Electrotactile Touch Surface by using transparent Graphene

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ABSTRACT

In this work we present a flexible Electrostatic Tactile (ET) surface/display realized by using new emerging material graphene. The graphene is transparent conductor which successfully replaces previous solution based on indium-thin oxide (ITO) and delivers more reliable solution for flexible and bendable displays. The electrostatic tactile surface is capable of delivering programmable, location specific tactile textures. The ET device has an area of 25 cm^2, and consists of 130 µm thin optically transparent (>76%) and mechanically flexible structure overlaid unobtrusively on top of a display. The ET system exploits electro vibration phenomena to enable on-demand control of the frictional force between the user's fingertip and the device surface. The ET device is integrated through a controller on a mobile display platform to generate fully programmable range of stimulating signals. The ET haptic feedback is formed in accordance with the visual information displayed underneath, with the magnitude and pattern of the frictional force correlated with both the images and the coordinates of the actual touch in real time forming virtual textures on the display surface (haptic virtual silhouette). To quantify rate of change in friction force we performed a dynamic friction coefficient measurement with a system involving an artificial finger mimicking the actual touch. During operation, the dynamic friction between the ET surface and an artificial finger stimulation increases by 26% when the load is 0.8 N and by 24% when the load is 1 N.

Keywords: programmable textures, electrostatic friction, tactile feedback, transparent graphene, flexible form factor.

1. INTRODUCTION

Electrostatic tactile sensations offer a means of breaking out of monolithic paradigm to haptic feedback. Electrostatic vibration (electovibration) is a phenomenon whereby a tactile effect is perceived when an alternating potential is applied between an insulated conducting surface and body parts in sliding contact [1]. The applied time varying potential induces an electovibration attraction between the ET surface and user skin, varying the normal contact force and thus modulating the perceived friction. In other words, ET feedback exploits capacitive coupling between the user skin and the device's surface (in non-galvanic contact) to deliver a tactile sensation. The ET feedback is particularly promising for use in mobile devices for a number of reasons. They typically require very low currents (less than a few microamperes) to generate perceivable haptic sensations and therefore use very low power, can be made very lightweight and flexible (enabling flexible form factor of future devices) and have no moving parts (e.g. the user skin is vibrated directly). Traditional metal oxide based transparent conductors (such ITO etc…) are fundamentally incompatible with flexible form factors due to their brittleness [2]. Graphene is new emerging material with advanced optical transparency, mechanical flexibility, robustness and environmental stability making it a perfect candidate not only for photonic and optoelectronic applications but also for completely new generation of passive as well as interactive devices with flexible form factors (`morphing' and shape change form factors). To challenge traditional haptic feedback paradigm and provide enabler for the future flexible devices we realized graphene based ET system. We used transparent graphene, novel dielectric materials with high dielectric constant (parylene, hafnium etc…) with advanced passivation by using diamond-like carbon (DLC) coating. The principal design of the graphene ET system is shown in FIG 1

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2. DESCRIPTION OF THE ET SYSTEM

For the graphene ET system characterization, a dedicated ET-driver circuitry was designed including the signal generator and a controller with the signal sharpening unit (see FIG 2). The ET-driver is capable of generating broaden set of ET signals in frequency range of 5-1500 Hz and with 0-150 V adjustable signal amplitude. When generating the stimulation the controller accepts actual x-y coordinates of the finger touch and in accordance with the image pixels at this particular location generates dedicated array of sharp unipolar (negative) pulses Such signal is further delivered to the conductive layer of graphene in the ET system (see FIG 1). The negative pulses were suggested by previous investigations [3]. As the user scans the finger across the ET surface appropriate virtual texture is perceived.

