Pertinence of new communicating material paradigm: A first step towards wood mass marking

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Abstract. To highlight the interest of a new communicating material paradigm, this paper presents a first step towards the wood mass marking: We decide to use Nuclear Quadrupole Resonance and molecule assembling to identify wood material. We imagine a new method to create identification codes by using different marks. So we present our first test of wood mass marking using NQR as reader.

1. Introduction

More and more, with a view to increase productivity or traceability, supply chain managers mark pieces. The auto-ID technologies, and in particular RFId, are more and more extended in the way to realize such product marking. A Research Community looks for the interest of communicating product in ~~a~~ manufacturing environment. Our Research Lab integrates this Community by showing the possibility to use communicating products [1]. Especially some research projects highlighted the relevance of communicating product concept in wood industry and search for spread out. It was highlighted it's possible to increase the productivity of the workshop by using communicating products [2], too.

But this product marking is discrete. That is to say one product is marked with only one tag. This is really practical for finished products but that means products could not be separate. We propose as hypothesis that the material could become communicating instead of the product. In this case the material would be cut and would be able to conserve the information associated with each element. Thus the material has its personal information like physical characteristic and origins within it. Under this new paradigm, our research group has studied the pertinence and the feasibility of this vision in wood and textile industries. This paper deals only with wood mass marking. In case of success for this first step, we will be interested to highlight how this information could be used to control the supply chain.

This paper was organized to follow the present plan: first we will focus on the traceability techniques in wood industry. Secondly we will study the wood mass marking using nuclear quadrupole resonance (NQR). In a third part we will highlight possible new techniques and our future~~s~~ researches.

2. Traceability in wood industry

2.1. Importance of tractability in wood industry

More and more, wood industry tries to setup systems of material traceability. Many reasons are put forward: the increase of the outlaw wood exploitation [3], the need to improve wood utilization [4] [5] and the important information loss all along the wood life cycle [5]. Some actions were realized by manufacturers to increase wood traceability as certifications of the wood origins like PEFC (Pan European Forest Certification) or FSC (Forest Stewardship Councilor) or the European project Indisputable key [6] which search improvement ways for the wood traceability and methods for the information conservation.

2.2. Information conservation in wood industry

The problems which are mentioned before have one common point: the wood industry can't conserve the information of the tree all along the supply chain. Finally the wood supply chain highlights a sequence of information losses. The European project indisputable key [6] shows that the losses are between every important step 'figure 1'. The solutions proposed by this project seek to solve the information losses between forest and log selection. Other papers like [4] look for solution between log selection and log sawing. In this fact, it seems important that the wood material has to be identifying for all steps in the manufacturing process.

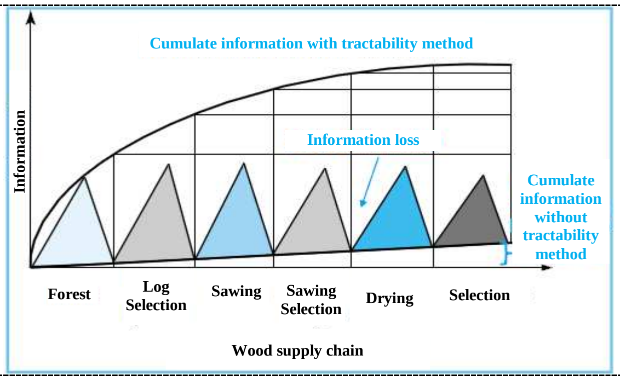

Figure 1. Scheme of information losses at each step during wood supply chain (source: the Indisputable Key).

2.3. The wood marking methods

The researchers try to put in place new identification and traceability methods for wood. There is three ways for traceability: the mark, the biometry and the DNA.

