate before any samples were evaluated. The recoveries for both the number of particles and the total mass for both Ag and CuO NPs are shown in Table 4. With greater than 80% recovery of both particles, the extraction methodology from the wipes is proven to be effective. Longer sonication times could be used to liberate more particles from the wipes, but the longer time risks dissolving some of the particles which were extracted earlier in the sonication process. It is interesting to note that the total mass recovery for the CuO NPs is greater than 100%, which indicates that some Cu is being introduced into the system, most likely as contamination in the wipes.

Table 4 . Recovery of Ag and CuO NPs from Method Validation Studies.

Parameter	Recovery Ag NPs	Recovery CuO NPs
Particle # Concentration	81%	84%
Total Mass	82%	109%

It is also important to determine if the extraction process affects the particle-size measurements. When the measured particle sizes are compared to the certificate values of the NP standards, there is very good agreement, as shown in Table 5. The results in Tables 4 and 5 indicate that this extraction process is effective for both Ag and CuO NPs.

Table 5. Comparison of Nominal and Measured Particle Sizes.

Nanoparticle	Certified Size (nm)	Measured Mean Size (nm)	
		NP	NP + Wipe
Ag	30	31	31
CuO	30-50	52	62

With the validity of the extraction established, the keyboard covers and wood blocks were analyzed next. First, Ag NP release from keyboard covers was evaluated. As shown in Figure 1, only one keyboard cover showed an increased number of Ag NPs over the course of three wiping events, when compared to the control (i.e. keyboard cover without any Ag NPs). However, when looking at the mass concentration, the wipes from all three keyboard covers have sub ng/cm^2 concentrations of Ag NPs, which is considered negligible and is unlikely to pose a health hazard.

Next, the release of CuO NPs from painted wooden blocks was evaluated in the same way as the keyboard covers. It was found that virtually no CuO NPs were extracted from the paint, as the number and concentration of CuO NPs was the same as the control sample (which does not to contain NPs), as shown in Figure 2. However, after the blocks were sanded, the number of CuO NPs increased significantly (Figure 2), demonstrating that as the paint wears, consumers will be more exposed to CuO NPs. With wooden blocks, this is a concern especially for children, due to higher frequency of hand-to-mouth contact.

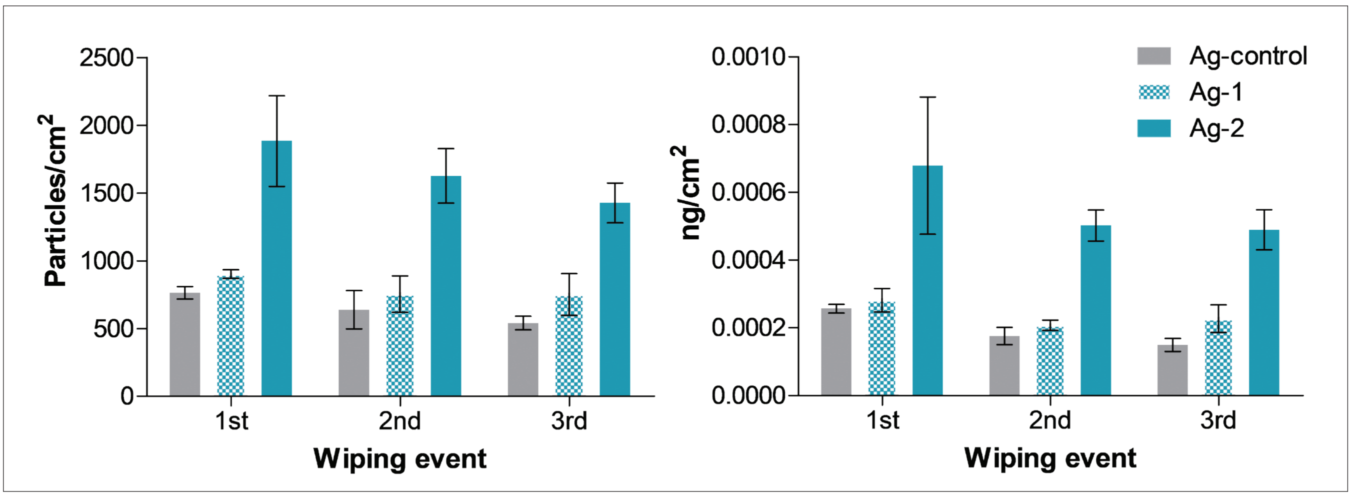

Figure 1. Ag NP transfer from keyboard covers with wipes. Left: transfer in number of particles per cm^2. Right: mass transfer in ng/cm^2. The error bars represent the standard error of the mean for three samples. The "Ag-control" is a keyboard cover that does not contain Ag NPs.

