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**Fiber Optic Connector Cleaner**

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*Linden Photonics, Inc., USA***Introduction**

Linden Photonics has developed a novel approach for cleaning a connector endface. We use a newly developed patent pending adhesive technology that can be pressed against the face of the connector and remove contamination by wiping, twisting or simply touching. This design has significant advantages over traditional cleaning methods. It is highly absorptive, will not cross contaminate and can be deployed in virtually any shape and size to fit into small and tight spots for high portability.

This new material is a “dry adhesive” nanotechnology that employs tiny structures which provide strong Van der Waals adhesive forces. This attractive force actively sticks to all types of contamination whether dry or oil based and the material can be used dry or with various solvents. This material can be applied to cleaning media in any form. It can be used by itself on the end of a swab or it can be deposited onto a substrate and used in the form of other conventional cleaning tools such as foam or cotton swabs, reel cleaners or IBC type cleaners.

The benefit from this design is the ability to quickly and much more efficiently clean a fiber optic connector endface with an inexpensive, reusable media. The design of this material has qualities desired by the large primes like Lockheed and addresses the biggest fiber optic related issue on programs like the F-18, connector cleanliness. In addition, non military applications are abundant for a small efficient hand held fiber optic cleaner that improves upon existing commercially available products.

**History of the Technology**

The Q-Tip was invented in 1923. It consisted of a cotton wad attached to the end of a toothpick. Since 1923, the cotton swab has changed little. The

vital telecommunications systems that connect our personal and business lives as well as run systems on multi-million dollar machines like F-35 are cleaned with tools that very closely resemble the cotton swab from 1923 – cotton attached to the end of a stick.

The evolution of fiber optic cleaning tools is a short one. Some swabs still actually consist of cotton stuck to the end of a toothpick. Slight variations are available, but they simply include changes to the shape of the swab (pointed, bent, etc.) or substituting foam for cotton. There have been no innovative advancements to the material itself.

Linden Photonics was awarded a NAVAIR funded SBIR grant in 2010 to develop a new cleaning material with the aggressive goal of cleaning connectors with a “target speed is 1 to 5 seconds per terminus...99% efficacy or higher so that inspection post cleaning is not required...The cleaning equipment must be field deployable and hand held. It must be self sufficient and be able to reach to wherever the connector may reside...” The material that we have developed harnesses the power of nature and employs Van der Waals forces to actually attract contamination off of a connector endface. The material can be used with solvents or as a “dry adhesive” – a material that can stick to a surface, but also be rubbed across it, unlike conventional viscoelastic based adhesive tape.

**Van der Waals Forces**

Van der Waals forces are attractive forces at a molecular level. When two surfaces come into close contact with each other at a molecular level, they generate these attractive forces. These are the very forces that allow Geckos to walk up walls. The Gecko has microscopic hairs on the pads of its feet and these hairs fill in the microscopic spaces and imperfections that exist in all surfaces – even those that appear flat.

The Microscopic hairs are made of a hierarchical structure, consisting of microscopic hairs called setae (micrometer in size), which further split into hundreds of smaller structures called spatulas (nanometer in size). On coming in contact with any surface, the spatulas deform, enabling molecular contact over large areas, thus translating weak van der Waals interactions into enormous attractive forces. They also stick to both hydrophobic and hydrophilic surfaces, and do so without using viscoelastic liquids.

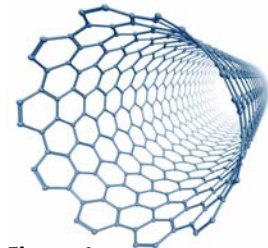
Linden Photonics' Lindex™ brand cleaners employ customized carbon nanotubes (CNT) to achieve the

Van der Waals based adhesion. CNT are very strong, very stiff structures made of 1 atom thick walls of carbon. Typically CNT is used for electrical applications. Through years of research Linden Photonics has identified very specific proprietary formulations of CNT that when placed in a vertical array or 3D array they generate high Van der Waals forces. This yields an adhesive material that allows horizontal movement across the surface. This is something you can't do with traditional tape. Our material sticks by touching, but can be swiped across the surface as well. The material will adhere to a surface while moving laterally across it.