The first markings put in place were paint mark or hammering, used by the log owners to recognize their own. While they are cheap these marks have a real big problem: they are easily reproducing. The logs owner think to a new method that could be harder to reproduce: the bar code print on a plastics stamp which is hammering on the log. These stamps are unique and their reproductions are harder than the paint marking. But this marking can be easily removed from the log. To improve the security and reading possibility, the idea was to put in the log an RFId or magnetic tag which can be read in a dirty, dusty or damp environment. The project [6] submits an idea of RFId tag: this tag was cast in a resin wedge. Then the wedge is hammering at the end of the log. Another solution was to print a bar code directly at the end of the log.

But all these markings are discrete (i.e. one mark for one object). Furthermore they mark wood between forests and sawmill. The mark can be easily removed from the log by sawing the end of the log because it is not attached to the totality of the log. That's why other technics have been found. The use of the micro waves [7] allowed having a biometric code of the wood piece. An emission of micro waves goes through the piece of wood and gives a biometric mark of the wood. But this biometric mark changes because wood could be manufactured or changed by the time. Another way to have a mark of the wood is the use of the X-ray to obtain internal pictures for all the pieces. By the similitudes, it is possible to recognize pieces. With this method the traceability can be possible by reconstruction of the log, and also the tree. But this technic repulse sawyers according to the huge quantity of pictures to save; moreover this technique is harder to use.

In the tree there is a unique code that could be used to identify it: the DNA [8]. This is the same technique than for human. It is used in the cooperage industry to identify the origins of the tree. But this identification method is too complicated to be integrated in an industrial process [3].

So it is obvious that a mass marking is necessary for the wood industry.

2.4. Issue

After having highlighted that mass marking is useful, the questions are: how marking the wood in the mass? If the code is unique for one tree, how to code the pieces cut in the tree? How to use this information to pilot the supply chain? This paper shows first results in this research area concerning the wood mass marking process and a pertinence analysis concerning the necessary technology.

3. Molecule assemblage like a tag and NQR reading technique

As one of the imperatives of the present project is the mass marking and as it will be probably (if not necessarily) a molecular marking, the non-destructive and non-invasive identification technique will use radio-frequency waves (not absorbed by the material). In addition, the chosen technique should be a molecular spectroscopy in order to identify the marker unambiguously. We have therefore to resort on Nuclear Magnetic Resonance (NMR), Electron Paramagnetic Resonance (EPR) or Nuclear Quadrupole Resonance (NQR). If we envision an industrial reading technique (*i.e.* a portable device), NQR appears to be the best candidate as it does not require a static magnetic field (thus a magnet, mandatory for the other two techniques) and as it imparts direct molecular identification. However, its major drawback is its poor sensitivity.

3.1. Principle of NQR

NQR results from nucleus quantum properties with a spin greater than ½. The nucleus is made up of protons and neutrons. The distribution of them inside the core creates a distribution of the charge that could be spherical or with an axial symmetry ‘figure2’. The spin is associated to the distribution: if the spin is ½ the distribution is spherical, if the spin is greater than ½ the distribution has an axial symmetry. This axial symmetry leads to a nuclear quadrupole moment. This moment can interact with the electric field gradient at the nucleus and is responsible for the splitting of energy levels. NQR transitions take place between these energy levels.

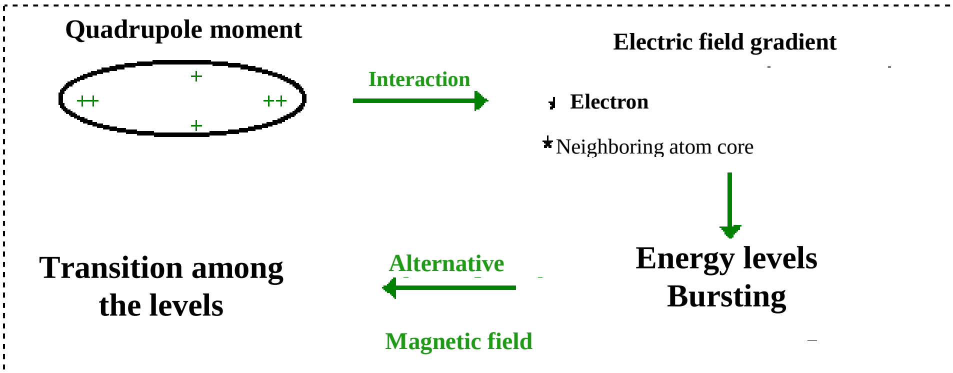

Figure 2. scheme of the NQR Principle (source : http://www.crystallography.fr/crm2/fr/labo/pages_perso/Ferrari/recherche/page%202.htm)