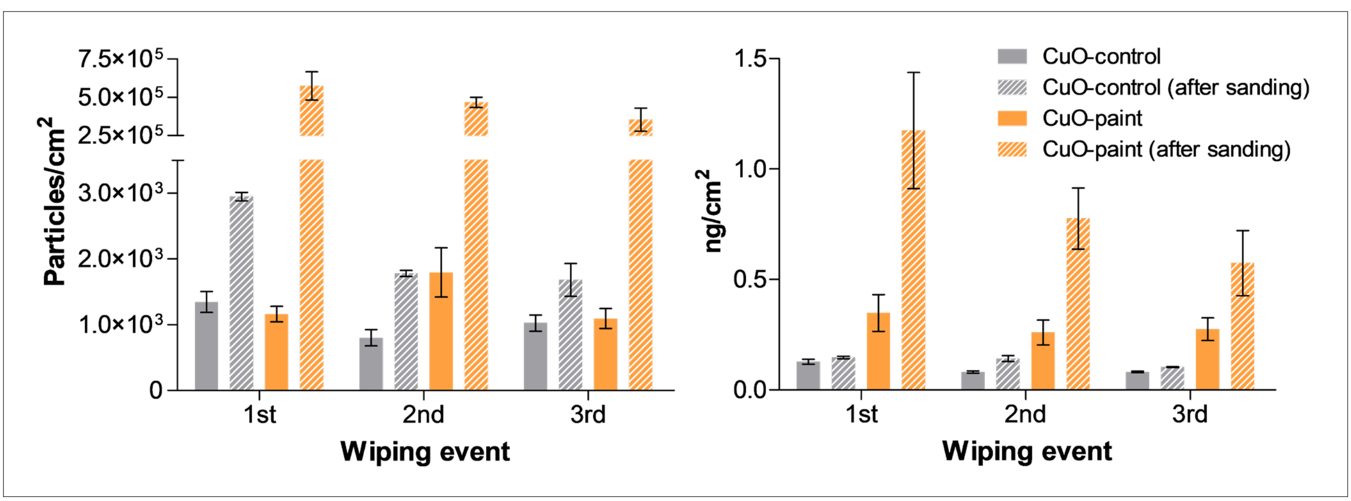

Figure 2. CuO NP transfer from painted wooden blocks. Left: transfer in number of particles per cm^2. Right: mass transfer in ng/cm^2. The error bars represent the standard error of the mean for three samples. The "CuO-Control" are blocks covered with paint that do not contain CuO NPs.

Conclusions

This work investigated the transfer of Ag and CuO nanoparticles from consumer products via simulated dermal contact by using textile wipes as a surrogate using PerkinElmer's NexION ICP-MS single particle analyzer with the unique Syngistix Nano Application software module for data collection and analysis. In both samples investigated (silicone keyboard covers and painted wooden blocks), NP transfer was negligible unless the surfaces were subject to wear. These results indicate that consumers generally do not have to worry about nanoparticle transfer through contact from products which do not show signs of wear.

References

1. Mackevica, A., Olsson, M.E., Mines, P.D., Heggelund, L.R., Hansen, S.F., "Dermal transfer quantification of nanoparticles from nano-enabled surfaces", NanoImpact, Available online 9 June 2018 (https://doi.org/10.1016/j.impact.2018.06.001).

2. ISO, 2013. ISO 105-E04:2013 - Textiles: Tests for colour fastness. Part E04: Colour fastness to perspiration.

3. NIOSH, 2003. Elements on wipes: Method 9102, in: NIOSH Manual of Analytical Methods 4th Edition.

Consumables Used

Component	Description	Part Number
Sample Uptake Tubing	0.38 mm id (Green/Orange), Flared, 2-Stop	N0777042
Drain Tubing	1.30 mm id (Gray/Gray), Santoprene, 2-Stop	N0777444
Gold Nanoparticles	60 nm, in Suspension	N8142303

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