IPC Standards and Printed Electronics Monetization

Daniel Gamota
Printovate Technologies, Inc.
Palatine, IL

Abstract
Printed Electronics is considered by many international technologists to be a platform for manufacturing innovation. Its rich portfolio of advanced multi-functional nano-designed materials, scalable ambient processes, and high volume manufacturing technologies lends itself to offer an opportunity for sustained manufacturing innovation. The success of introducing a new manufacturing technology is strongly dependent on the ability to achieve high final product yields at current or reduced cost. In the past, standards have been the critical vehicles to enable manufacturing success.

During the past few years the Printed Electronics Field has seen an increase in the number of companies attempting to scale-up their manufacturing processes for new product introduction. A key operations-related activity during this exercise is the establishment of a robust supply chain. Many of the printed electronics companies have negotiated unique quality conformance documents (i.e., Certificates of Compliance) with each individual supply chain member. Also, these companies have made significant investments to develop internal standard operating procedures.

Historically, the adoption of standards has shown that it facilitates the growth of an emerging field and reduces the burden placed on individual companies to invest significant resources in the development of company specific compliance documentation. This paper provides an overview of the recently established IPC Printed Electronics Standards initiative.

Introduction
The development of standards can be critical to the successful launch of an advanced technology.[1] If introduced at the appropriate time during technology development, significant resources can be conserved and redeployed into other new product introduction operations to ensure commercial success. However, standards also have the potential to squelch creativity by demanding rigorous structure and great oversight. Therefore, it is critical to ensure that standards are introduced at the optimal time. The time for printed electronics standards appears to have arrived based on two general trends: 1) the number of companies interested in integrating printed electronics technologies in high volume products to reduce expenses related to product manufacturing has increased substantially over the past three years and 2) many well funded ventures are attempting to scale-up manufacturing of printed electronics-based products. Moreover, two organizations that have published printed electronics roadmaps during the past five years, International Electronics Manufacturing Initiative (iNEMI) [2] and Organic Electronics Association (OE-A) [3], have stressed the importance of the development of standards.

As early as 2008, IPC stakeholders began to identify printed electronics as a potential game changer and suggested that the field should be closely monitored. This IPC activity, initiated by David Torp (Vice President Standards and Technology at IPC) led to the exploratory standards working group meeting that was held in late 2010 which was the foundation for the present IPC Printed Electronics Standards Portfolio development effort. In an effort to facilitate group discussion, questions were posed to the attendees at these events:

- What value can PE offer you today? In the future?
- Can your existing products or manufacturing processes benefit from PE?
- Can your company extend product portfolios or expand into new businesses by developing products and manufacturing processes that leverage PE?

The dialogue was energetic and the participants found the activity rewarding. The recorded topics of discussion were analyzed, and it appears that the potential benefits from PE can be categorized into two groups: 1) operations related impact and 2) final device/component/product attributes. Table 1 is a compilation of the insight collected during meetings and discussions with PE subject matter experts.

Table 1 – IPC Stakeholders and Printed Electronics

Operations Related Impact	Final Device/Component/Product Attributes
Raw materials – cost reduction	*Thinner - lower profile*
Utilities – lower electricity demand, less stringent manufacturing environment	*Conformal/Flexible – unique designs*
Personnel – fewer engineers and operators required	*Lighter - reduced weight*
Equipment – less costly processing and assembly platforms	*Large Area – distributed functionality*
Manufacturing – high product pulse rate	
Waste – Greater material usage resulting in lower waste related expenses	*Energy Efficient – energy harvesting*

Background

PE Industry participants have stressed the importance of standards since as early as 2004 when the first international activity was formed to develop standards for organic electronics. The activity was established within Institute of Electrical and Electronics Engineers (IEEE) and had international participants from large companies, academia, and well funded venture backed start-ups. A key underlying theme for the formation of the standards working group was that Printed Electronics represented a manufacturing innovation that would disrupt the traditional microelectronics and semiconductor industries. The disruption was fundamentally grounded on the development of innovations that integrated novel solution-processable materials and scalable high volume manufacturing processes to offer unique electronic product designs.

