METALLURGICAL AND ELECTRONIC WASTE RECYCLING

Dr. Arunabh Meshram

Department of Materials Science and Engineering

Indian Institute of Technology Kanpur

Week-7

Lecture-32

Greetings, I welcome you all to the next lecture of this course wherein we were now discussing on electronic waste recycling and previously we had just a discussion on how important it is to sort the waste streams and arrange the waste stream in the broad categories and perform the operations, manual dismantling and shredding and separation of materials. We have already studied the basics of various materials processing and the important strategies that are involved in extracting valuable materials. This strategy we will be developing for different types of wastes of e-wastes, the different categories of e-wastes. We will now continue where we had left previously. We have seen that physical operations is very much important, manual dismantling is very important, we are able to separate out different components which otherwise would directly be ending up in the shredder.

If we have let's say an AC, discarded AC, or a discarded washing machine we just put it i n a shredder. Irrespective of whether it is an automatic front loading or top loading machine we just put it in a shredder. What will happen? The components will break, the PCBs will be dismantled, everything will be shredded in a suitable shredder and then what we get is a combination of materials. Whatever materials were present in the manufacturing will mostly be present as we had discussed previously that we have reasons due to which particular material or parts of it are removed. It could be due to mechanical wear or due to some damage. Not considering those cases, we must easily be able to get out almost all of the materials that we feed in. And those materials that we feed in are actually those materials that were used to make the electronic device. We must know that the operations that we choose in a recycling unit are very important and we have studied it just in the shredding point. What happens beyond that is again one can think of attaching pyrometallurgy or hydrometallurgy or any other type of recycling strategy for the metal recovery or for any other material recovery. We will continue. In most of the electronic devices, and we are talking about electronic devices, and not very

simple electrical devices, so we are talking about electronic devices, we will have some sort of, even if it is a rudimentary, we will have some sort of control mechanism.

Because it's an electronic device, it has to do something. It has some sort of control mechanism. It could be very simple on-off or any other signal mechanism. That control mechanism is usually governed by a circuit board, which means if we have a control mechanism, we are actually talking about printed circuit board or we can have printed wired board. PCBs. PWBs. We have printed circuit boards. We have printed. We get PCBs. And we know that we are going to get WPCBs after it reaches its waste or WPWBs. Generally speaking, we get a PCB and we can just club these two terms together.

If we have the circuit boards, we have the mechanism of controlling the various operations that electronic devices perform and these PCBs are made of wide range of materials which makes it difficult to recycle and we'll just study a bit more about PCBs. Circuit boards have very large variety of categories but we can just have rigid circuit boards, some are flexible whereas some are rigid and flexible, so we have rigid flexible boards. Depending on what is the application, we can have a rigid board on which all of the electronic components, ECs and ICs, whatever are the components we are attaching them or we can have a flexible board. That is used only when the application is such that we need a flexible board. or there can be some parts that are rigid and some parts that are flexible. Depending on type of application, we can have rigid boards, flexible boards or combination rigid flexible boards. Similarly, we have the components that are attached on the PCB. Why are we so much interested in boards and electronic components? This is important because these boards and the components are going to end up almost in pristine state when we are discarding the washing machines or ACs. Apart from the wear and tear that happens during the service, most of the materials are mostly not damaged much unless until it really faces some sort of mechanical damage. What happens to these materials? If we are not so careful, we just put it in a shredder and then we are shredding the glass fibers, we are shredding polymer epoxies, we are shredding metals, we are shredding all of the electronic components directly that are attached on the PCB along with the whole of the other waste. Let us say we were talking about washing machine, the whole of the washing machine is getting shredded and PCB is also going in. But if we are able to remove these components beforehand and we are recycling them, then comes the challenge of isolating the important materials that can be directly reused or ECs that can be removed from a discarded PCB and installed on a fresh PCB. One has to analyze

whether that EC component itself is functional or not and if it passes then how are they going to reuse it that is another way of recycling one has to think how they are going to do it. We will now focus on what are the ECs that are normally installed on the boards electronic components can be generally classified as surface mounts or through hold components. We can have surface mounts or through hole components. What do we mean by that? It is connected to the circuit board.