### What are Carbon Nanotubes?

Carbon Nanotubes are cylindrical nanostructures (see figure 2) that are commonly used as structural additives for various products and are commonly known as carbon fibers. CNT can be single walled (SWNT) or multi walled (MWNT). The single wall version as shown in figure 1 is a single layer of carbon atoms. Single Walled Nanotubes can have a diameter as small as 1 nm and a length millions of times longer. A multi wall CNT consists of multiple concentric layers of carbon atoms. CNT are the strongest and stiffest structures known having a Young's Modulus of approximately 1 TPa compared to stainless steel's Young's Modulus of 0.2 TPa. The tensile strength of CNT is on the order of 25 to 125 GPa, compared again to stainless steel at

approximately 1 GPa. Carbon nanotubes also have unique electrical properties making them very desirable for many applications including nanotube

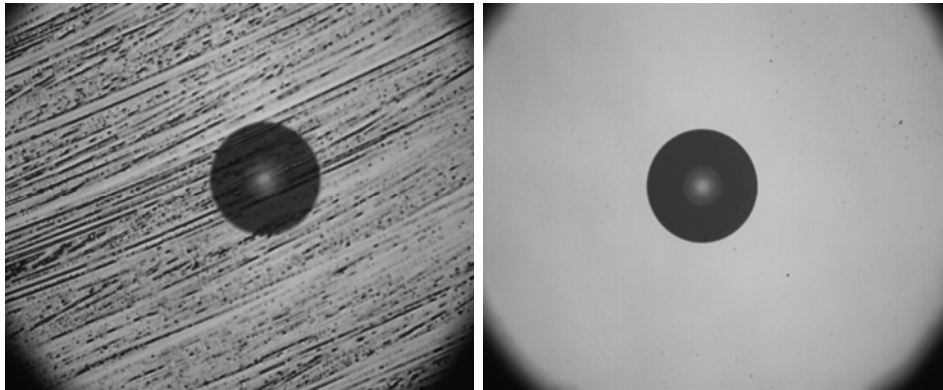


**Figure 1.** Carbon Nanotube based transistors. In our application carbon nanotubes are ideal because we need a small yet strong subcomponent that will be small enough to interact with surfaces on a molecular level and achieve good adhesion through Van der Waal forces as described above and yet be strong enough to withstand large forces applied during the cleaning process.

### Cleaning Results

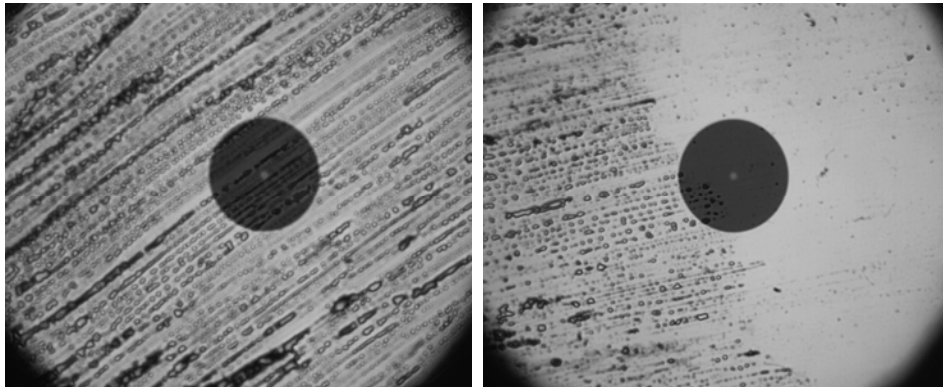
CNT has been proven to remove all types of contamination including; metal flakes, graphite flakes, finger oil, axle grease, carbon black, Arizona road dust, dried salt and an oil and graphite slurry that includes both dry and liquid contamination. This oil and graphite mixture was obtained by mixing in our lab as well as removing contamination from an automobile engine.