The IEEE standards initiative resulted in the 1st (IEEE 1620™) and 2nd (IEEE 1620.1™) organic electronics standards that enabled the community to progress down the path toward product commercialization. The topics for these standards were selected based on input from subject matter experts that identified the topics as potential roadblocks for adoption of the emerging PE technology.

Since the publishing of the IEEE 1620™ standard its value has been quantified and reported during various printed electronics workshops. More than twenty subject matter experts formed the P1620 Standards Working Group to develop a standard for characterizing solution processable semiconducting materials. The driver for its creation was the increase in the number of companies offering higher performance semiconductors. A standardized test for characterizing solution processed thin film transistor devices was necessary to reduce the increase in expenses incurred by companies interested in designing products that integrated PE-based thin film transistors.

At the Printed Electronics Foundation Conference held in 2006, a presentation was given that discussed the value of the IEEE 1620™ standard. A brief overview of an internal Case Study (Adherence to Standard Results in Realized Savings) was provided.[4] The presenter stated that prior to the publishing of the standard the company incurred approximately $29K in expense to assess one solution-processable material. This expense was determined by the resources (human capital and materials) necessary to perform the activities listed in Table 2.

Table 2 – Materials Assessment Related Activities

Expense Category	Activity
Introductory Meeting (1 vice president, 1 director, 3 engineers)	Initial materials due diligence (background)
Process Engineering (2 engineers, 1 operator)	Materials selection Process development Fabricate devices
Electrical Engineering (1 engineer, 1 operator)	Test fixture design and set-up Test parameter selection
Follow-up Meeting (1 director, 3 engineers)	Reporting of processing and electrical performance testing

Since the first publishing of IEEE 1620™ it has been updated based on the PE community having identified a critical characterization parameter that was not included. The parameter when not considered led to the publishing of inaccurate device performance data which subsequently caused circuit designers to produce invalid designs. The original standard was modified and later adopted after an in-depth review to ensure that the protocol outlined in the standard captured all recently published nuances for device performance.

Printed Electronics Standards Development at IPC

The interest in the PE industry by large OEMs has grown as the fundamental PE materials and processing technologies have continued to mature. Representatives from OEMs have stated that PE can be leveraged in the near-term to reduce costs associated with existing products and can be used for the future to expand and develop new product offerings.

Since late 2010, IPC stakeholders have supported the commitment to become the Printed Electronics Intellectual Capital leaders. The commitment is built on the establishment of a portfolio of PE standards that provides the tools to facilitate the PE industry to grow.

An environmental scan was conducted to appreciate the PE standards landscape. Also, the scan was necessary to identify potential standards development organizations for collaboration. Table 3 shows several standards development activities that will be complemented by the IPC standards development effort. The leadership teams of the organizations listed in this table have been contacted and arrangements are being made to establish pathways for collaboration and to mitigate redundancy.

Table 3 – Printed Electronics Standards Efforts

Standards Development Organization	Effort Description and Update
ASTM International	Portfolio of standards for printed membrane switches published: materials, design, processing, and performance. (Standards groups continue to identify topics)
International Electrotechnical Commission (IEC)	New Technical Committee for Printed Electronics established - IEC TC 119 (Kickoff Meeting scheduled for first quarter 2012)
IEEE	IEEE 1620-2008™ [5] *Standard for Test Methods for the Characterization of Organic Transistors and Materials* (First published in 2004; later modified in 2008) IEEE 1620.1-2006™ [6] *Standard for Test Methods for the Characterization of Organic Transistor-Based Ring Oscillators* (First published in 2006, presently under IEEE mandated 5yr review)
IPC	D60 IPC Printed Electronics Standards Committee D61, D62, D63, and D64 Subcommittees
Japan Electronics Packaging and Circuits Association (JPCA)	Printed electronics standards under development. (Release date in mid 2012)

Printed Electronics Stakeholders

It is well known that the printed electronics field is a compilation of diverse technologies leveraged from several well established industries: graphic arts printing, microelectronics, semiconductor, and nanotechnology. Thus, it is critical to have representatives from each of these groups participating in the PE standard development effort to ensure that an accurate foundation on which to build is created.