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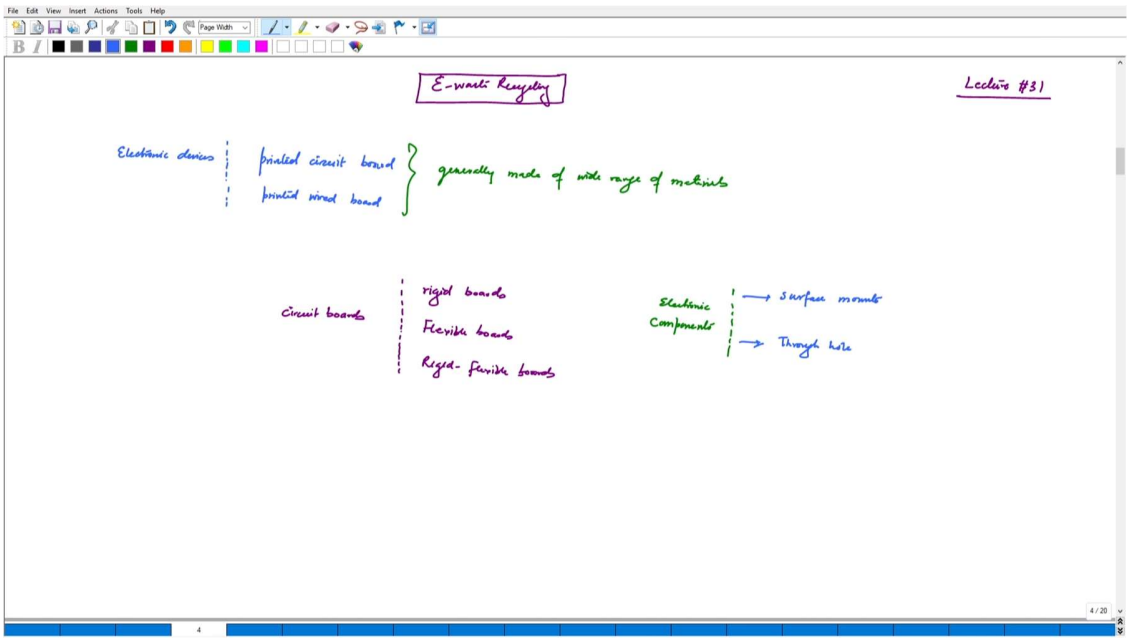

If circuit boards have through holes in them, if the holes and the interconnects are present in the board, then it is possible to install an EC that has those longs the longs small miniature pins that can penetrate through those holes. It depends whether these components are used in the PCB manufacturing or not. If not then we have surface marks wherein these the components are attached directly on the PCB and not and these components are do not go throughout the PCB and then the appropriate soldering strategy is done. Soldering can be done behind the board or on top of the board depending on what type of component was used and then this defines how complex it is to manufacture a PCB.

We are more interested in dismantling a PCB, but it is also important that we are able to understand what are the materials that are used. The masking, solder masks, the layers

that are present in the PCBs, we will be discussing this in greater detail in the upcoming classes, but we know that these layers and these interconnects and the ECs that are installed on the computer or on the PCB, these need to be separated out so that we are able to look at our materials that we are interested in extracting. What do we know about chemical composition of PCBs? And right now, I did not write PCBs, now I am talking about WPCBs. Because right now I am assuming that we are looking at a waste printed circuit board and it has reached the recycling unit and then we are analyzing. The most important aspect that one has to think of is what is the source of the WPCB. If we are not able to isolate the source of the WPCB, it becomes a bit of a question that how we will be able to recycle it. Because PCBs can originate from so many different sources and we have already seen that the recycling of PCBs or any other waste, e-waste, electronic waste comes with the challenge of manufacturer. Every manufacturer has its own way of using materials and those materials can be having wide range of variety. If we look at the whole lot of e-waste that we look. For instance, we had discussed this, TVs can be produced by n-number of manufacturers. Computers, laptops, TV screens, tablets, every device has this problem.

Variety of materials, in those materials, variety of composition. Even if we say, a generalized statement could be, we have let us say 30% of metal. What do we mean by 30% of metal? Do we mean by ferrous metal or non-ferrous metal or platinum group metals? What are we talking about? That internal division for a waste fluctuates per sample. That is why we need a very good, generalized data and such a data is very important input for the recycling industry. We will continue on chemical composition of WPCBs. We have seen sources of WPCB. This is very important. We are assuming that we have sorted e-waste streams and then we were able to isolate the WPCBs. What are the sources? We have discarded PCs and laptops, we have mobile phones, we have telecommunication devices, washing machines, we have ACs, we have so many different other components that will have WPCB. If we have some sort of control in the given device then there is a fair possibility that there is some motherboard, some printed circuit board that is governing what is functioning, what is the functionality of the equipment? This changes the whole scenario of the composition. Let us see what we are looking at when we are seeing the category of WPCB. We have waste electronic components. And why are we talking about waste electronic components?