Various images below illustrate the cleaning abilities of the Lindex™ CNT based cleaning material. Figures 2a and 2b show a dirty fiber optic connector that has been contaminated with finger oil and swiped on 5mm of Lindex cleaning material. As a matter of comparison, figures 3a and 3b are images of the same contamination cleaned using Scotch tape. As is shown, the viscoelastic adhesive on Scotch tape does not stick to the oil contamination nearly as well as the Lindex cleaning material.



**Figure 2a.** Fiber optic connector contaminated with finger oil.

**Figure 2b.** Fiber optic connector cleaned with Lindex cleaning material.

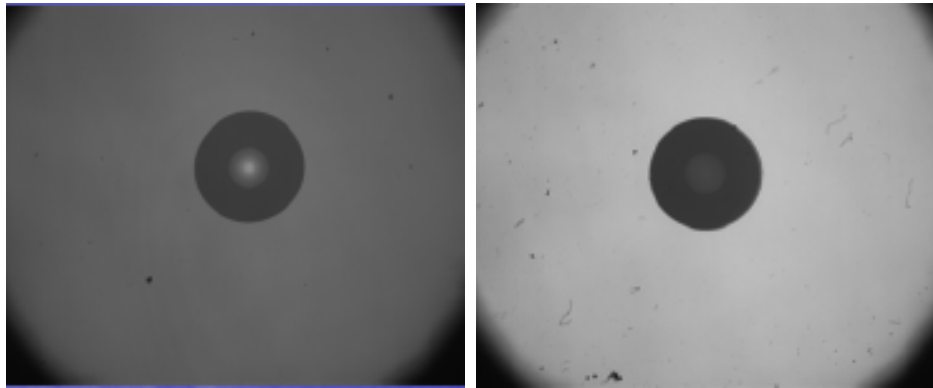


**Figure 3a.** Fiber optic connector contaminated with finger oil.

**Figure 3b.** Fiber optic connector cleaned with Scotch tape.

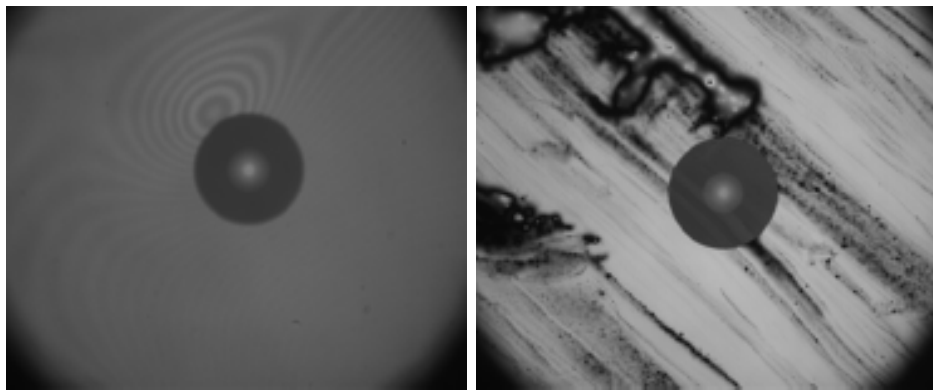
Many additional materials were tested and some of the most difficult to remove were oil based contamination. In the following example, we used Lindex cleaners to clean hydraulic oil and a thick layer of axle grease. In each case a complete contamination of the endface was used as the beginning state. This was considered to be a gross, 100%, contamination of the connector. For each of these contamination types, the connector was cleaned using only a 5mm section of Lindex cleaning material. In figures 4a and 4b, a connector contaminated with hydraulic oil is cleaned on a 5mm

section of Lindex material. One can see the ability of the material to absorb a large amount of contamination even in a small amount of cleaning material. A similar amount of contamination was cleaned on a 50mm section of Cletop material and the results are shown in figures 5a and 5b. Because traditional cleaning media does not have any ability to adhere to and soak up contamination, particularly liquid contamination, even a length of material 10 times that of the Lindex material will not clean nearly as well.