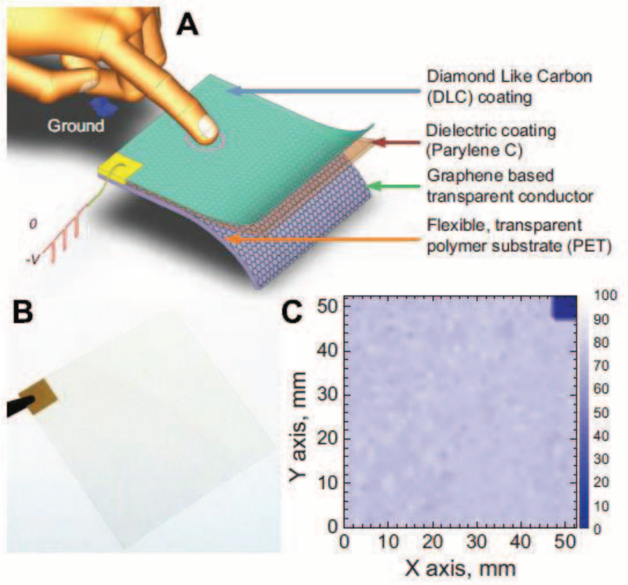

FIG. 1 (A) principal schematic of the graphene ET device. The stimulating signal is applied to the graphene coating which is electrically insulated from the finger by parylene coating and protected by a DLC-film. As the user scans their finger on the ET surface and thus, completes the circuit, the stimulating electrical signal creates an intermittent attractive and repulsive electrostatic forces between the finger and ET-surface. (B) Photograph of the transparent graphene sample used for the system. (C) Spatial transmittance (76%) measurement of the graphene film.

In this demo basic signal generator was a MP3 player in a mobile phone with a set of principal audio files. We wanted to demonstrate generality of possible applications and we used a set of audio files with frequency ranges such 5,20,50,75,100,150 Hz and in MP3 form. The files were on a phone generating a sinusoidal audio signal with particular frequency which is then fed to the ET controller.

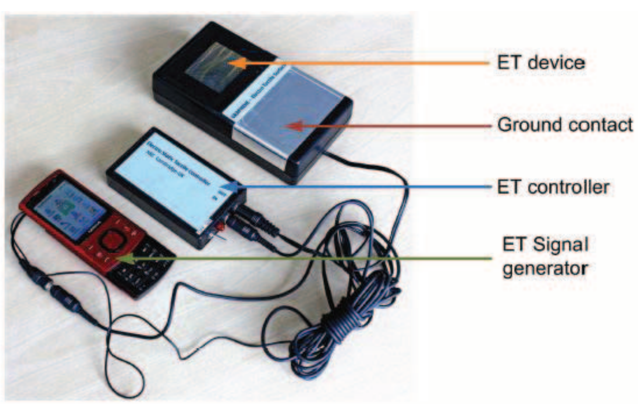

FIG. 2 Graphene ET system. Upon receiving electrical signal from the generator, the controller sends stimulating signals to the visually transparent ET device. The user completes the electrical circuit by touching the ground contact.

Such audio signals triggered the controller and the sharpening unit generating the ET signals which are then delivered to the ET surface. At the end the ET surface generates virtual textures with the surface roughness in accordance with the frequency of the audio file used.

The next version of the ET system was realized in a form of mobile phone with touch screen display (as shown in Fig 3). Virtual texture on the display surface is generated in accordance with the image seen and actual position of the touch. The tests are conducted by “real touch", i.e., by scanning fingers on the ET surface and sensing the virtual texture (roughness and intensity).

FIG 3 Implementation of the ET system in accordance with actual touch coordinates on the display. Different tactile signals are generated on the alternating stripes.

For a quantitative analysis of the ET stimulation, we carry out dynamic friction test measurements on the ET device during operation at a fixed operating frequency using a proprietary tactile measurement system. The system (see FIG 4) consists of a two-axis load cell (MiniDyn multicomponent dynamometer type 9256C2, Kistler), an x-y motion table (series 1000 cross roller, motion link), an artificial finger and a controller.

The artificial fingertip (FIG 4B) consists of four layers: an outer, thin skin layer of acrylic to represent the skin. The inner layer is a combination of silicone gel base and elastomer which represent soft tissue; and a hard polyurethane core to represent the bone. The detailed shape including fingerprint is constructed as a real fingertip. The softness and friction properties of the artificial fingertip are similar to those of the index finger of humans on a wide range of surface textures and materials [4,5].

FIG 5 shows a plot of dynamic friction against load conditions when the ET device is ON/OFF (e.g. with/without the ET stimulation). The touch screen was attached directly on to the surface of the load cell. The output from the ET controller is connected to the artificial finger, and the ground output is connected to the device ET device. The artificial fingertip is slid over the sample using the motorized motion control. The frictional force and normal force are recorded against time. For these tests, the target normal forces were 0.25N, 0.45N, 0.8N and 1N. The speed of the finger in all tests was 0.5mm per second. The frequency of the square wave input to the controller was 20Hz and each condition was measured 10 times and averages taken. We observe that application of tactile stimulation increases the dynamic friction between the finger and the ET surface by 26% when the load is 0.8N and by 24% when the load is 1N. In a real life scenario, this change in dynamic friction is then perceived as a change in texture as the user examines the surface by sliding the finger.