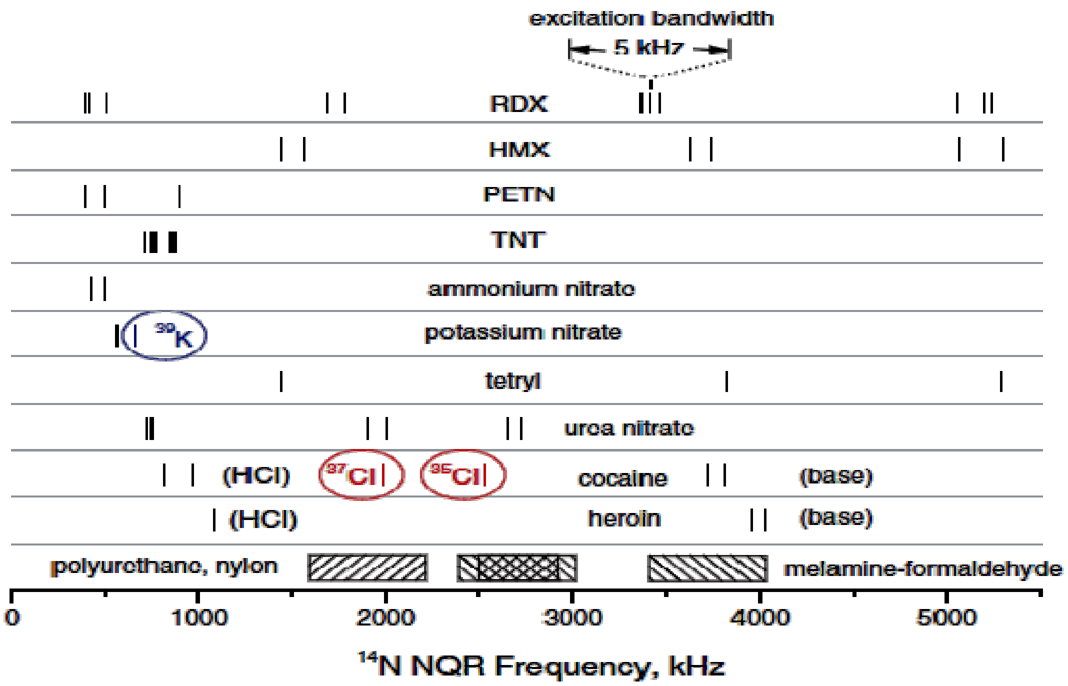

Figure 3. Representative NQR frequency for some explosives and narcotics (Source : detection of the landmine, appendix k de Garroway. A.N)

The frequency of these transitions is a direct measure of the quadrupolar interaction, and depends on the electronic distribution around the nucleus. This is a sort of fingerprint of the molecule. For example, landmines can be detected that way [9] (see figure 3).

3.2. Wood mass marking and NQR used for reading

The objective is to create an identifying code that could be integrated in trees. This could be different mixtures of several selected molecules, the NQR response of each of them being perfectly characterized.

As NQR is a difficult technique due to its low sensitivity and to the strong dependence of the resonance frequency upon temperature [10], we decided to run experimental trials with sodium nitrite (NaNO2) because we have lots of experience concerning this system. Because NQR is operative exclusively with solid state samples (powder or single crystals), we performed two preliminary experiments:

- Powder of NaNO2 mixed with sawdust just to verify that wood does not influence the sodium nitrite NQR signal.
- A piece of wood impregnated with an aqueous solution of sodium nitrite to determine if sodium nitrite properly crystallizes in wood after drying and yields a NQR signal.