**Figure 4a.** Fiber optic connector contaminated with hydraulic oil.

**Figure 4b.** Fiber optic connector cleaned with 5mm of Lindex cleaning material.

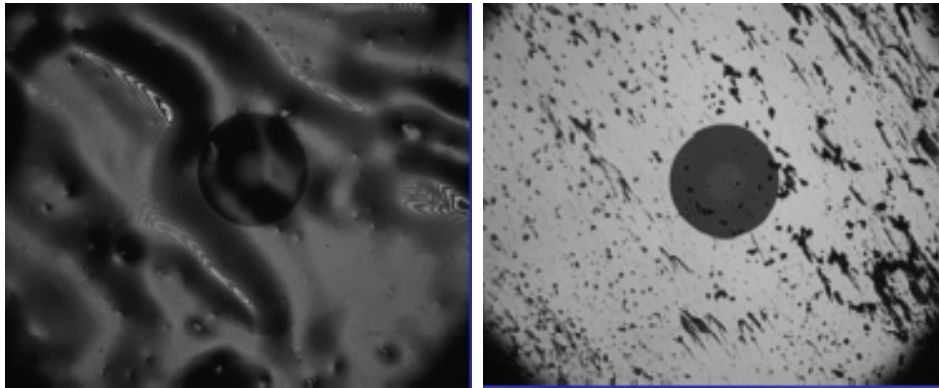


**Figure 5a.** Fiber optic connector contaminated with hydraulic oil.

**Figure 5b.** Fiber optic connector cleaned with 50mm of Cletop material.

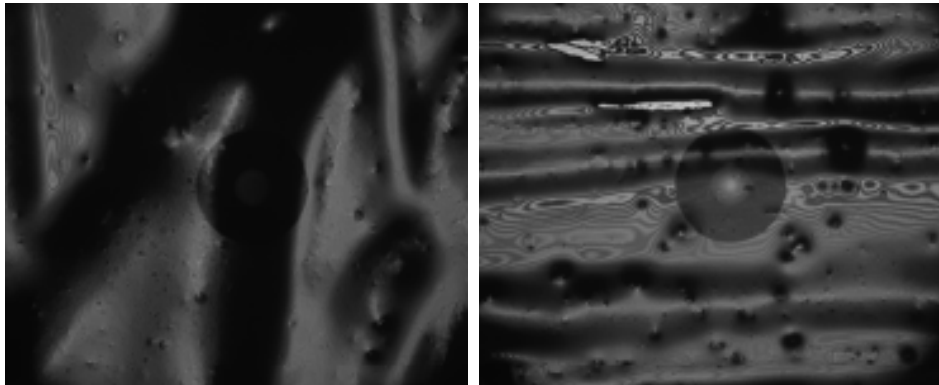
Another example that illustrates the superior cleaning power and absorption properties of the Lindex cleaning material is an experiment we performed using axle grease. In this case we can see just how thick the layer of grease was on the endface. One can see the ripples in the contamination that indicate its thickness. In figures

6a and 6b, we have a connector contaminated with axle grease and once again cleaned with 5mm of Lindex cleaning material. In figures 7a and 7b we take a similarly contaminated connector and clean with a commercial off-the-shelf foam swab. As is shown, the contamination is more aligned than removed by the swab.