Because it is a part of the PCB. This is a very rudimentary schematic of printed circuit board. We have this board and this board itself is comprising of multiple layers of

different materials but we have various types of components that are attached to it and so on and so forth. So, if we are looking at waste printed circuit board,

we are also looking at the electronic components and these electronic components have their own properties. We look at this. The classification is capacitors, integrated circuit, we have ICs, we have transistors, resistors, we have connectors and at times we can also have interconnects also, so connectors wires, wires again for connections, we have inductor, diodes and we see that these components are already present on up WPCB. The question comes can we really directly reuse these components if we are able to successfully dismantle? When we think of direct reuse of these electronic components, one has to think whether they are functional or not. Even before we reach to that point, the most important part is can we really separate out these electronic components without damaging the ECs.

This is a challenge. Safe dismantling of electronic components in such a way that neither we are damaging the board nor we are damaging the ECs. And one must mind it that when we are looking at a PCB, this PCB with the electronic components attached to it is generally strong. It would not really break if we are trying to swing it.

The components will not fall off, it means that it has been made in a way that it stays safe. One has to think of a way of dismantling these components and reusing them if we can reuse it by some refurbishment it would be a nice idea. What exactly is the composition of PCB, we know that these parts are there and these parts are called the electronic components, what else is present in a PCB?

Material composition of WPCB. We have WPCBs and we have oxides, we have polymers and we have metals and alloys. And generally speaking, we can have a higher share of metals and alloys, but it really fluctuates a lot the major components that are present are oxides, the polymers and the metal and what do we mean by having the division? It means that these materials were used in manufacturing the ECs or the PCBs. Metal oxides, polymers and metals were used and of course, some sort of composites can also be present, but these materials were generally used to make the whole PCB and the ECs. What are the oxides that are present and ceramics? If we look at ceramics, ceramics in the WPCBs, which are basically oxides. If we have SiO_2, Al_2O_3, TiO_2, so we have a major contribution of silica this means that the oxides which are basically generalized in the head of ceramics.

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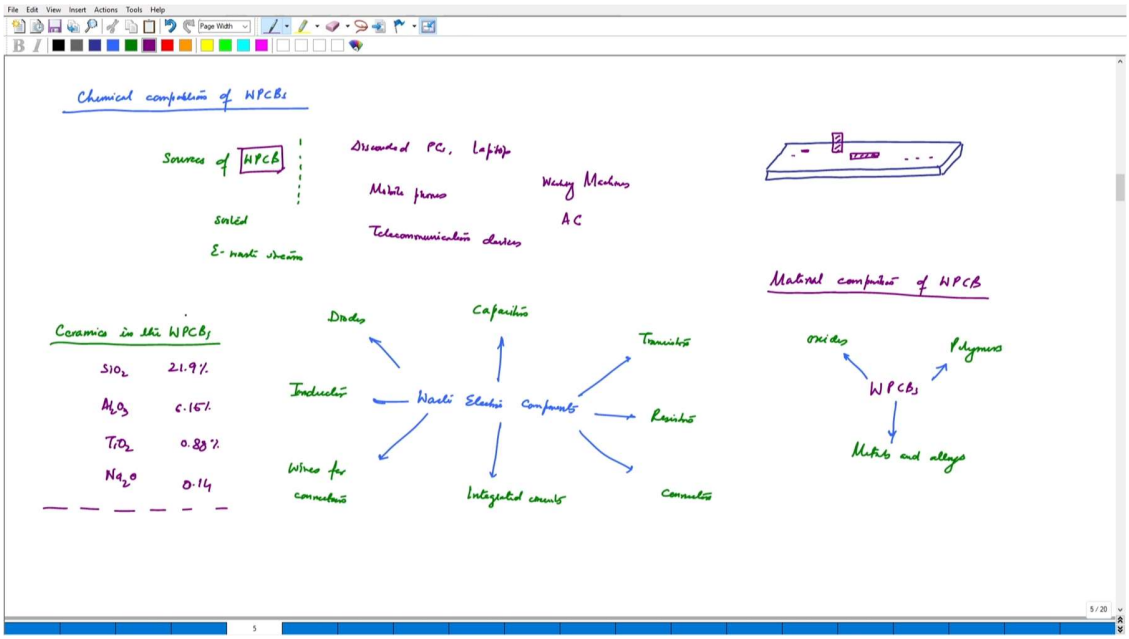

These oxides have a major contribution in the overall PCB construction and then now we are going to look at what are the key metallic contribution in the metals and alloys segment. If you look at types of PCB and this is very important when we look at this table, we see that there is we have the type of PCB right at the front. This is important that because we see that some data are for PC, we have for TV and we have copper and mixed WPCBs. This data tends to fluctuate a lot if we are looking at a specific category of PCB which is why we were discussing so much about why we need to isolate PCBs as well and sort them. We see that copper is one of the most important elements followed by lead or nickel or tin or zinc but again it depends on what type of PCB we are looking and we are looking at the PCB itself, the board and not the ECs.