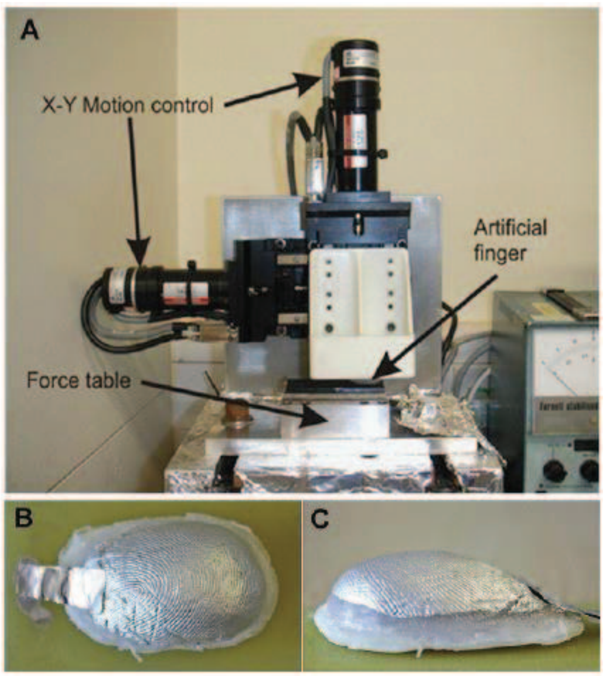

FIG. 4: a) Setup for the dynamic friction test measurement during ET device operation. The ET device is secured on a backing layer. Photograph of the B) top and C) side view of the artificial finger.

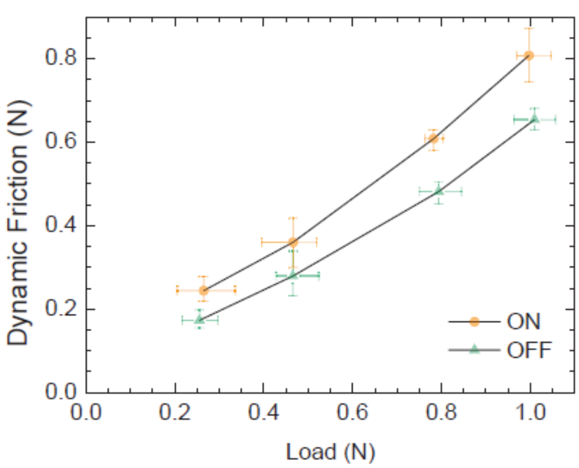

FIG. 5: Change in dynamic friction between the artificial finger and ET device touch surface against different loads in ON and OFF states.

3. DISCUSSIONS and CONCLUSION

In this work we have investigated possibility to introduce new optically transparent thin conducting film of graphene on mobile devices and displays. Graphene is emerging material which aims to replace traditional oxide based conductors on rigid surfaces. Graphene is more robust material and might present fruitful solution for new flexible and compliant form factors of the future devices. The ET system have been fabricated on flexible substrate (such as PET and PDMS) by using graphene material coated with appropriate dielectric materials (parylene, hafnium etc…) and then passivized by a DLC finishing layer. This is also worth mentioning that bill of the materials used in the ET system is compatible with scratch resistant, hydrophobic and oleophobic materials on the top surface to enable electrical insulation, scratch resistance and stain/water/fingerprint repellency in a single finishing layer. This will help maintain and protect a pristine display surface, and could help make graphene-based touchscreens a viable design concept for future UI solutions. The graphene ET system is fully programmable electrostatic tactile feedback system capable to deliver a range of tactile textures to a mobile display. The ET system can be overlaid unobtrusively on top of a display screen to deliver localized control of friction, which can be synchronized with images or icons on the display. Since there are no moving parts in the tactile stimulation (skin is directly stimulated), the ET system is extremely efficient in terms of energy consumption. On average, the power consumption is around 50 µW. This is due to the very low current requirements (as low as 5 µA) and a transient electric pulse (70-100 V peak with 1-2 ms duration) mode of operation. Such level of ultra-low power consumption opens a new horizon for continuously delivered tactile feedback in portable devices (dynamic feedback solutions). This opens possibility to realize different future functions on a mobile display such as “easy-to-find”, “finger navigation” and other real time finger guidance functions by tactile perception on-display with continuous dynamic feedback.

4. REFERENCES

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