IPC has actively been recruiting and reaching out to the leadership teams at organizations such as IEC [7], SEMI [8], IMAPS [9], SGIA [10], PIA [11], OE-A, NPES [12], iNEMI, IEEE [13], and JPCA [14] to provide an overview of the IPC standards activity and to discuss opportunities for collaboration. The IPC strategy is based on engaging individuals that can provide insight into product markets, guidance for the standards' landscape, and visibility in trade associations. Several calls for participation were sent to graphic arts printing, microelectronics, and manufacturing equipment groups. The three major contributors – 1) standards development organizations, 2) trade associations, and 3) markets – that form the printed electronics crowd-sourcing strategic framework are presented in Figure 1. IPC will continue to actively engage representatives from each contribution group to establish a robust strategy that is aligned with sustained long term PE enabled product commercialization.

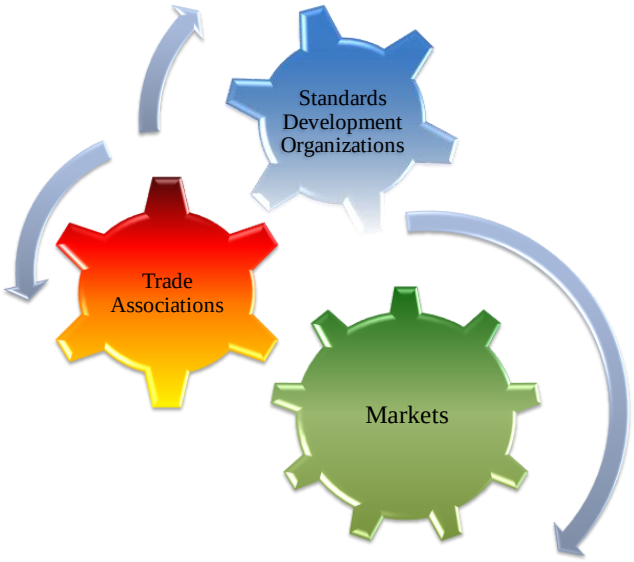

Figure 1 - Printed Electronics Crowd Sourcing Strategic Framework

Strategy

A strategy was developed and implemented at IPC based on due diligence performed to appreciate the industry needs and market readiness. The strategy has received balanced input from PE ecosystem members to ensure that the most relevant topics for standardization are addressed in a timely manner. Furthermore, the strategy is dynamic; it was designed to enable the IPC Printed Electronics Standards Committee (D60) to respond quickly based on industry trends and market dynamics. A hierarchical structure was established to enable the formation of subcommittees (D61, D62, D63, and D64) to focus on PE community identified areas for standards development (Figure 2).

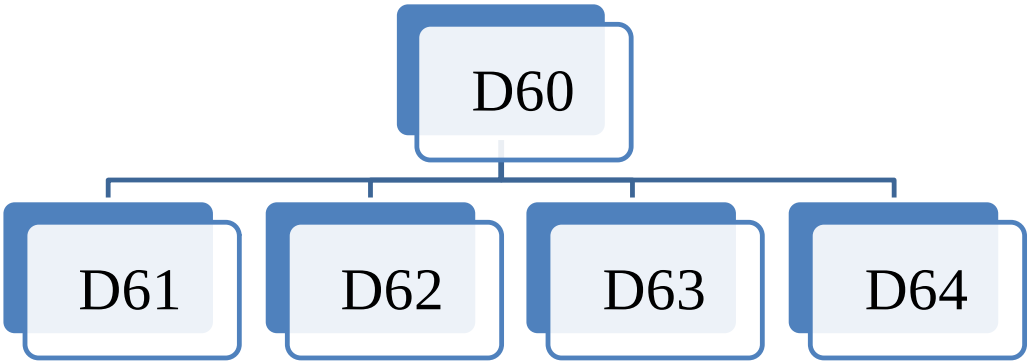

Figure 2 - IPC Printed Electronics Standards Hierarchical Structure

The subcommittees were formed to focus on specific critical topics that were identified and refined over several months of discussion. These four initial topics are fundamentally well aligned with the printed electronics supply chain and have been identified as critical for PE technology adoption (Figure 3). The different elements and listed topics highlighted in the supply chain represent those that have been most often mentioned by representatives from the ecosystem. Members have suggested that in the long term several additional subcommittees will be formed to develop standards supporting the various supply chain elements.

