



Adhesion of Dust Particles to Common Indoor Surfaces in an Air-Conditioned Environment

Cher Lin Clara Tan,¹ Shaokai Gao,² Boon Siong Wee,³ Akua Asa-Awuku,^{2,4} and Beng Joo Reginald Thio¹

¹Engineering Product Development, Singapore University of Technology and Design, Singapore

²Bourns College of Engineering, Center for Environmental Research and Technology, University of California, Riverside, California, USA

³Malaysian Nuclear Agency, Kajang, Selangor, Malaysia

⁴Department of Chemical and Environmental Engineering, University of California—Riverside, California, USA

Adhesion between dust particles and indoor surfaces can lead to negative effects on human health by triggering allergic and asthmatic reactions. In this study, adhesion forces of indoor office dust and activated carbon (AC, as model soot) particles to four common indoor materials (Al, Cu, PVC, and glass) were measured by colloidal probe atomic force microscopy. Chemical analysis of office dust shows it is largely made up of oxygenated hydrophilic organic carbon material. Both metal surfaces experienced weaker dust and AC adhesion than PVC or glass by up to 2–12 times lower primarily due to the presence of attractive electrostatic forces in the latter two (non-conducting) surfaces. Dust and AC adhesion were also highly sensitive to surface roughness, with an inverse relationship between adhesion force and roughness due to the reduction in contact area between the particle and a rougher material surface. Capillary forces play only a minor or negligible role in dust and AC surface adhesion. Adhesion models utilizing a purely van der Waals approach such as the simple Hamaker model and modified Rumpf's model are insufficient to determine the actual particle-surface contact radii and requires the accounting of non-van der Waals forces to adhesion.

1. INTRODUCTION

The indoor air quality of air-conditioned homes and offices is critical to human respiratory health since residents in urban areas spend the bulk of their daily hours inside (Hess-Kosa 2011). The World Health Organization has suggested that up to 30% of new and remodeled buildings globally subject their occupants to health hazards related to poor indoor air quality

(1991). The indoor air pollutants most commonly observed include chemicals such as volatile organic compounds including formaldehyde from adhesives, upholstery, carpeting, computers, copy machines, and cleaning agents. Indoor respirable solid particles (known colloquially as dusts) varying widely in size from $<2.5 \mu\text{m}$ ($\text{PM}_{2.5}$) to $>0.1 \text{ mm}$ originate from copy machines, soot from motor vehicle exhausts through air intake vents/windows/doors, plants (pollen), fungi (mold spores), dust mites, and human activities such as smoking, vacuuming, and cooking.

Indoor airborne particulate matter can deposit onto indoor surfaces over time if air circulation and ventilation is poor. The deposition rate is dependent on the particle size, surface type (e.g., plastic vs. metal, wet vs. dry), orientation (horizontal or vertical surface), and air flow conditions. Furthermore, when human or animal (e.g., pets and pests) activity is present, the deposited particles can get detached and resuspended from the surface back to the air. Deposited particles can also be moved from one surface to another by contact transfer, e.g., a person rests his arm on a table and some deposited dust particles are transferred from the table onto his clothing (McDonagh et al. 2012).

In the study of indoor particle transport, it is important to recognize that particle size plays an important role in determining whether the particles stay airborne or get deposited on various surfaces (Hess-Kosa 2011). In general, the particle size spectrum can be broadly classified into two categories according to the particle diameter (Liu et al. 2004): fine ($<2.5 \mu\text{m}$) and coarse ($>2.5 \mu\text{m}$). Fine particles were typically found to be a mixture of solid carbon from incomplete fuel combustion and secondary particulates generated by chemical reactions in the atmosphere (acid condensates, sulfates, and nitrates) (Ormstad 2000). Coarse particles are generally of organic material origin and larger soot aggregates (Ormstad et al. 1997). Coarse particles

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Address correspondence to Beng Joo Reginald Thio, Engineering Product Development, Singapore University of Technology and Design, 20 Dover Drive, 138682, Singapore. E-mail: reginaldthio@sutd.edu.sg