**Figure 6a.** Fiber optic connector contaminated with axle grease.

**Figure 6b.** Fiber optic connector cleaned with 5mm of Lindex cleaning material.



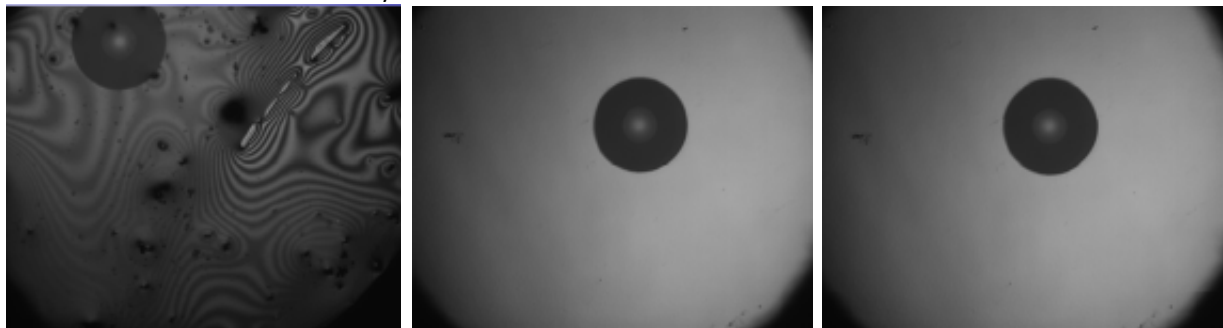
**Figure 7a.** Fiber optic connector contaminated with axle grease.

**Figure 7b.** Fiber optic connector cleaned with foam swab. Wiped 4 times.

**No Cross Contamination**

Because Lindex material actually sticks to contamination, another attribute of the material is that it will not cross contaminate. Unlike conventional cleaning media which will not “hold on” to the contamination that they come in contact

with Lindex material adheres to the contamination and will not let go even if you reuse or touch a dirty section of material to a clean surface. This is demonstrated below in figures 8a, 8b and 8c.



**Figure 8a.** Fiber optic connector contaminated with graphite and oil

**Figure 8b.** Fiber optic connector cleaned with Lindex cleaning material

**Figure 8c.** Connector endface after being touched to section used to clean connector in figure 8a.

As illustrated in the figures above. A fiber optic connector was contaminated with a mixture of graphite and oil and Lindex cleaning material was used to remove the contamination. The same dirty section that was used to clean the connector was now put in contact with the cleaned connector endface. Instead of depositing the contamination back onto the endface, which would be the case with a cotton or foam material, our material holds onto the contamination so well that it will not let go and redeposit the contamination back onto the clean connector. This is an important safeguard against a technician accidentally reusing a swab or section of cleaning material while performing maintenance duties.

#### Summary

Lindex cleaning material is a large technological advancement to the cleaning industry. By developing a highly advanced nanomaterial we have shown vast improvements in efficacy from legacy cleaning products. In one case a side-by-side comparison was performed using Lindex swabs and COTS foam swabs. A subset of 100 termini were contaminated with graphite and oil were. Fifty (50) out of 50 were all able to be cleaned (as per NAVAIR 01-1A-505-4 definition of clean) with 5 Lindex swabs or less. Only 1 out of 50 was able to be cleaned with 5 or less COTS foam swabs.

By design we are only using a small amount of material to clean. This allows us to keep costs low and offer Lindex cleaning tools at a competitive price. The cost savings in technician time and reduced disposables per clean can be invaluable

when repairing a vital network. Using Lindex cleaning tools a technician will realize a greater than 50% reduction in cleaning time.

The versatility of the material allows Lindex to be used as a swab or in popular forms like reel cleaners. Contact us for more details.

#### References

1. NAVAIR 01-1A-505-4 Technical Manual, Installation and Testing Practices, Aircraft Fiber Optic Cabling, 13 August 2004
2. Belluci, S. (2005). "Carbon nanotubes: Physics and applications". *Physica Status Solidi C* **2** (1): 34–47.
3. Chae, H.G.; Kumar, S. (2006). "Rigid Rod Polymeric Fibers". *Journal of Applied Polymer Science* **100** (1): 791–802.
4. Meo, M.; Rossi, M. (2006). "Prediction of Young's modulus of single wall carbon nanotubes by molecular-mechanics-based finite element modelling". *Composites Science and Technology* **66** (11–12): 1597–1605.
5. Sinnott, S.B.; Andrews, R. (2001). "Carbon Nanotubes: Synthesis, Properties, and Applications". *Critical Reviews in Solid State and Materials Sciences* **26** (3): 145–249.
6. Postma, Henk W. Ch.; Teepen, T; Yao, Z; Grifoni, M; Dekker, C (2001). "Carbon Nanotube Single-Electron Transistors at Room temperature". *Science* **293** (5527): 76–9.