3.3. Results and discussion

We note from the two spectra shown in figure 4 that wood does significantly affect the NQR signal. The parasitic signals in the spectrum in red are attributed to piezoelectric effects. They anyway tend to disappear as time elapses.

The second set of experiments (figure 5) is especially interesting (almost unexpected) since it demonstrates that sodium nitrite can crystallize in wood and afford NQR signals: the usual resonance is effectively retrieved but is accompanied by an additional broad resonance. The sharp line is assigned to properly crystallized sodium nitrite while the broad signal is tentatively assigned to sodium nitrite in the solid state (necessary condition to observe a NQR signal) interacting with the host material. Such line broadening has already been observed in explosives and attributed to lattice defects [11].

Those results are very preliminary but, at least, validate the very idea of using NQR as a tag reading technique. In fact, a proper crystallization process within wood and the subsequent ability to observe NQR signals was far from being granted before the experiments reported here. Nevertheless, overcoming the difficulties inherent in the actual application of the technique is another story.

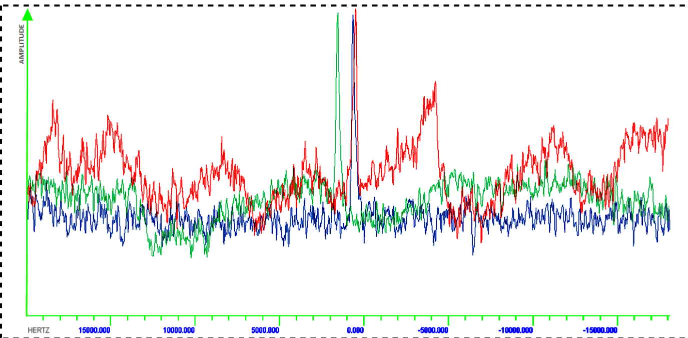

Figure 4. Sodium Nitrite response Spectrum at 4,64MHz. Blue Spectrum: 100% $NaNO_2$ (powder), reference (8 scans). Red spectrum: 50% $NaNO_2$, 50% sawdust (32 scans). Green spectrum: 25% $NaNO_2$, 75% sawdust (128 scans).

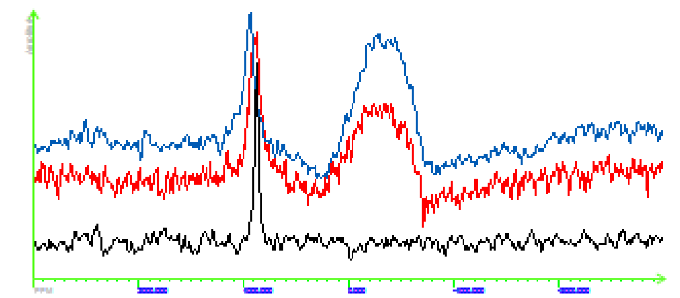

Figure 5. Sodium Nitrite response Spectrum at 4,64MHz. Black spectrum: 100% $NaNO_2$, reference (8 scans). Red and blue spectra: wood impregnated with a $NaNO_2$ aqueous solution (40 000 scans). Samples differing by the drying procedure and by the sodium nitrite provenance.

4. Conclusion and perspectives

Finally, nowadays the wood mass marking stays a futurist project. But with this project we show that it is not impossible to mark the wood. Further researches could be envisaged: i) look for other molecules or improve NQR sensitivity leading to a better signal, ii) if we accept the validity of this new paradigm, new traceability and supply chain control techniques have to be found, iii) to do that we'll have to model the information flow on one side and to build a demonstrator to lead experiences on the other side.

In the future, the mass marking would be efficient in wood. For the moment the textile mass marking seems to be more concrete than the wood mass marking and first research results have highlighted that this innovation way could be also promising.

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