ECs can have large variation in chemical composition because they have very specific applications. Specific applications would require specific elements. We are right now looking at the PCB after the removal of the components. We are not generalizing the statement that we have PCB with the ECs because that really expands the number of elements that we should be putting on this table. We have really large number of elements in our cell phones right now, so this makes the recycling process even more complex which is why we are saying that this table is for and again it's a very short range of data that we have presented, the data can have very large number of outliers also. PCB is discussed and we see that copper is one of the most important elements along with we have these elements like lead, nickel, tin, zinc, iron, and we also have gold and silver and

platinum group metals. This is presented separately because the units are different. The units are in parts per million. Gold and silver are also present depending on what type of PCB we are looking at.

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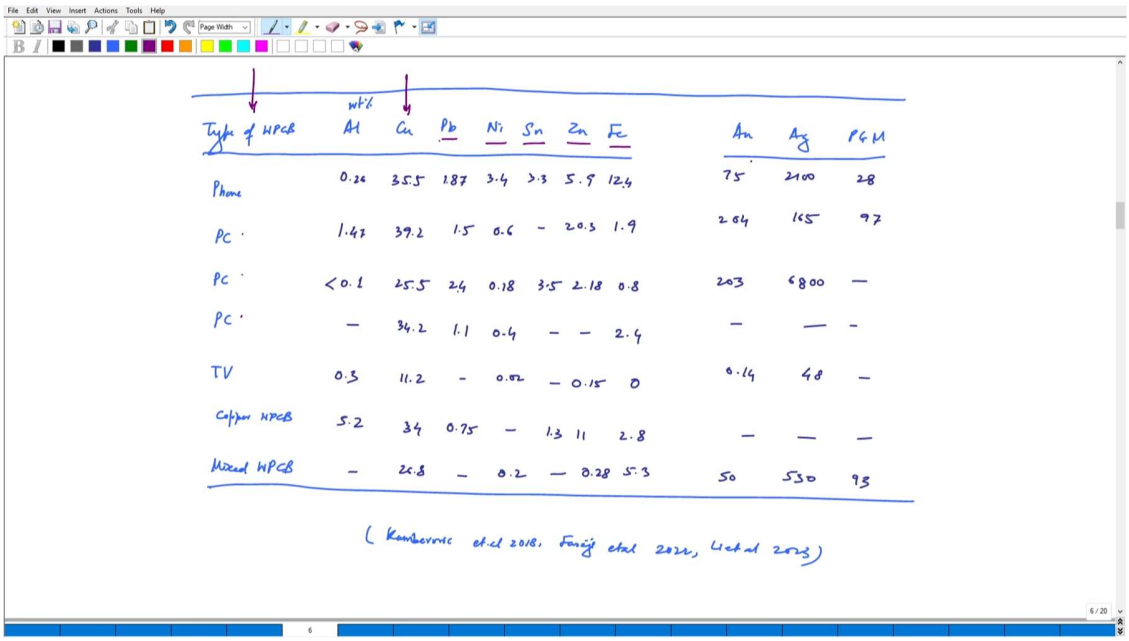

Phone can have phone PCB, mobile phone PCBs can have silver PCBs. PC PCBs can have gold and silver. Depending on what type of waste we are looking at we will be having wide range of chemical composition variation and this makes the recycling lot more challenging. Which brings us to the challenges. Challenges in e-waste recycling. We have been discussing this a lot and now we need to just consolidate the ideas, given the complex nature of the raw materials in the WPCBs the recycling becomes a challenge. Some important challenges are, presence of epoxy resins, flame retardants, phenolic resins, etc., What does this mean? These materials are added to basically keep the material safe. Flame retardant is added. Why? Because we do not want the PCB to catch fire during its operation. Similarly, we have epoxy resins to basically at times hold the material together.