At the present time, subcommittees D62 and D63 are furthest along having published and circulated preliminary drafts while the other two subcommittees, D61 and D64, continue to identify topics for review by the subcommittee members in an effort to down-select the potential topic list.

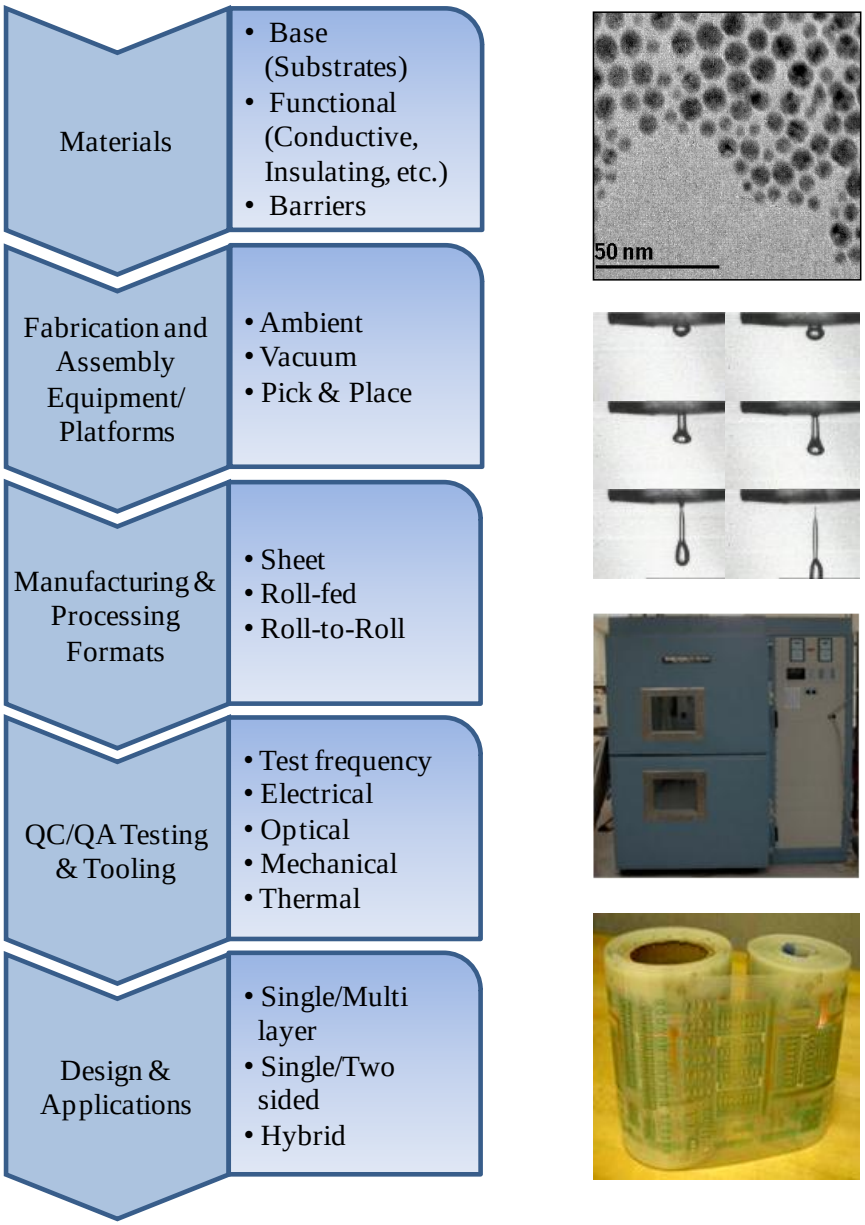

Figure 3 - Printed Electronics Supply Chain

D61 Subcommittee

The title of the project in development by D61 subcommittee members is - *Design Guidelines for Printed Electronics (IPC-2291)*. This area is considered a bridging topic for it establishes the bridge necessary between the product designers and the manufacturing engineers. The specific topics that have been discussed can be organized into four groups: 1) Compute-Aided Design Tools, 2) Data Transfer, 3) Substrates, and 4) Conductors. Table 4 is a snapshot of the topics that have been mentioned within the four groups.

The most often stated topic during D61 meetings is PE design & layout. In the past PE companies have developed internal procedures for design & layout of PE-enabled products using tools from the electronics industry; as an example, some companies use Gerber format which is specialized electronic design automation (EDA) software commonly used by printed wiring board designers. Once the design in Gerber format is validated it is prepared for transfer to the printing platform operations group within the company or sent outside the company to a receiving manufacturing services provider. This handoff is viewed as a critical gating step in new product introduction.

Discussion among D61 subcommittee members continues in an effort to identify the most appropriate topic framework for the first standard undertaken by D61. The subcommittee is preparing the final list of IPC-2291 potential topics for review and selection during APEX 2012.

Table 4 – Potential Topics for IPC-2291

Computer-Aided Design Tools	Substrates
• File format • Design rules • Layout rules • Test & Simulation	• Mechanical properties • Electrical properties • Optical properties • Thermal properties
Data Transfer	**Conductors**
• File format • Conversion • Check	• Electrical properties • Optical properties • Mechanical properties • Thermal properties

D62 Subcommittee

The D62 Subcommittee has circulated a draft of IPC-4921: *Requirements for Printed Electronics Base Materials*. This topic was identified as a key structural material for the field of PE. Also, the growth in variety and number of commercially available and near-commercially available materials has fueled the innovation of novel PE-based products in new fields. Figure 4 provides the general layout of the document as built around five substrate categories. These categories capture the broad families of substrate materials. As new substrate materials are introduced into the field of PE they will be added to the list appearing in IPC-4921.

The IPC-4921 document has been referred to as fundamental for the field of printed electronics. Moreover, it is considered by many as one of the most critical drivers of manufacturing innovation. The paradigm shift that flexible substrates offers for transitioning from batch to roll-fed and roll-to-roll manufacturing is considered paramount for realization of vibrant new areas of manufacturing growth.

Several meetings have been held to discuss the content and comments received during draft circulation. The D62 subcommittee is modifying the document to include the discussed changes in preparation of the document for ballot during the beginning of the first quarter of 2012.

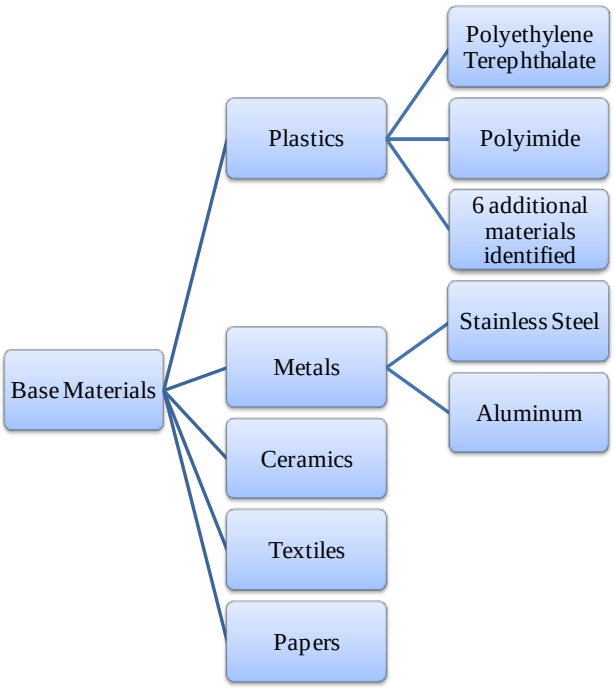

Figure 4 – IPC 4921 Document Structure

D63 Subcommittee

The next subcommittee to prepare and circulate a draft was D63. This subcommittee is presently preparing the modified draft of - *Requirements for Printed Electronics Functional Materials (IPC-4591)* – based on comments and edits received during the circulation. The content of IPC-4591 is considered as important as that in IPC-4921. Also, many view this

subcommittee as long term providing the greatest number of standards documents due to the continued expansion of material categories. These categories are based on materials systems that demonstrate novel intrinsic properties provided by the design and synthesis of advanced materials structures: conductive, semi-conductive, dielectric, photoactive, thermally active, and chemically active.