These reasons can be helping in the component attachment. These materials have their own particular set of applications which are way beyond what we really intended but these help in making the component safer for application. What happen is after

application we need to remove these components and if these components are not properly treated, these materials are not properly treated, these can generate hazardous waste. Presence of resins and then there is improper method. Improper recycling methods. This is a very big challenge. Why? Because incorrect dismantling or will lead to what? Correct dismantling of the raw materials. In this case it's a PCB, we can have different examples also will lead to discards of reusable. And what do we mean by reusable? These are potentially reusable components which we could have used, but because incorrect dismantling is done, so we have to see that these are actually discarded. And then what happens?

Since we have discarded these waste, we have also unsorted and incorrect, improper metal recovery methods. Unsorted and improper metal recovery methods, these are followed. What will this do? This is going to lead to lower metal recovery. And this is followed by release of hazardous gases. Which means again this is environmental impact, harm to surrounding. This is an interconnected problem. If I do not know how to recycle, I will just put it in a small makeshift furnace. I will just shred the PCB and I'll put and I'll take those shredded scrap of PCB and I'll put it in furnace and this furnace may not be safe for processing it may just release gases and those gases can harm the surroundings. Improper recycling is a bit of a challenge it creates potential hazardous materials because we do not know what we are trying to recycle and this material distribution of PCBs is very complex. Safe dismantling thus becomes very important. A general statement could be generalized and we are we will be discussing this further in the upcoming classes.

General method of WPCB recycling will involve and we are not even going into recycling we are just starting to see what the initial steps are, and which are basically crucial, collection and sorting of WPCB from various sources and then we have sorted WPCBs and recovery of materials valuables we have separation of ECs and then we have shredding or mechanical operations and then we can have milling of WPCBs. And this is a very generalized outline of what we can do. And we know that we have dismantling.

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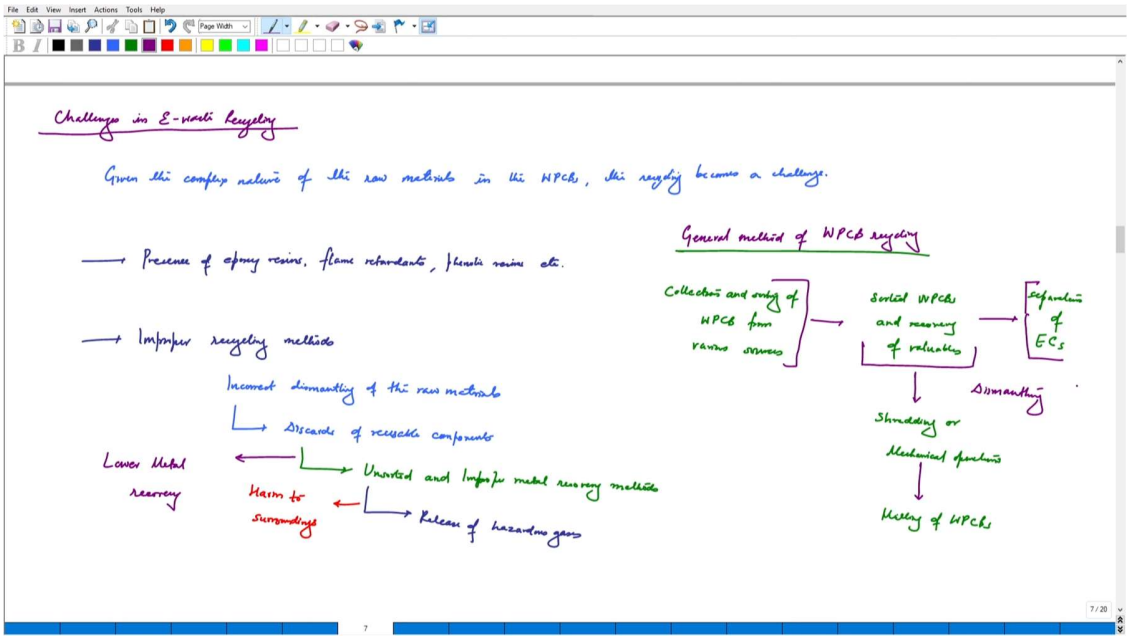

We know that this is the most initial and the most crucial step at the beginning because if we miss this and we just start recycling and recycling strategies are enormously complex and lot many research groups have been exploring their own method of recycling WPCBs. If we bypass this process, we may not be able to control it properly, which is why collection, sorting and the removal of those components are basically the most important initial steps. When we remove the ECs, now we have cleaned the WPCBs and now we can recycle it properly. We will be discussing the recycling strategies of WPCB in the upcoming classes. Thank you.