IPC-4591 compiles the general requirements to specify and quantify the mechanical, surface, and optical properties for functional materials displaying electrical conductivity. This document will serve as an example for the general outline of future documents that will focus on the previously mentioned intrinsic property specified topics. Future topics that may be undertaken by the D63 Subcommittee are shown in Table 5.

Well attended meetings to discuss the content of IPC-4591 coupled with strong participation during circulation for review of the draft have resulted in a solid document. Members of the D63 Subcommittee are modifying the most recent draft IPC-4591 with focus to prepare the document for ballot in mid first quarter of 2012.

Table 5 – D63 Proposed Functional Materials Topics for Standardization [15]

Fundamental Electrical Functionality	Electro-optical Functionality	Other Response Driven Functionality
• Conducting materials (existing IPC 4591 standard draft) • Semiconducting materials • Resistive materials • Capacitive materials • Piezo-electrical materials	• Light emitting • Light sensing (PV, optical sensors) • Color change (i.e. thermochromic) • Piezochromic • Pyroelectric	• As function of temperature • As function of pressure • As function of humidity

D64 Subcommittee

Independent of the debate for whether PE commercial success will ultimately be determined by developer push or customer pull, industry members agree that a clearer go-to-market strategy must be articulated. This need has fueled the identification of potential topics for the D64 Subcommittee-led project titled – *Performance Requirements for Printed Electronics Assemblies (IPC-6901)*. During the past 10 years the PE industry has observed several high visibility opportunities for early PE-based products such as RFID, flexible displays, etc. A component for success to launch these products is based on the performance demanded by the end-customer.

Members participating in D64 meetings have identified five markets that can benefit from PE-based technologies (Table 6). During the D64 Subcommittee meetings, examples of existing PE-based products are used to facilitate the discussion to identify appropriate D64 projects.

Several project topics have been identified for further discussion and vetting during market focused discussion groups; output from these groups will enable D64 to develop a stronger appreciation for the near-term market opportunities and aligned standards topics. This gathered information will be used to prepare an IPC-6901 draft topic outline for review during APEX 2012.

Table 6 – Potential Topics for IPC-6901

Markets	Level
• Aerospace • Automotive • High Performance Consumer Electronics & Communications • Medical • Office/Home Structural & Architectural Building Materials	• Device • Component • Module • Product

Conclusion

IPC has been able to establish a robust standards development initiative by implementing a strategy based on 1) partnering with leading organizations within the PE industry and 2) reaching out to subject matter experts from the different technical fields that have nurtured PE innovations. The IPC PE Standards Committee and Standards Project Subcommittees have been established to provide the greatest support to the emerging field of PE by maintaining a level of discipline that does not impede creativity and sustained innovation.

References

[1] Rashba, E. and Gamota, D., "Anticipatory Standards and the Commercialization of Nanotechnology," Journal of Nanoparticle Research, Vol. 5, 2003.

[2] International Electronics Manufacturing Initiative (iNEMI), http://www.inemi.org/2011-inemi-roadmap

[3] Organic Electronics Association (OE-A), http://www.vdma.org/oe-a

[4] Brazis et al., "Printed Electronics at Motorola," Plastic Electronics Foundation Conference, Frankfurt, Germany, October, 2006.

[5] http://standards.ieee.org/findstds/standard/1620-2008.html

[6] http://standards.ieee.org/findstds/standard/1620.1-2006.html

[7] International Electrotechnical Commission (IEC), www.iec.ch

[8] SEMI, http://www.semi.org

[9] International Microelectronics And Packaging Society (IMAPS), http://www.imaps.org

[10] Specialty Graphic Imaging Association (SGIA), http://www.sgia.org

[11] Printing Industries of America (PIA); http://www.printing.org

[12] NPES The Association for Suppliers of Printing, Publishing and Converting Technologies (NPES), http://www.npes.org

[13] Institute of Electrical and Electronics Engineers (IEEE), http://www.ieee.org

[14] Japan Electronics Packaging and Circuits Association (JPCA), http://www.jpca.org

[15] Potential topics for future projects initiated by D63 Subcommittee, provided by Co-Chairman Markus Riester.